Inheritance & Polymorphism

Week 7

Gaddis: Chapter 15

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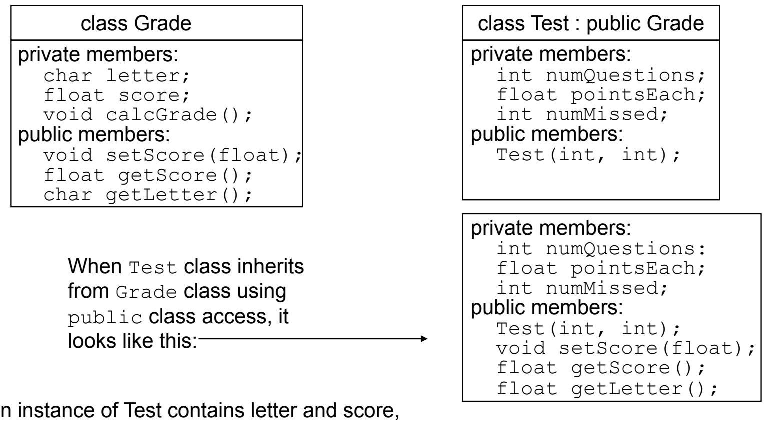
Inheritance

- A way to create a new class from an existing class
- The new class is a specialized version of the existing class
- Base class (or parent) – the existing class
- Derived class (or child) – inherits from the base class
- The derived class contains all the members from the base class (in addition to the ones in the derived class).

```
class Student {

  . . .

}    Base class
```

```
class UnderGrad : public Student {

  . . .

}    Derived class
```

Access to private members



```
class Grade
private members:
   char letter;
   float score;
   void calcGrade();
public members:
   void setScore(float);
   float getScore();
   char getLetter();
```

```
class Test : public Grade
private members:
   int numQuestions;
   float pointsEach;
   int numMissed;
public members:
   Test(int, int);
```

When `Test` class inherits from `Grade` class using `public` class access, it looks like this:

```
private members:
   int numQuestions:
   float pointsEach;
   int numMissed;
public members:
   Test(int, int);
   void setScore(float);
   float getScore();
   float getLetter();
```

An instance of Test contains letter and score, but they are **not** directly accessible from inside (or outside) the Test member functions.

Constructors and Destructors in Base and Derived Classes

- Derived classes can have their own constructors and destructors
- When an object of a derived class is **created**,
  1. the base class's (default) constructor is executed first,
  2. followed by the derived class's constructor
- When an object of a derived class is **destroyed**,
  1. the derived class destructor is called first,
  2. then the base class destructor

Constructors and Destructors:
example

```
class BaseClass {
public:
   BaseClass()
      { cout << "This is the BaseClass constructor.\n"; }
   ~BaseClass()
      { cout << "This is the BaseClass destructor.\n"; }
};
class DerivedClass : public BaseClass {
public:
   DerivedClass()
      { cout << "This is the DerivedClass constructor.\n"; }
   ~DerivedClass()
      { cout << "This is the DerivedClass destructor.\n"; }
};
int main() {
   cout << "We will now define a DerivedClass object.\n";
   DerivedClass object;
   cout << "The program is now going to end.\n";
}
```

Output:

```
We will now define a DerivedClass object.
This is the BaseClass constructor.
This is the DerivedClass constructor.
The program is now going to end.
This is the DerivedClass destructor.
This is the BaseClass destructor.
```

Passing Arguments to a non-default Base Class Constructor

- Allows programmer to choose which base class constructor is called from the derived class constructor
- Specify arguments to base constructor in the derived constructor function header:

```
//assuming Square is derived from Rectangle:
Rectangle::Rectangle(double w, double len)
              { width = w; length = len; }

Square::Square(int side) : Rectangle(side, side)
{  // code for Square constr goes here, if any  }
```

- You **must** specify a call to a base class constructor if base class has no default constructor

Redefining Base Class Functions

- Redefining function: a function in a derived class that has the same name and parameter list as a function in the base class
- Not the same as overloading – with overloading, parameter lists must be different
- Objects of base class use base class version of function; objects of derived class use derived class version of function.
- To call the base class version from the derived class version, you must prefix the name of the function with the base class name and the scope resolution operator:

```
Rectangle::display()
```

Redefining Base Class Functions:
example

```
class Animal {
 private:
  string species;
 public:
  Animal()  { species = "Animal";}
  Animal(string spe)
           { species = spe ;}
  void display()
    {cout << "species " << species; }
};
```

```
int main() {
    Animal  jasper;    //  Animal()
    Primate fred(4);   //  Primate(int)
    jasper.display(); cout << endl;
    fred.display();   cout << endl;
}
```

```
class Primate: public Animal {
 private:
  int heartCham;
 public:
  Primate()       : Animal("Primate")  { }
  Primate(int in) : Animal ("Primate")
                    { heartCham = in; }
  void display()
    { Animal::display(); //calls base class display()
      cout << ", \n# of heart chambers " << heartCham;
    }
};
```

Output:

```
species Animal
species Primate,
# of heart chambers 4
```

Include Guards

Rectangle.h

```
#ifndef RECTANGLE_H
#define RECTANGLE_H
class Rectangle
{
   private:
      double width;
      double length;
   public:
      void setWidth(double);
      void setLength(double);
      double getWidth() const;
      double getLength() const;
      double getArea() const;
};
#endif
```

- These preprocessor directives prevent the header file from accidentally being included more than once.
- Required when a base class has 2 derived classes, and both derived classes are included in a driver

Polymorphism

- The Greek word poly means many, and the Greek word morphism means form.
- So, polymorphism means 'many forms'.
- In object-oriented programming (OOP), polymorphism refers to
  - identically named (and redefined) functions
  - that have different behavior depending on the (specific derived) type of object they are called on.

Example of polymorphism?

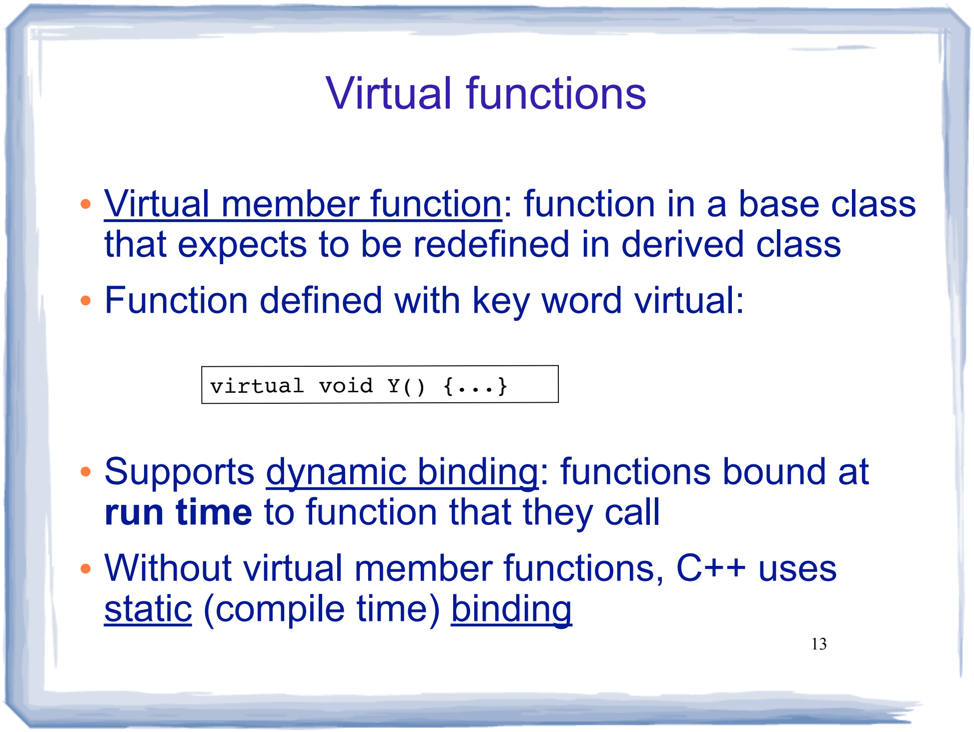
```
class Animal {
  private:
    ...
  public:
    void speak() { cout << “none ”; }
};
class Cat : public Animal {
  private:
    ...
  public:
    void speak() { cout << “meow ”; }
};
class Dog : public Animal {
  private:
    ...
  public:
    void speak() { cout << “bark ”; }
};
```

```
void f (Animal a) {
  a.speak();
}

int main() {
   Cat c;
   Dog d;
   f(c);
   f(d);
}
```

- IF the output is “meow bark”, yes, polymorphism.
  - The behavior of a in f would depend on its specific (derived) type.
- IF the output is “none none”, no it’s not.

Polymorphism in C++

- Polymorphism in C++ is supported through:
  - virtual functions AND
  - pointers to objects OR reference parameters.
- without these, C++ determines which function to invoke at <u>compile time</u> (using the variable type).
- when virtual functions and pointer/references are used together, C++ determines which function to invoke at <u>run time</u> (using the specific type of the instance currently referenced by the variable).

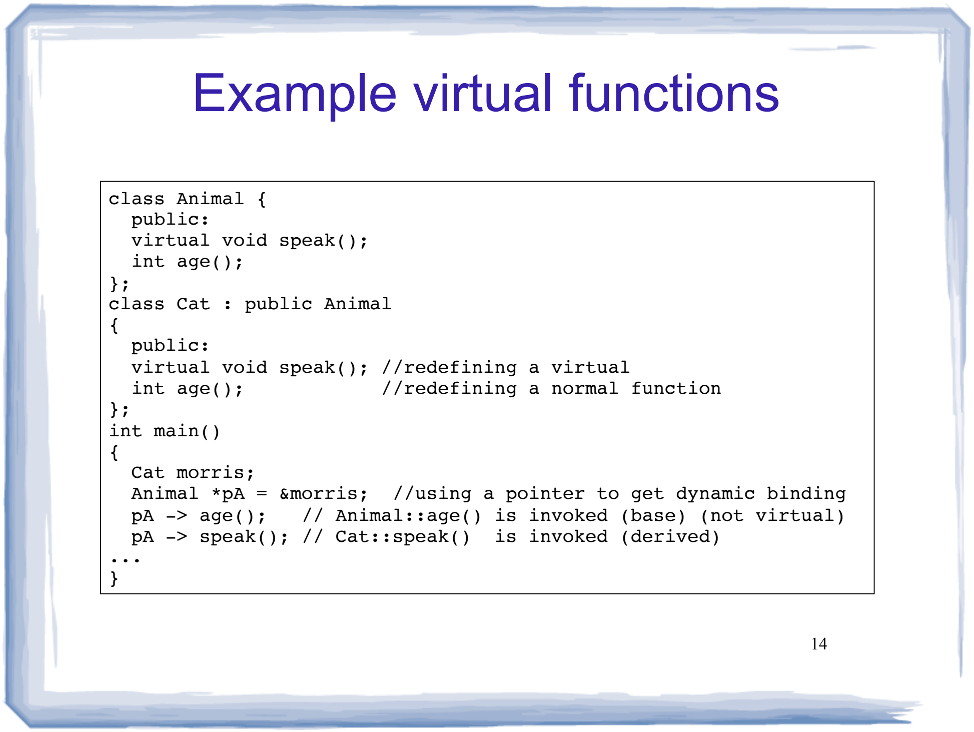


Virtual functions

- Virtual member function: function in a base class that expects to be redefined in derived class
- Function defined with key word virtual:

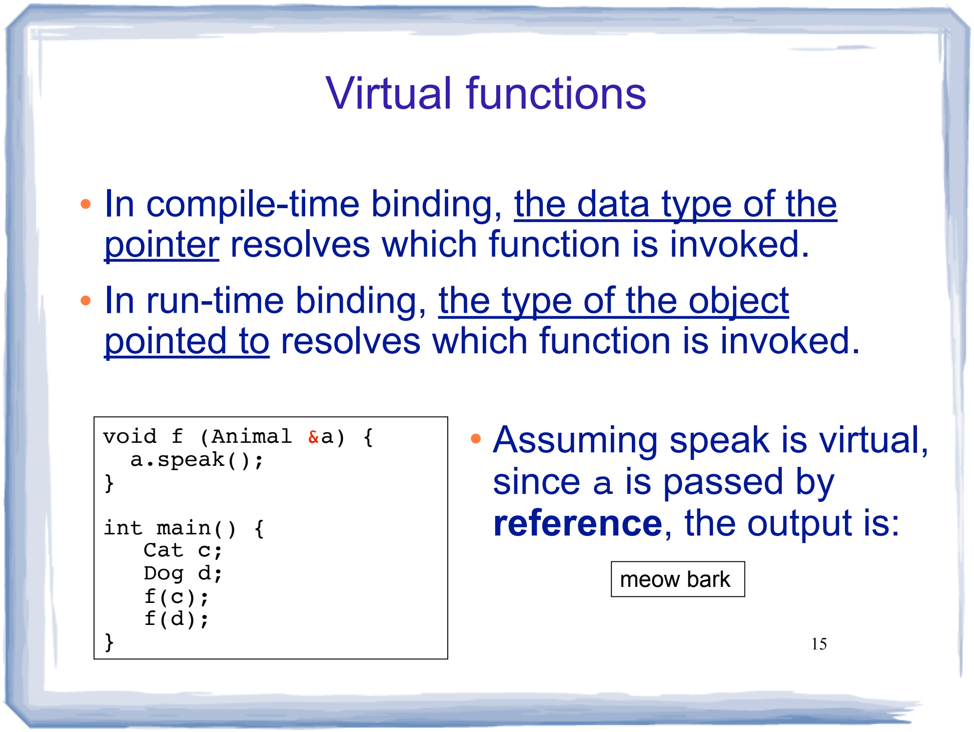
```
virtual void Y() {...}
```

- Supports dynamic binding: functions bound at **run time** to function that they call
- Without virtual member functions, C++ uses static (compile time) binding



Example virtual functions

```
class Animal {
  public:
  virtual void speak();
  int age();
};
class Cat : public Animal
{
  public:
  virtual void speak(); //redefining a virtual
  int age();            //redefining a normal function
};
int main()
{
  Cat morris;
  Animal *pA = &morris;  //using a pointer to get dynamic binding
  pA -> age();   // Animal::age() is invoked (base) (not virtual)
  pA -> speak(); // Cat::speak()  is invoked (derived)
...
}
```



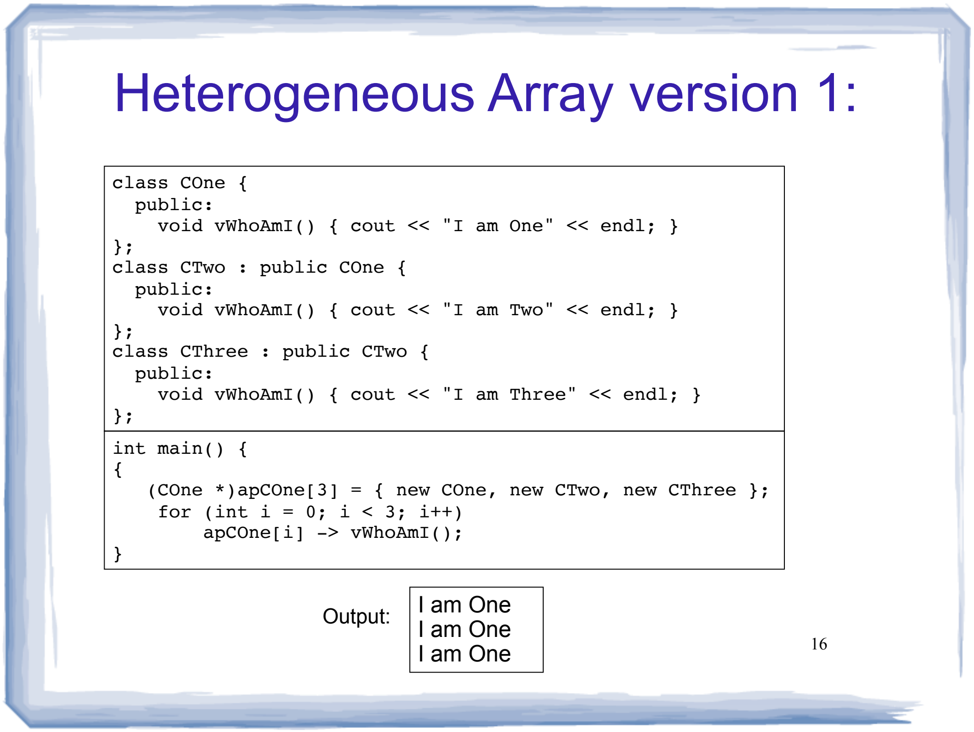
Virtual functions

- In compile-time binding, the data type of the pointer resolves which function is invoked.
- In run-time binding, the type of the object pointed to resolves which function is invoked.

```
void f (Animal &a) {
   a.speak();
}

int main() {
    Cat c;
    Dog d;
    f(c);
    f(d);
}
```

- Assuming speak is virtual, since a is passed by **reference**, the output is:

```
meow bark
```



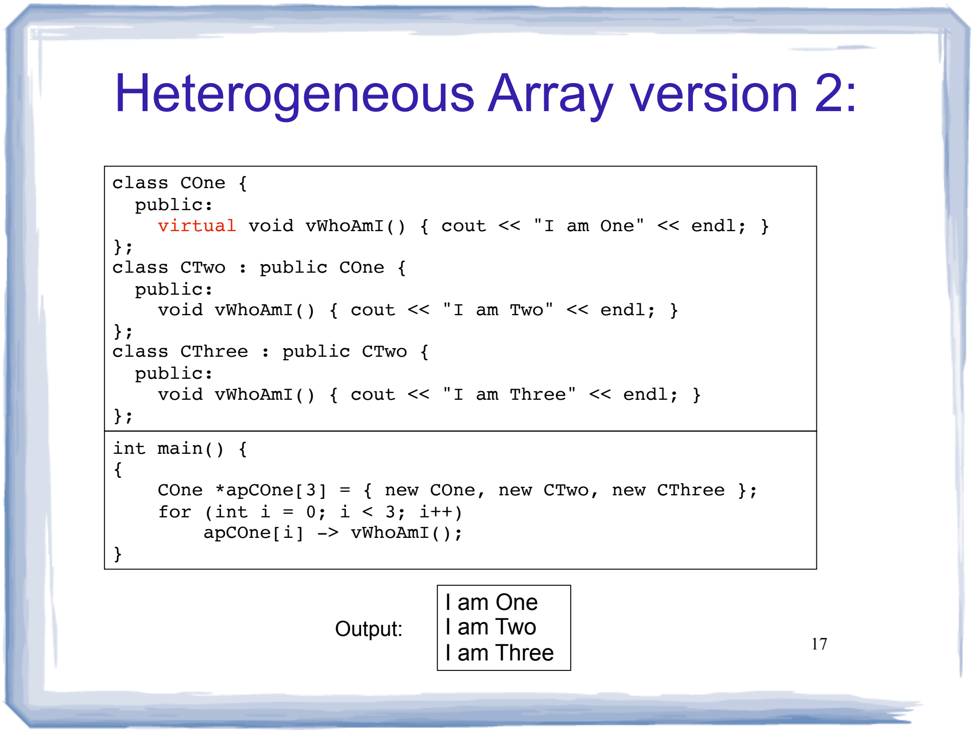
Heterogeneous Array version 1:

```
class COne {
  public:
    void vWhoAmI() { cout << "I am One" << endl; }
};
class CTwo : public COne {
  public:
    void vWhoAmI() { cout << "I am Two" << endl; }
};
class CThree : public CTwo {
  public:
    void vWhoAmI() { cout << "I am Three" << endl; }
};
```

```
int main() {
{
   (COne *)apCOne[3] = { new COne, new CTwo, new CThree };
    for (int i = 0; i < 3; i++)
        apCOne[i] -> vWhoAmI();
}
```

Output:

```
I am One
I am One
I am One
```



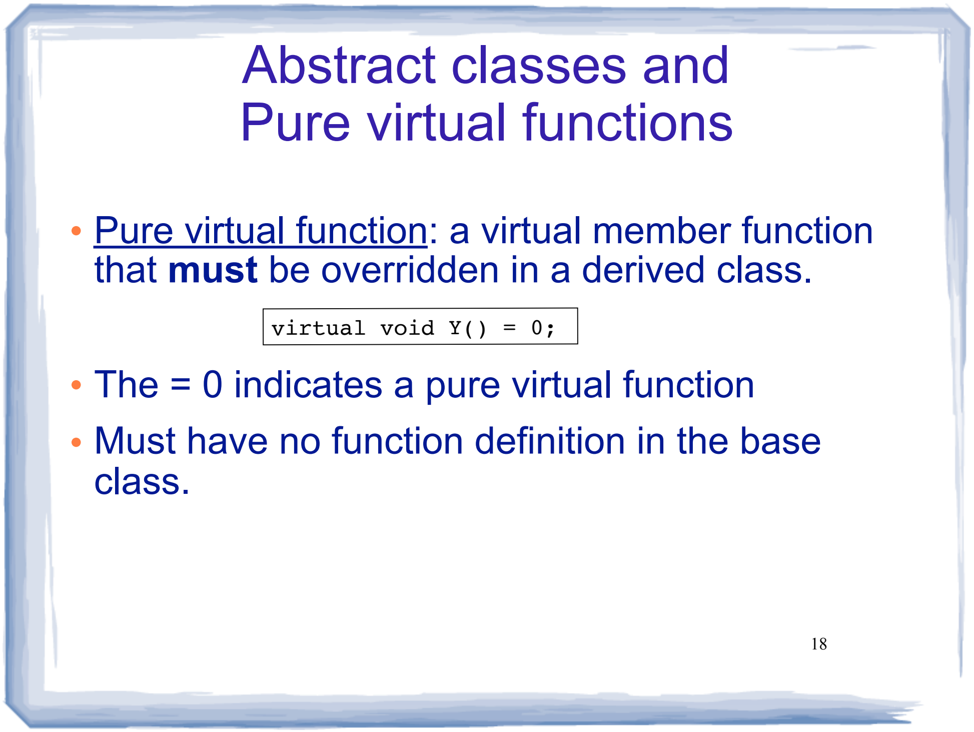
Heterogeneous Array version 2:

```
class COne {
  public:
    virtual void vWhoAmI() { cout << "I am One" << endl; }
};
class CTwo : public COne {
  public:
    void vWhoAmI() { cout << "I am Two" << endl; }
};
class CThree : public CTwo {
  public:
    void vWhoAmI() { cout << "I am Three" << endl; }
};
```

```
int main() {
{
    COne *apCOne[3] = { new COne, new CTwo, new CThree };
    for (int i = 0; i < 3; i++)
        apCOne[i] -> vWhoAmI();
}
```

Output:

```
I am One
I am Two
I am Three
```

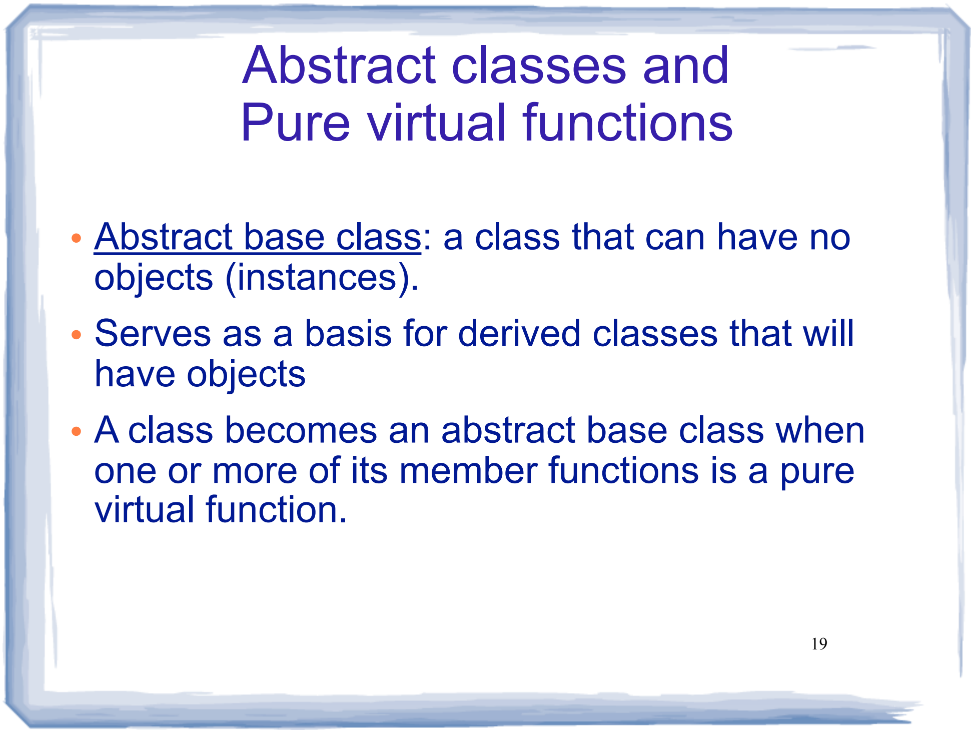


Abstract classes and Pure virtual functions

- Pure virtual function: a virtual member function that **must** be overridden in a derived class.

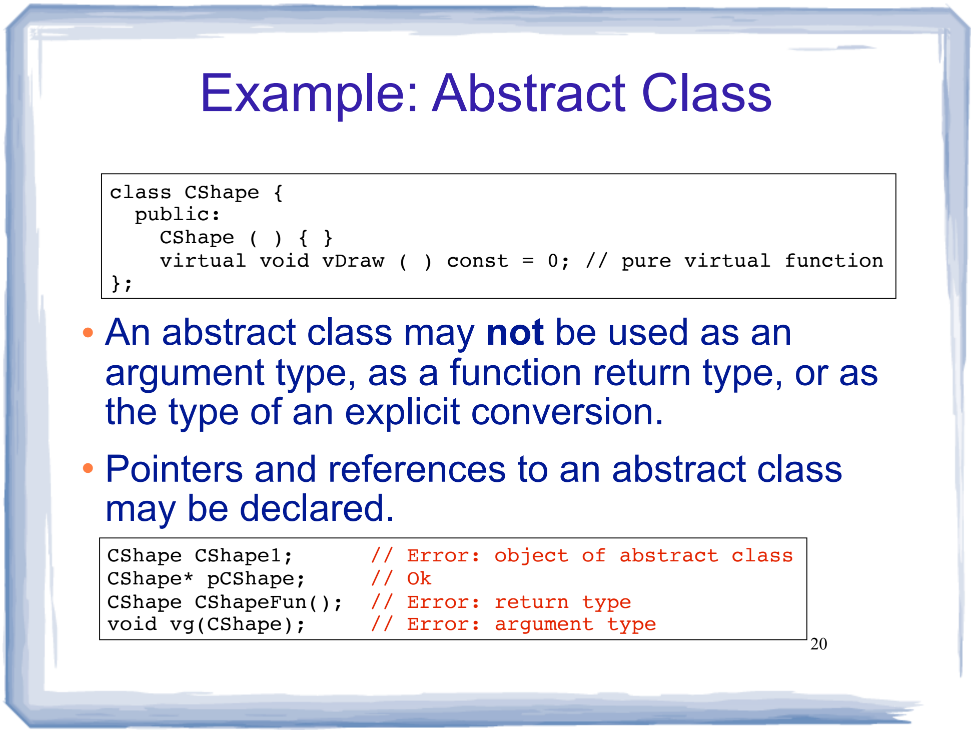
```
virtual void Y() = 0;
```

- The = 0 indicates a pure virtual function
- Must have no function definition in the base class.



Abstract classes and Pure virtual functions

- Abstract base class: a class that can have no objects (instances).
- Serves as a basis for derived classes that will have objects
- A class becomes an abstract base class when one or more of its member functions is a pure virtual function.



Example: Abstract Class

```
class CShape {
  public:
    CShape ( ) { }
    virtual void vDraw ( ) const = 0; // pure virtual function
};
```

- An abstract class may **not** be used as an argument type, as a function return type, or as the type of an explicit conversion.
- Pointers and references to an abstract class may be declared.

```
CShape CShape1;      // Error: object of abstract class
CShape* pCShape;     // Ok
CShape CShapeFun();  // Error: return type
void vg(CShape);     // Error: argument type
```

Example: Abstract Class

- Pure virtual functions are inherited as pure virtual functions.

```
class CAbstractCircle : public CShape {
  private:
    int m_iRadius;
  public:
    void vRotate (int) {}
    // CAbstractCircle ::vDraw() is a pure virtual function
};
```

- Or else:

```
class CCircle : public CShape {
  private:
    int m_iRadius;
  public:
    void vRotate (int) {}
    void vDraw();   //define here or in impl file
};
```

Heterogeneous collection: abstract base class

```
class Animal {
  private:
    string name;
  public:
    Animal(string n) {name = n;}
    virtual void speak() = 0;
};
class Cat : public Animal {
  public:
    Cat(string n) : Animal(n) { };
    void speak()  {cout << "meow "; }
};
class Dog : public Animal {
  public:
    Dog(string n) : Animal(n) { };
    void speak()  {cout << "bark "; }
};
class Pig : public Animal {
  public:
    Pig(string n) : Animal(n) { };
    void speak()  {cout << "oink "; }
};
```

```
int main()
{
    Animal* animals[ ] = {
        new Cat("Charlie"),
        new Cat("Scamp"),
        new Dog("Penny"),
        new Cat("Libby"),
        new Cat("Patches"),
        new Dog("Milo"),
        new Pig("Wilbur") };

    for (int i=0; i< 7; i++) {
        animals[i]->speak();
    }
}
```

Output:

meow meow bark meow meow bark oink