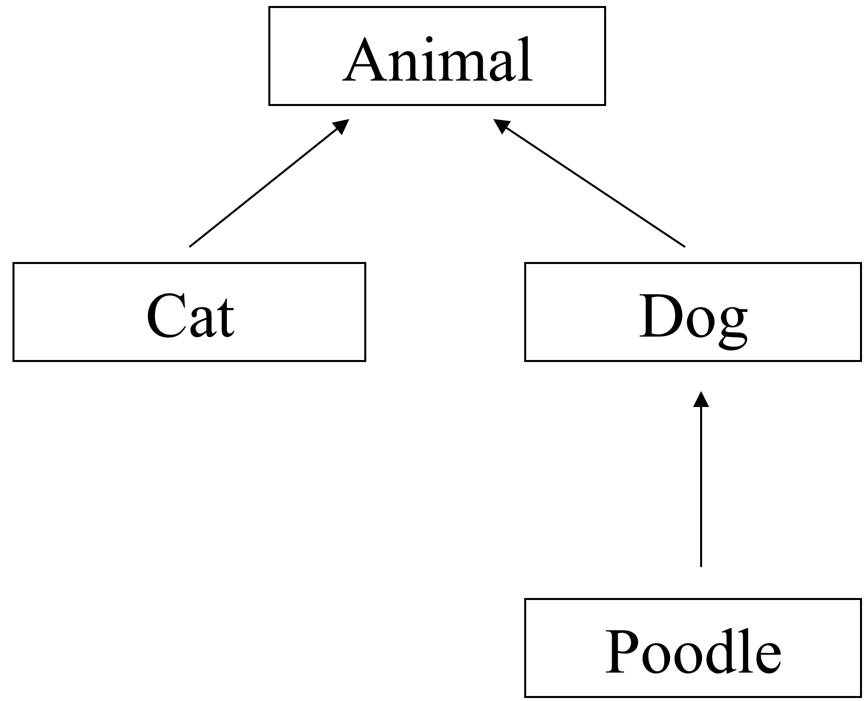
CS 162
Intro to Programming II

Polymorphism Ib

Type Compatibility in Inheritance Hierarchies

- Classes in a program may be part of an inheritance hierarchy

- Classes lower in the hierarchy are special cases of those above



Type Compatibility in Inheritance

- A pointer to a derived class can be assigned to a pointer to a base class. Another way to say this is:
- A base class pointer can point to derived class objects

```
Animal *pA = new Cat;
```

Type Compatibility in Inheritance

- Assigning a base class pointer to a derived class pointer requires a cast

```
Animal *pA = new Cat;
Cat *pC;
pC = static_cast<Cat *>(pA);
```

- The base class pointer must already point to a derived class object for this to work

Using Type Casts with Base Class Pointers

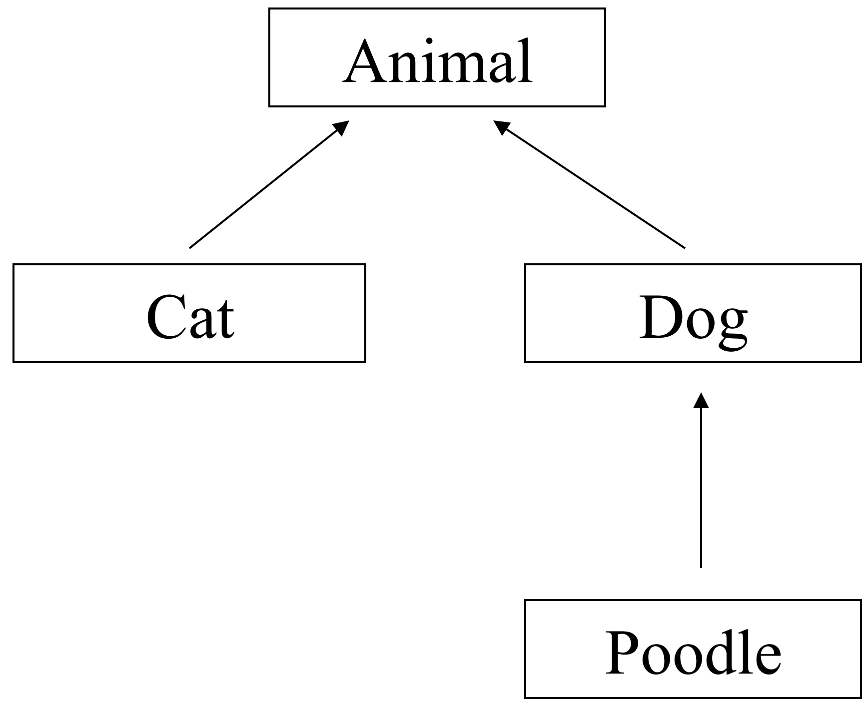
- C++ uses the declared type of a pointer to determine access to the members of the pointed-to object
- If an object of a derived class is pointed to by a base class pointer, all members of the derived class may not be accessible
- Type cast the base class pointer to the derived class (via `static_cast`) in order to access members that are specific to the derived class

Virtual Member Functions

- Polymorphic code: Code that behaves differently when it acts on objects of different types
- Virtual Member Function: The C++ mechanism for achieving polymorphism

Polymorphism

Consider the Animal, Cat, Dog hierarchy where each class has its own version of the member function id( )



Polymorphism

```
class Animal{
 public: void id(){cout << "animal";}
}
class Cat : public Animal{
 public: void id(){cout << "cat";}
}
class Dog : public Animal{
 public: void id(){cout << "dog";}
}
```

Polymorphism

- Consider the collection of different Animal objects

```
Animal *pA[] = {new Animal, new Dog,
                          new Cat};
```

and accompanying code

```
for(int k=0; k<3; k++)
    pA[k]->id();
```

- Prints: **`animal animal animal`**, ignoring the more specific versions of **`id()`** in **`Dog`** and **`Cat`**

Polymorphism

- The preceding code is not polymorphic: it behaves the same way even though **`Animal`**, **`Dog`** and **`Cat`** have different types and different **`id()`** member functions
- Polymorphic code would have printed "**`animal dog cat`**" instead of "**`animal animal animal`**"

Polymorphism

- The code is not polymorphic because in the expression

  `pA[k]->id()`

  the compiler sees only the type of the pointer `pA[k]`, which is pointer to `Animal`
- Compiler does not see type of actual object pointed to, which may be `Animal`, or `Dog`, or `Cat`

Virtual Functions

Declaring a function **`virtual`** will make the compiler check the type of each object to see if it defines a more specific version of the virtual function

Virtual Functions

If the member functions **`id()`** are declared virtual, then the code

```
Animal *pA[] = {new Animal,
                new Dog,new Cat};
for(int k=0; k<3; k++)
    pA[k]->id();
```

will print **`animal dog cat`**

Virtual Functions

How to declare a member function virtual:

```
class Animal{
 public: virtual void id(){cout << "animal";}
}
class Cat : public Animal{
 public: virtual void id(){cout << "cat";}
}
class Dog : public Animal{
 public: virtual void id(){cout << "dog";}
}
```

Function Binding

- In **`pA[k]->id()`**, Compiler must choose which version of **`id()`** to use: There are different versions in the **`Animal`**, **`Dog`**, and **`Cat`** classes
- Function binding is the process of determining which function definition to use for a particular function call
- The alternatives are *static* and *dynamic* binding

Static Binding

- Static binding chooses the function in the class of the base class pointer, ignoring any versions in the class of the object actually pointed to
- Static binding is done at compile time

Dynamic Binding

- Dynamic Binding determines the function to be invoked at execution time
- Can look at the actual class of the object pointed to and choose the most specific version of the function
- Dynamic binding is used to bind virtual functions
- Also called late binding

Abstract Base Classes and Pure Virtual Functions

- An abstract class is a class that contains no objects that are not members of subclasses (derived classes)
- For example, in real life, Animal is an abstract class: there are no animals that are not dogs, or cats, or lions…
- In other words you cannot instantiate an object of class Animal

Abstract Base Classes and Pure Virtual Functions

- Abstract classes are an organizational tool. They are useful in organizing inheritance hierarchies
- Abstract classes can be used to specify an interface that must be implemented by all subclasses

Abstract Functions

- The member functions specified in an abstract class do not have to be implemented
- The implementation is left to the subclasses
- In C++, an abstract class is a class with at least one abstract member function

Pure Virtual Functions

- In C++, a member function of a class is declared to be an abstract function by making it virtual and replacing its body with **`= 0;`**

```
class Animal{
 public:
  virtual void id()=0;
};
```

- A virtual function with its body omitted and replaced with **=0** is called a pure virtual function, or an abstract function

Abstract Classes

- An abstract class can not be instantiated
- An abstract class can only be inherited from; that is, you can derive classes from it
- Classes derived from abstract classes must override all pure virtual functions with a concrete member functions before they can be instantiated.