Software Engineering 2 (C++)

CSY2006 (Week 16)

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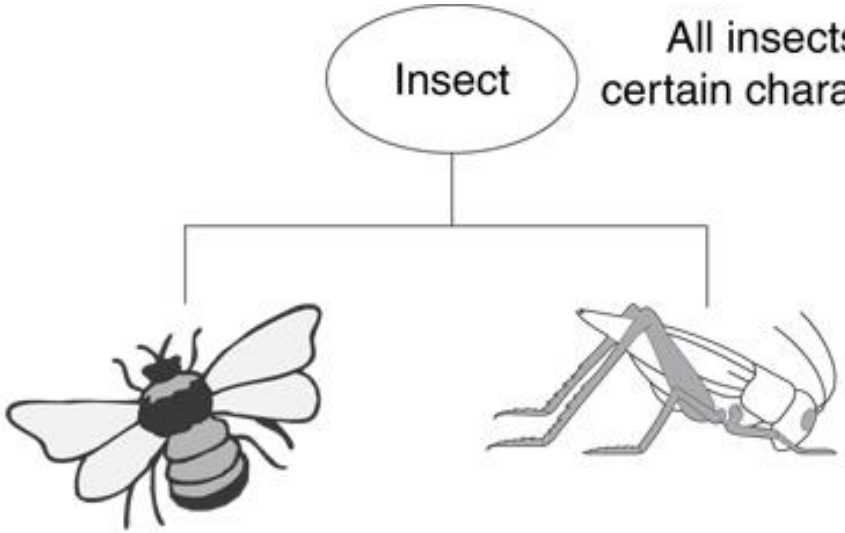
What Is Inheritance?

What Is Inheritance?

- Provides a way to create a new class from an existing class
- The new class is a specialized version of the existing class

Example: Insects



In addition to the common insect characteristics, the bumble bee has its own unique characteristics such as the ability to sting.

In addition to the common insect characteristics, the grasshopper has its own unique characteristics such as the ability to jump.

The "is a" Relationship

- Inheritance establishes an "is a" relationship between classes.
  - A poodle is a dog
  - A car is a vehicle
  - A flower is a plant
  - A football player is an athlete

Inheritance – Terminology and Notation

- Base class (or parent) – inherited from
- Derived class (or child) – inherits from the base class
- Notation:

```
class Student                    // base class
{
  . . .
};
class UnderGrad : public student
{                                // derived class
  . . .
};
```

Back to the ‘is a’ Relationship

- An object of a derived class 'is a(n)' object of the base class
- Example:
  - an `UnderGrad` is a `Student`
  - a `Mammal` is an `Animal`
- A derived object has all of the characteristics of the base class

What Does a Child Have?

An object of the derived class has:

- all members defined in child class
- all members declared in parent class

An object of the derived class can use:

- all `public` members defined in child class
- all `public` members defined in parent class
- Example: GradedActivity Version 1 (Pr 15-2); Employ.cpp

Protected Members and Class Access

Protected Members and Class Access

- `protected` member access specification: like `private`, but accessible by objects of derived class

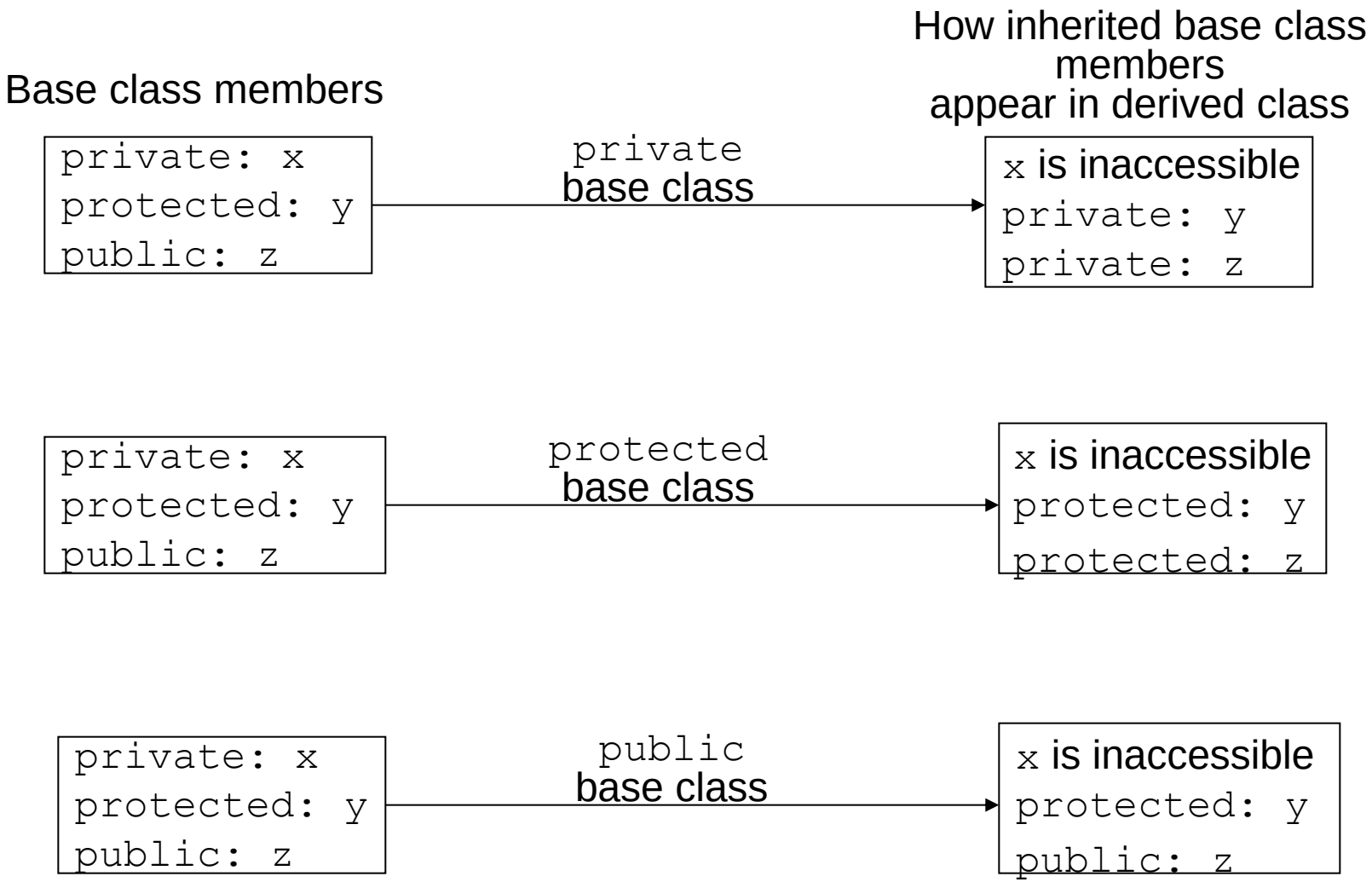
- Class access specification: determines how `private`, `protected`, and `public` members of base class are inherited by the derived class

Class Access Specifiers

1) `public` – object of derived class can be treated as object of base class (not vice-versa)
2) `protected` – more restrictive than `public`, but allows derived classes to know details of parents
3) `private` – prevents objects of derived class from being treated as objects of base class.

Example: GradedActivity Version 2 (Pr 15-3); Pubpriv.cpp

Inheritance vs. Access



More Inheritance vs. Access

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();`
`char getLetter();`

More Inheritance vs. Access (2)

class Grade

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

class Test : protected Grade

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

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

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

More Inheritance vs. Access (3)

class Grade

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

class Test : private Grade

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

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

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

Constructors and Destructors in Base and Derived Classes

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, the base class's constructor is executed first, followed by the derived class's constructor
- When an object of a derived class is destroyed, its destructor is called first, then that of the base class

Constructors and Destructors in Base and Derived Classes

Program 15-4

```
1  // This program demonstrates the order in which base and
2  // derived class constructors and destructors are called.
3  #include <iostream>
4  using namespace std;
5
6  //*********************************
7  // BaseClass declaration          *
8  //*********************************
9
```

Program 15-4 *(continued)*

```
10  class BaseClass
11  {
12  public:
13     BaseClass()  // Constructor
14        { cout << "This is the BaseClass constructor.\n"; }
15
16     ~BaseClass() // Destructor
17        { cout << "This is the BaseClass destructor.\n"; }
18  };
19
20  //*********************************
21  // DerivedClass declaration      *
22  //*********************************
23
24  class DerivedClass : public BaseClass
25  {
26  public:
27     DerivedClass()  // Constructor
28        { cout << "This is the DerivedClass constructor.\n"; }
29
30     ~DerivedClass()  // Destructor
31        { cout << "This is the DerivedClass destructor.\n"; }
32  };
33
```

Program 5-14 (Continued)

```
34  //*********************************
35  // main function                  *
36  //*********************************
37
38  int main()
39  {
40     cout << "We will now define a DerivedClass object.\n";
41
42     DerivedClass object;
43
44     cout << "The program is now going to end.\n";
45     return 0;
46  }
```

Program 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.
```

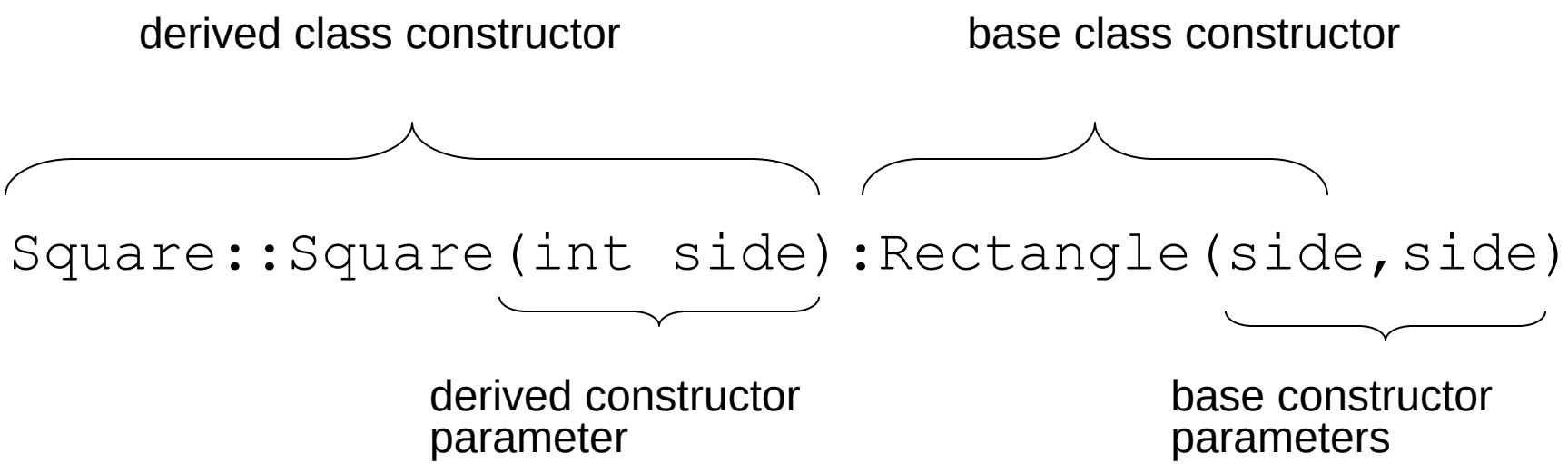
Passing Arguments to Base Class Constructor

- Allows selection between multiple base class constructors
- Specify arguments to base constructor on derived constructor heading:

```
Square::Square(int side) :
                    Rectangle(side, side)
```

- Can also be done with inline constructors
- Must be done if base class has no default constructor
- Example: Pr 15-5, Cube.h, Rectangle.h

Passing Arguments to Base Class Constructor



Passing Arguments to Base Class Constructor

```
1  #ifndef RECTANGLE_H
2  #define RECTANGLE_H
3  class Rectangle{
4  private:
5     double width;
6     double length;
7  public:
8     // Default constructor
9     Rectangle()
10       { width = 0.0;
11         length = 0.0; }
12
13    // Constructor #2
14    Rectangle(double w, double len){
15         width = w;
16         length = len; }
17
18    double getWidth() const
19       { return width; }
20
21    double getLength() const
22       { return length; }
23
24    double getArea() const
25       { return width * length; }
26 };
27 #endif
```

Passing Arguments to Base Class Constructor

```
1  #ifndef CUBE_H
2  #define CUBE_H
3  #include "Rectangle.h"
4
5  class Cube : public Rectangle
6  {
7  protected:
8     double height;
9     double volume;
10 public:
11    // Default constructor
12    Cube() : Rectangle()
13       { height = 0.0; volume = 0.0; }
14
15    // Constructor #2
16    Cube(double w, double len, double h) : Rectangle(w, len)
17       { height = h;
18         volume = getArea() * h; }
19
20    double getHeight() const
21       { return height; }
22
23    double getVolume() const
24       { return volume; }
25 };
26 #endif
27
```

Passing Arguments to Base Class Constructor

```
1  // This program demonstrates passing arguments to a base
2  //uses cube.h and rectangle.h
3  // class constructor.
4  #include <iostream>
5  #include "Cube.h"
6  using namespace std;
7  int main(){
8     double cubeWidth;   // To hold the cube's width
9     double cubeLength;  // To hold the cube's length
10    double cubeHeight;  // To hold the cube's height
11
12    // Get the width, length, and height of the cube from the user.
13    cout << "Enter the dimensions of a Cube:\n";
14    cout << "Width: ";
15    cin >> cubeWidth;
16    cout << "Length: ";
17    cin >> cubeLength;
18    cout << "Height: ";
19    cin >> cubeHeight;
20    // Define a Cube object and use the dimensions entered by the user.
21    Cube myCube(cubeWidth, cubeLength, cubeHeight);
22    // Display the Cube object's properties.
23    cout << "Here are the Cube's properties:\n";
24    cout << "Width: " << myCube.getWidth() << endl;
25    cout << "Length: " << myCube.getLength() << endl;
26    cout << "Height: " << myCube.getHeight() << endl;
27    cout << "Base area: " << myCube.getArea() << endl;
28    cout << "Volume: " << myCube.getVolume() << endl;
29    return 0;
30 }
```

Redefining Base Class Functions

Redefining Base Class Functions

- Redefining function: function in a derived class that has the *same name and parameter list* as a function in the base class

- Typically used to replace a function in base class with different actions in derived class

Redefining Base Class Functions

- 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
- Example: Pr15-7, Pr15 -8

Base Class

```
class GradedActivity
{
protected:
   char letter;              // To hold the letter grade
   double score;             // To hold the numeric score
   void determineGrade();    // Determines the letter grade
public:
   // Default constructor
   GradedActivity()
      { letter = ' '; score = 0.0; }

   // Mutator function
   void setScore(double s)
      { score = s;
        determineGrade();}

   // Accessor functions
   double getScore() const
      { return score; }

   char getLetterGrade() const
      { return letter; }
};
```

Note `setScore` function

Derived Class

```
1  #ifndef CURVEDACTIVITY_H
2  #define CURVEDACTIVITY_H
3  #include "GradedActivity.h"
4
5  class CurvedActivity : public GradedActivity
6  {
7  protected:
8     double rawScore;      // Unadjusted score
9     double percentage;    // Curve percentage
10 public:
11    // Default constructor
12    CurvedActivity() : GradedActivity()
13       { rawScore = 0.0; percentage = 0.0; }
14
15    // Mutator functions
16    void setScore(double s)
17       { rawScore = s;
18         GradedActivity::setScore(rawScore * percentage); }
19
20    void setPercentage(double c)
21       { percentage = c; }
22
23    // Accessor functions
24    double getPercentage() const
25       { return percentage; }
26
27    double getRawScore() const
28       { return rawScore; }
29 };
30 #endif
```

Redefined `setScore` function

From Program 15-7

```
13      // Define a CurvedActivity object.
14      CurvedActivity exam;
15
16      // Get the unadjusted score.
17      cout << "Enter the student's raw numeric score: ";
18      cin >> numericScore;
19
20      // Get the curve percentage.
21      cout << "Enter the curve percentage for this student: ";
22      cin >> percentage;
23
24      // Send the values to the exam object.
25      exam.setPercentage(percentage);
26      exam.setScore(numericScore);
27
28      // Display the grade data.
29      cout << fixed << setprecision(2);
30      cout << "The raw score is "
31           << exam.getRawScore() << endl;
32      cout << "The curved score is "
33           << exam.getScore() << endl;
34      cout << "The curved grade is "
35           << exam.getLetterGrade() << endl;
```

Program Output with Example Input Shown in Bold

```
Enter the student's raw numeric score: 87 [Enter]
Enter the curve percentage for this student: 1.06 [Enter]
The raw score is 87.00
The curved score is 92.22
The curved grade is A
```

Problem with Redefining

- Consider this situation:
  - Class `BaseClass` defines functions `x()` and `y()`. `x()` calls `y()`.
  - Class `DerivedClass` inherits from `BaseClass` and redefines function `y()`.
  - An object `D` of class `DerivedClass` is created and function `x()` is called.
  - When `x()` is called, which `y()` is used, the one defined in `BaseClass` or the the redefined one in `DerivedClass`?

Problem with Redefining

BaseClass

```
void X();
void Y();
```

DerivedClass

```
void Y();
```

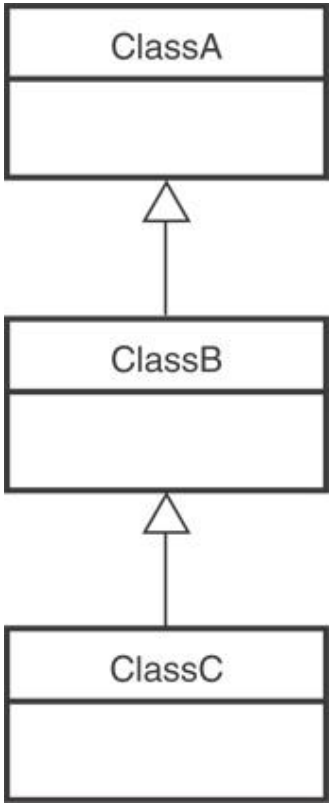
```
DerivedClass D;
D.X();
```

Object `D` invokes function `X()` In `BaseClass`. Function `X()` invokes function `Y()` in `BaseClass`, not function `Y()` in `DerivedClass`, because function calls are bound at compile time. This is static binding.

Class Hierarchies

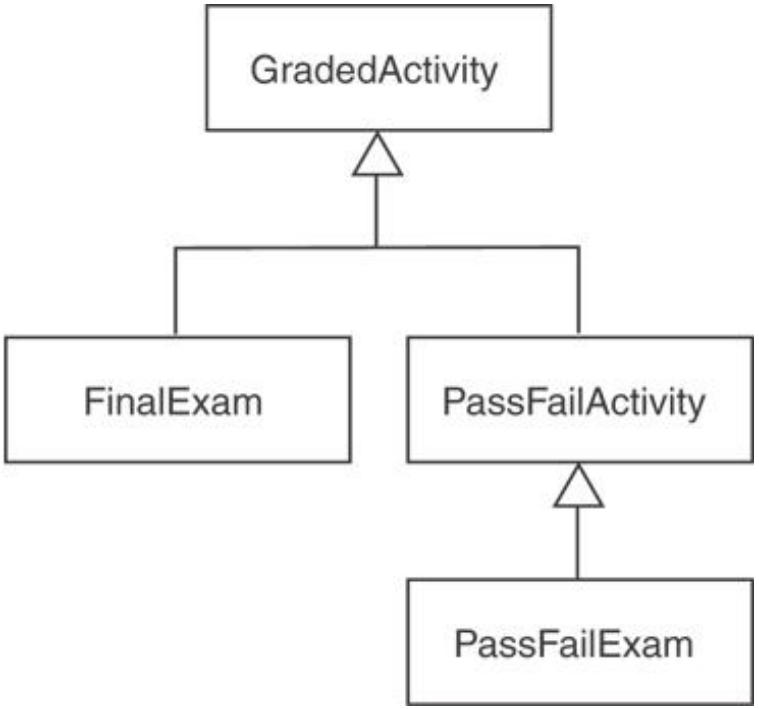
Class Hierarchies

- A base class can be derived from another base class.



Class Hierarchies

- Consider the GradedActivity, FinalExam, PassFailActivity, PassFailExam hierarchy in Pr15-9.

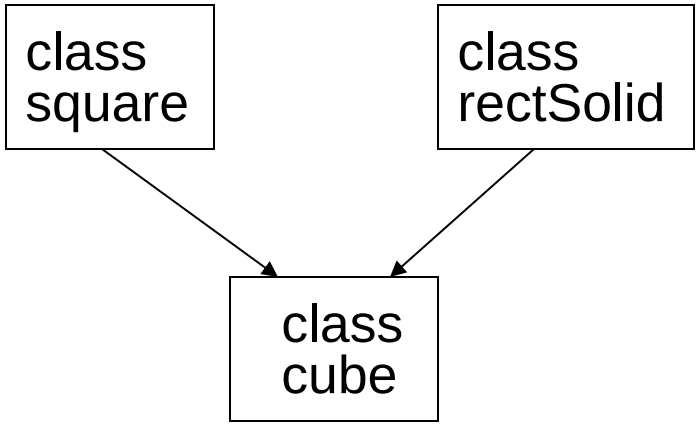


Multiple Inheritance

Multiple Inheritance

- A derived class can have more than one base class
- Example: Engmult.cpp
- Each base class can have its own access specification in derived class's definition:

```
class cube : public square,
                    public rectSolid;
```



Multiple Inheritance

- Arguments can be passed to both base classes' constructors:

```
cube::cube(int side) :
square(side),
      rectSolid(side, side, side);
```

- Base class constructors are called in order given in class declaration, not in order used in class constructor

Multiple Inheritance

- Problem: what if base classes have member variables/functions with the same name?
- Solutions:
  - Derived class redefines the multiply-defined function
  - Derived class invokes member function in a particular base class using scope resolution operator `::`
- Compiler errors occur if derived class uses base class function without one of these solutions
- See Ambigu; Date, Time, DateTime and Program 15-18 for examples