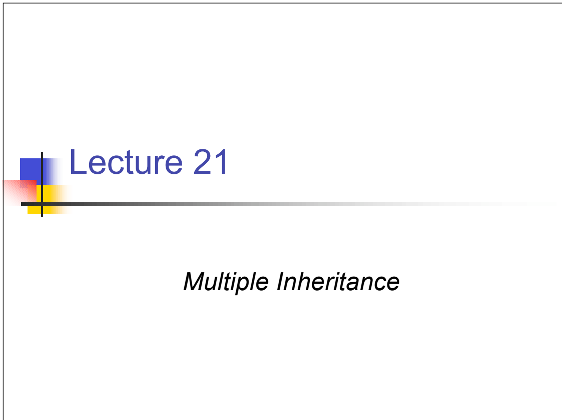


What is Multiple Inheritance?

- We defined inheritance earlier in the semester as a relationship between classes.
- If class C inherits from class B it is normally the case that C *is a* B or that C *is a kind of* B.
- But what happens when we discover that C is a kind of B *and* C is also *a kind of* D?
- For example, remember our `Student` and `Instructor` classes? They both were derived from `Person`.
- But let's throw another class into the mix: `Employee`
- An `Instructor` is certainly a kind of `Employee`, but an `Instructor` is also a kind of `Person`.
- This seems like a possible candidate for multiple inheritance!

What is Multiple Inheritance?

- In C++ code, multiple inheritance looks just like single inheritance, except there are "multiple" base classes specified.
- They are separated by commas.
- They may individually be declared as public, private or protected.
- If a given class is not declared as being of type public, private or protected, the default is private.
- Inherited member variables are accessible according to the rules of single inheritance.

```
class Instructor : public Person, public Employee
{
…
};
```

Arguing about it…

- One can argue that multiple inheritance shouldn't be necessary if you've defined your class hierarchy properly.
- As a matter of fact, most books don't cover it.
- Since every Employee really is a Person, should we be able to do this?

```
class Employee : public Person
{
…
};
class Instructor : public Employee
{
…
};
class Student : public Person
{
…
};
```

Arguing about it…

- Well, certainly you can. Remember, this is C++. You can do just about anything you want to!
- Here's another wrench in the puzzle…
- What happens when a `Student` is an `Employee` as well?
- You still wouldn't derive every `Student` from `Employee` either through single or multiple inheritance.
- What it might suggest is that you need to re-think your object hierarchy before starting to code.
- This is usually the point of view of those who don't believe in multiple inheritance.
- We won't settle the argument here.
- We will concentrate on the other side of the argument, which was that sometimes you need to derive from two pre-existing classes. It's called a "mix-in".

What are Mix-Ins?

- A mix-in is really just what it sounds like.
- It's a combination of two classes through multiple inheritance.
- Think back to interfaces for a moment.
- Consider a `DataPrinter` interface which allows us to derive a class used to print either an array of string or List data types…

```
// The following class is an example of an interface
class DataPrinter
{
public:
  virtual void printData(string *,int)=0;
  virtual void printData(List &)=0;
};
```

What are Mix-Ins?

- Now, suppose you had to “derive” a class from `DataPrinter` to do printing to `cout`.
- It might be called `CoutPrinter` and looked like this:

```
class CoutPrinter : public DataPrinter
{
public:
  void printData(string *,int);
  void printData(List &);
};
void CoutPrinter::printData(string *stringArray,int size)
{
  cout << "ARRAY OUTPUT: " << endl;
  for (int i=0; i<size; i++)
  {
    cout << i << ". " << stringArray[i] << endl;
  }
}
```

What are Mix-Ins?

```
void CoutPrinter::printData(List &aList)
{
  List::Node *aNode = aList.the_head;
  int i= 0;
  cout << "LIST OUTPUT:" << endl;
  while (aNode)
  {
    cout << i << ". " << aNode->the_value << endl;
    i++;
    aNode = aNode->next;
  }
}
```

- Now, consider that you would like to define another class to output to a dot matrix printer instead of `cout`.
- You might call it `DMDataPrinter`.
- The thing is, you already have a class for representing dot matrix printers:

What are Mix-Ins?

```
class DotMatrixPrinter {
public:
  DotMatrixPrinter():port(“”){}
  DotMatrixPrinter(string argPort):port(argPort){}
  void setPort(string argPort);
  string getPort();
  bool openPort();
  void closePort();
protected:
  ofstream outStream;
private:
  string port;
};
```

- You don’t want to duplicate the functionality in either of the existing classes in `DMDataPrinter`.
- You need to derive `DMDataPrinter` from `DataPrinter` so that all the virtual functionality we rely on with interfaces still works.

What are Mix-Ins?

- You don’t want to duplicate the functionality of DotMatrixPrinter which appears to take care of some of the overhead involved in opening a connection to the printer .
- So, you make use of multiple inheritance to create a *mix-in* of two existing classes, namely `DotMatrixPrinter` and `DataPrinter`.
- The argument that perhaps our object hierarchy needs rethinking is still somewhat valid, but not as strong.
- You see, DataPrinter is an interface.
- To try and incorporate it into the DotMatrixPrinter hierarchy (which is probably derived from a generic “Printer” class in the real world) doesn’t make sense because you would then be forcing every printer to implement the printData method (remember, it’s pure virtual).
- No, this is clearly a case for multiple inheritance:

What are Mix-Ins?

```
class DMDataPrinter : public DataPrinter, public DotMatrixPrinter
{
public:
  void printData(MyString *,int);
  void printData(List &);
};
```

- Since this class is derived from `DotMatrixPrinter` as well, the `printData` member function can be implemented like this:

What are Mix-Ins?

```
void DMDataPrinter::printData(MyString *anArray,int size)
{

    if (openPort())
  {
    outStream << "ARRAY OUTPUT: " << endl;
    for (int i=0; i<size; i++)
    {
      outStream << i << ". " << anArray[i] << endl;
    }
    closePort();
  }
}
```

- Let’s see this work...

Demonstration #1

Simple Multiple Inheritance

More About Multiple Inheritance

- Multiple base classes may share member function names, but...
- The following code will generate a compiler error:

```
class A {
public:
  void printSomething() { cout << "Something from A" << endl;}
};
class B {
public:
  void printSomething() { cout << "Something from B" << endl;}
};
class C : public A, public B {
};
main()
{
  C c;
  c.printSomething();
};
```

More About Multiple Inheritance

- This code is OK...

```
class A {
public:
  void printSomething() { cout << "Something from A" << endl;}
};
class B {
public:
  void printSomething() { cout << "Something from B" << endl;}
};
class C : public A, public B {
public:
  void printSomething() { A::printSomething(); }
};
main() {
  C c;
  c.printSomething();
  c.B::printSomething();   // That looks weird!
};
```

More About Multiple Inheritance

- Earlier we talked about additions to our old friends, the `Student` and `Instructor` classes.
- They were both derived from `Person`.
- We added `Employee` and showed how we could derive `Instructor` from both `Person` and `Employee`.
- That was our example of multiple inheritance.
- For another example, consider a hierarchy of "meals"
- Assume we have a base class called `meal`.
- Next we have three derived classes, `breakfast`, `lunch` and `dinner`.
- But, there's this meal called brunch.
- It's really a kind of breakfast and a kind of lunch, so we use multiple inheritance to derive `brunch` from `breakfast` and `lunch`.
- Graphically, that might look like this:

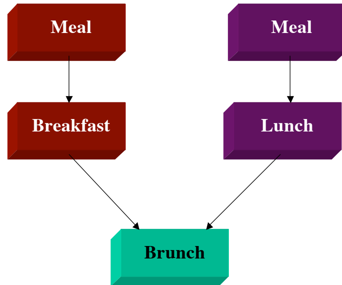
More About Multiple Inheritance

There is an interesting problem/side effect here!

Demonstration #2

Our Hierarchy of Meals

More About Multiple Inheritance



- There are actually *two* instances of `Meal` present in an instance of `Brunch`!

More About Multiple Inheritance

- Since `Breakfast` and `Lunch` are both derived from `Meal`, using multiple inheritance to derive `Brunch` from `Breakfast` and `Lunch` causes duplication in the `Meal` base class.
- This leads to ambiguous access errors when attempting to access `Meal` from `Brunch`.
- We can fix these problems with explicit references to which version of `Meal` we want.
- We do this by explicitly referencing the appropriate class derived from `Meal` (`Breakfast` or `Lunch`)
- This fixes the compile time problem(s)...

Demonstration #3

Our Next Hierarchy of Meals

Virtual Base Classes

- OK, so now it works. But is it what we want?
- In general, probably not.
- You can avoid this sub-object duplication by making any classes which derive directly from Meal derive it *virtually*.
- Virtual again?

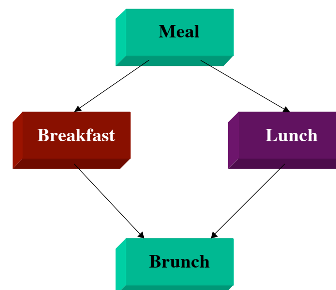
```
class Breakfast : virtual public Meal
{
…
};

class Lunch : virtual public Meal
{
…
};
```

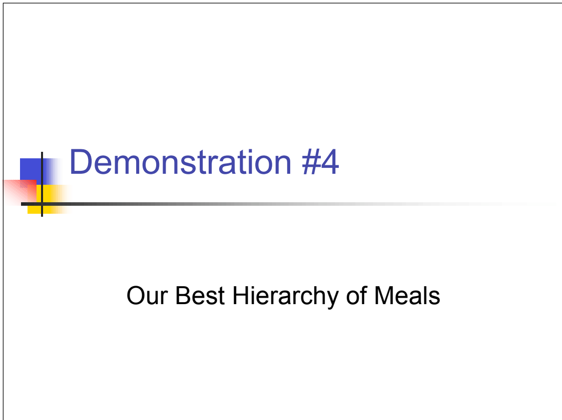
Virtual Base Classes

- In defining our classes this way we eliminate duplication if we derive through both of these classes via multiple inheritance later.
- But that means we have to *know* that we will be deriving from both of these classes via multiple inheritance later!
- One major point in the argument for multiple inheritance was that you would be more likely to use multiple inheritance for classes which already existed, that is, to create “mix-ins”.
- But in order to utilize virtual base classes the two classes you might be inheriting from must have inherited from a common base class virtually.
- If you didn’t write them as part of your current design effort, the programmer of those classes must have had foresight to realize that virtual base classes were appropriate.
- Our picture now looks like this:

More about Multiple Inheritance



- And now we can go back to our original code...



Ambiguity

- Last time we talked about ambiguous access when two base classes implement the same member function.
- What follows is an interesting twist where a virtual base class is involved as well (from LNG):

```
class B {
public:
  virtual void f() { cout << “She loves me!!!!” << endl; }
};
class D1 : virtual public B {
public:
  void g() { f(); }
};
class D2 : virtual public B {
public:
  void f() { cout << “She loves me not” << endl; }
}
class DD: public D1, public D2 { };
```

Ambiguity

```
int main()
{
  DD me;
  me.g();
  return 0;
}
OUTPUT:
She loves me not
```

- You see, this really isn’t a case of ambiguity.
- `D1::g()` is defined to call `B::f()`
- `B::f()` is a *virtual function* in a *virtual base class*
- Since `D2::f()` is derived from the same instance of `B` (via the virtual base class mechanism), `D2::f()` ends up getting called.
- If `me.g()` was defined to call `B::f()` instead of just `f()`, we’d see the other output!