Assignment 3

Due Monday, 9/18/2000

- Identify a partner with whom you will work on this assignment.
- Using the set of use cases provided for the meeting scheduler system, develop a set of CRC (Classes, Responsibilities, Collaborations) cards.
- Also develop a traceability matrix that shows which use cases are handled by which classes and responsibilities.

Traceability Matrix Example (from the graph-drawing example)

	Class: Responsibility							
Use Case	Drawing: remember components	Shape: draw	Shape: remember position	Shape: remember size	Shape: remember connectors	Connector: draw	Connector: remember start	Connector: remember end
Draw shape	x	x	x	x				
Move shape		x	x		x			
Erase shape	x				x		x	x
Resize shape		x	x	x	x			
Connect shapes	x				x	x	x	x
Erase connector	x				x			

Modeling Class Structure with UML

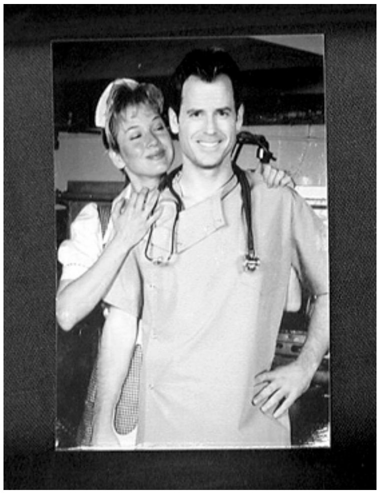
OMG =
“Object Management Group”,
a consortium, not a company

http://www.omg.org/

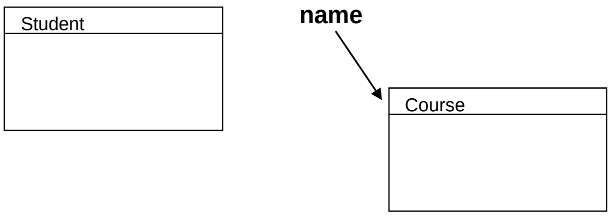
UML

- Unified Modeling Language
- unifies the approaches of the “three amigos”:
  - Grady Booch
  - Ivar Jacobson
  - James Rumbaugh
- Includes E-R (Entity-Relationship) diagrams from database world.

The two amigos



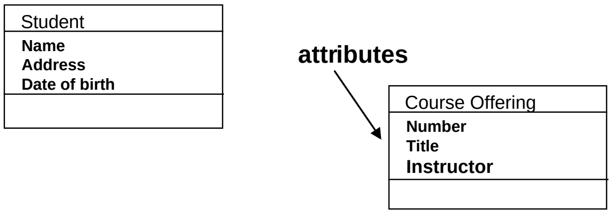
Classes are shown by boxes



Classes, not actual objects

(Objects can also be shown by boxes;
For objects, names are always *underlined*.)

Attributes may be listed



Student

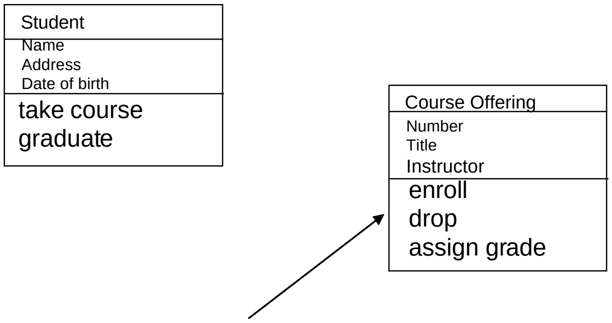
Name
Address
Date of birth

attributes

Course Offering

Number
Title
Instructor

Operations (methods) may be listed



Student

Name
Address
Date of birth

take course
graduate

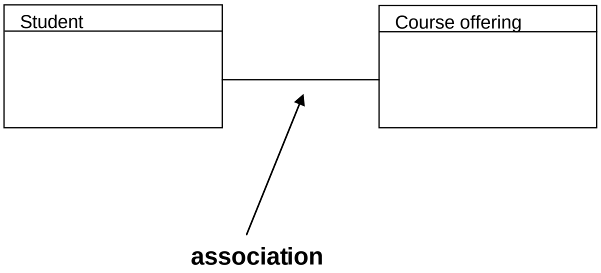
Course Offering

Number
Title
Instructor

enroll
drop
assign grade

methods
(more detail can be given,
such as argument and result types, and visibility)

Associations are shown by lines



What is an *Association*?

- An association exists when an object of one class ***needs to know*** about one or more objects in another class.
- Associations are abstract.
- Typically associations are implemented by pointers or references, although one should not infer that this is ***the*** implementation. We *could* have an association determined in some other way.

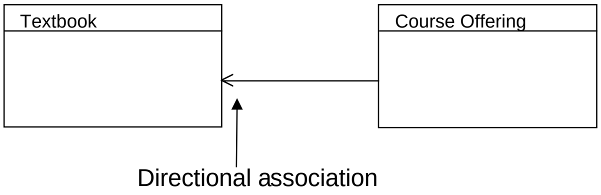
Directionality of Associations

- By default, associations allow “bi-directional” navigation:

  From an object in either class, one can get to an associated object the other class.

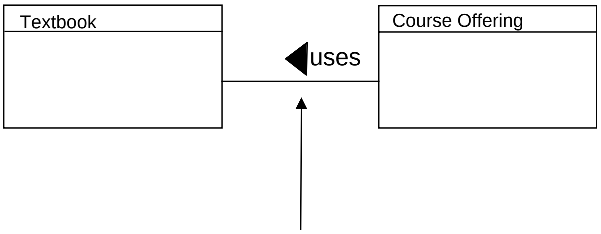
- Adding an open arrow-head **restricts** to **navigation** to be one-way, in the direction of the arrow.

Directional Association



- Here a Course Offering knows about its Textbook but not vice-versa.
- This is sometimes called a “navigation arrow”.
- If **absent**, then navigation is assumed to be bi-directional.

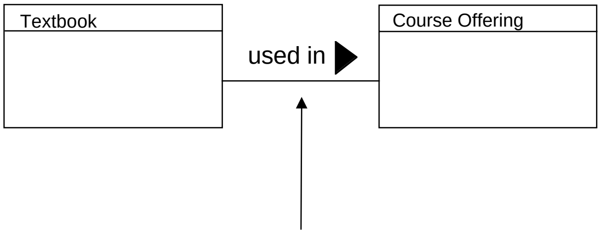
Ordered Reading of Associations



Arrowhead shows direction of ***reading*** the name of the association,

e.g. “A Course Offering uses a Textbook”.

Ordered Reading of Associations

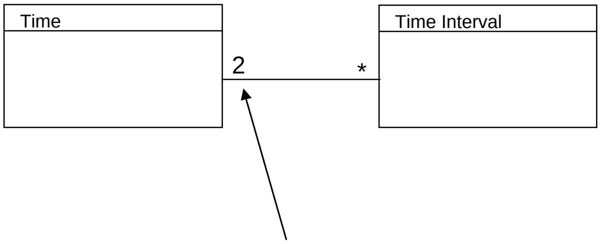


“A Textbook is used in a Course Offering”.

Ordered vs. Directional

- Ordered involves the **reading** interpretation of the association only.
- Directional determines the navigability.
- The two are totally independent.

Associations have a multiplicity

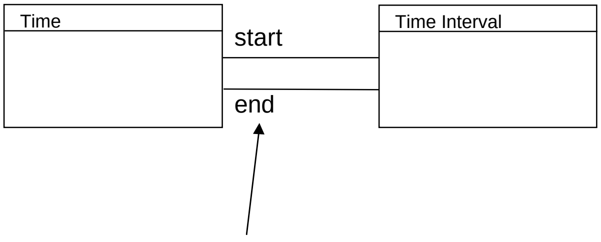


Multiplicity: says that each Time Interval has two Times (such as a start time and an end time)

Association multiplicities

- The default multiplicity is 1.
- m .. n means m through n.
- m .. * means m or more.
- * means the same as 0..* (0 or more).
- a, b, c, ... means one of a, b, c ...
- 0, 1 or 0..1 means optional.

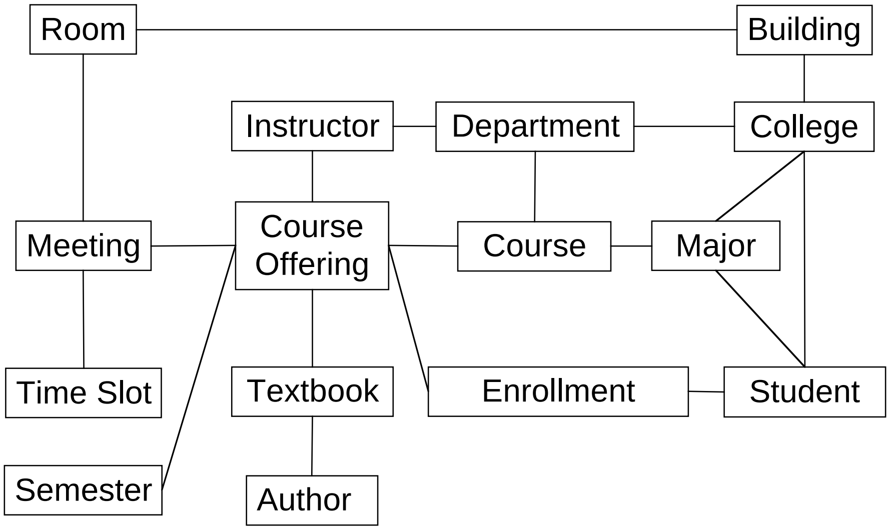
Roles in Association



roles: indicate what role a Time plays with respect to Time Period

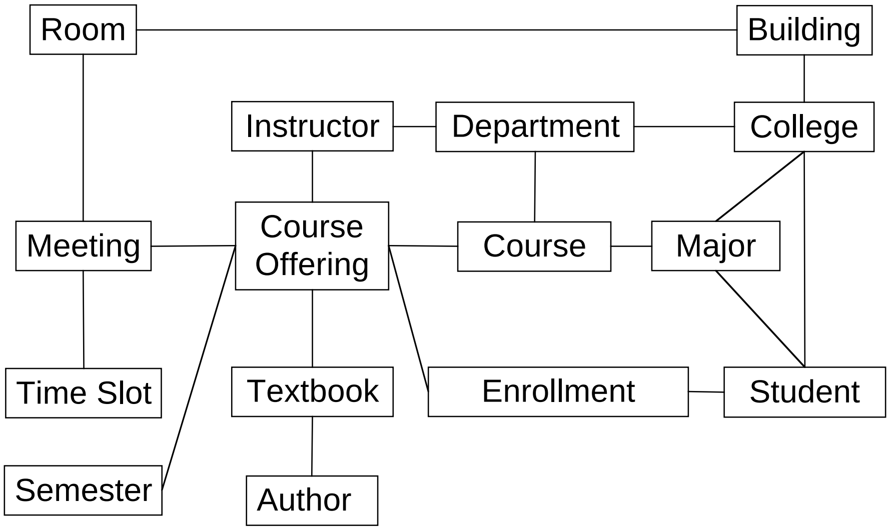
Since this is a *class* diagram and not an *object* diagram, it is not implied that start and end are the same Time.

Exercise: Identify Roles



Room
Building
Instructor
Department
College
Meeting
Course Offering
Course
Major
Time Slot
Textbook
Enrollment
Student
Semester
Author

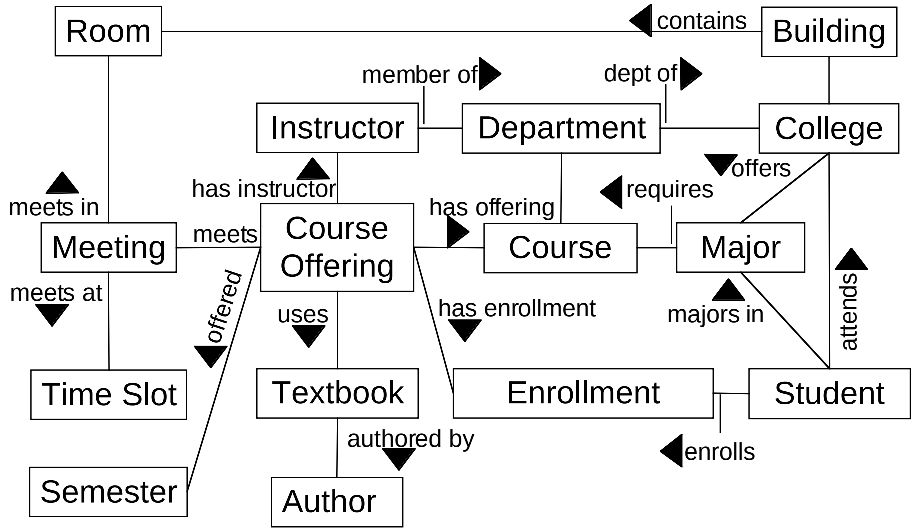
Exercise: Identify Multiplicities



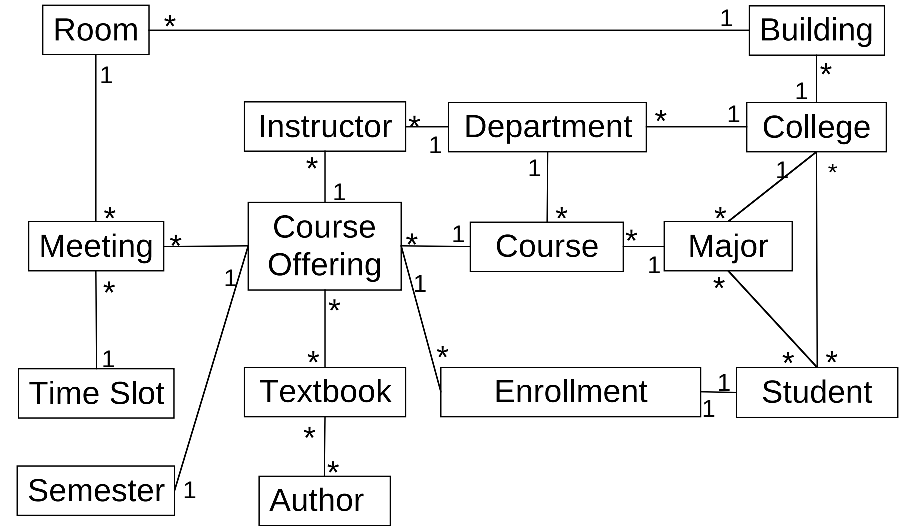
Room
Building
Instructor
Department
College
Meeting
Course Offering
Course
Major
Time Slot
Textbook
Enrollment
Student
Semester
Author

Roles

(In most cases, only one direction is shown)



Multiplicities

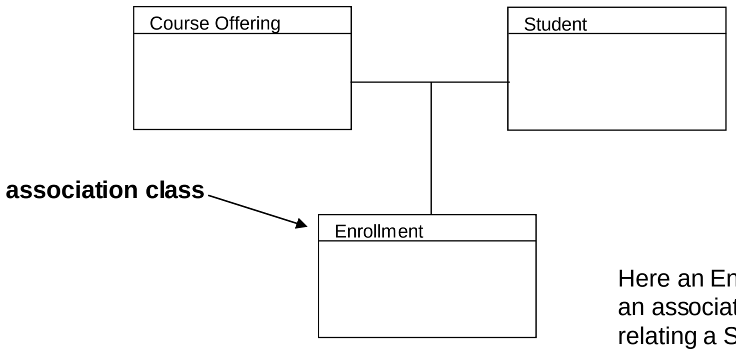


Note on Multiplicities

- Multiplicity should be the one that you wish the **application** to address, rather than what might be the case in nature.
- For example, a major of a given *name* may exist in several colleges, suggesting * * association.
- However, * 1 association might be wanted (one college has multiple majors), but a given major belongs to a college.

Association Classes

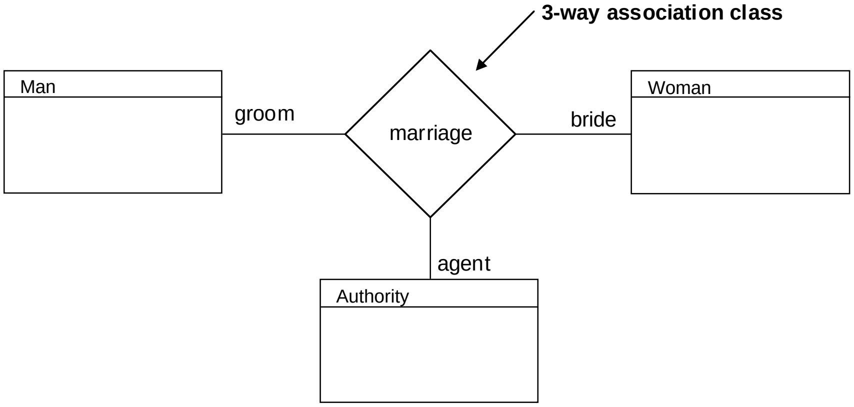
An association may itself take the form of an object relating two or more other objects together.



Here an Enrollment is an association object relating a Student and a Course Offering.

Multi-Way Associations

Associations aren’t limited to 2-way.



3-way association class

Man

groom

marriage

bride

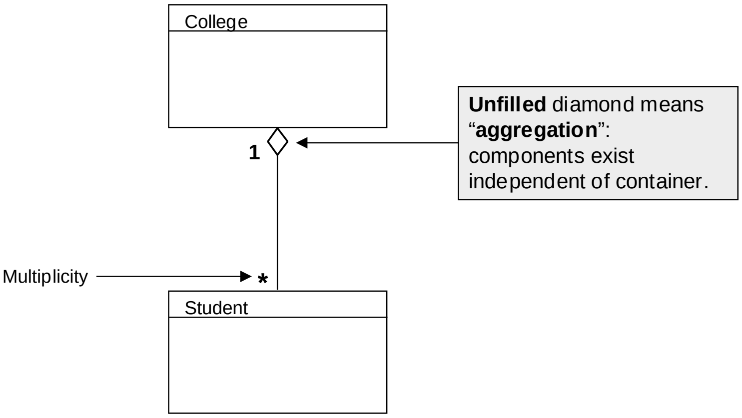
Woman

agent

Authority

Aggregation

An aggregation is a special form of association in which
a collection of objects is associated with a single object.



College

Unfilled diamond means “**aggregation**”: components exist independent of container.

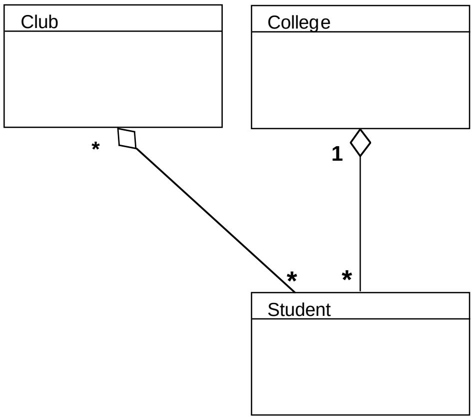
1

Multiplicity

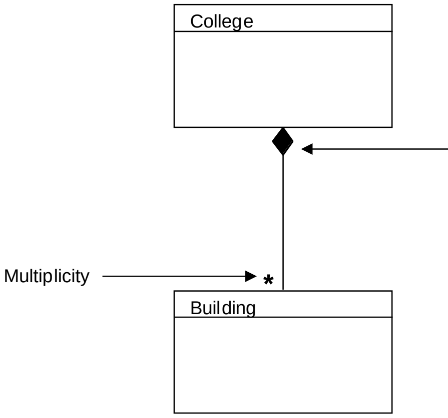
*****

Student

An object can be in multiple distinct aggregations.



Composition



Filled diamond means "**composition**": components are **inseparable, non-sharable, part** of container.

The container is composed of the components (and possibly others).

Multiplicity 1 is thus implied.

Question

- Can an object be in an aggregation and a composition simultaneously?

Possible C++ comparison

- Aggregation

e.g. STL list

```
class College
   {
   list<Student*> students;

public:
   void addStudent(Student *s)
     {
     students.add(s);
     }
     ...
   }
```

Students exist outside of the college.

- Composition

array of buildings

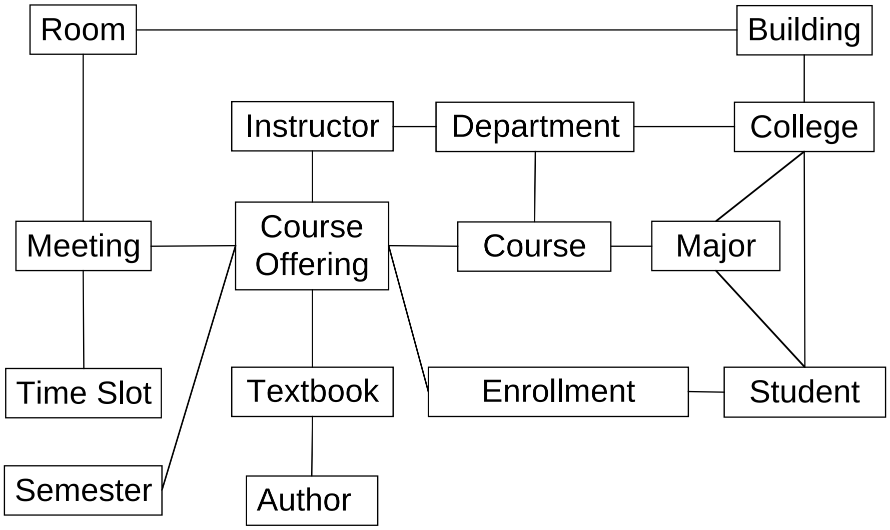
```
class College
   {
   Building* building;

public:
   College(int n)
     {
     building = new Building[n];
     }
     ...
   }
```

Buildings don’t exist outside of the college.

C++ Destruction Note

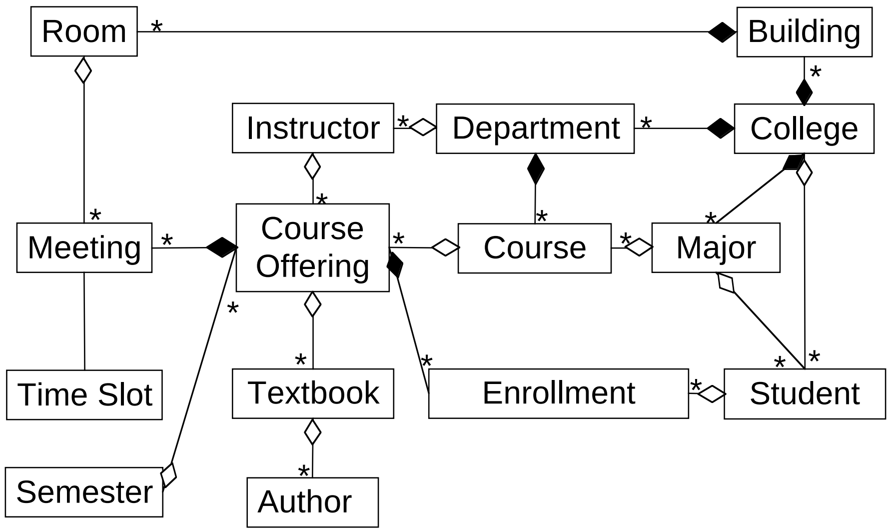
- With **composition**, contained objects should be created/destroyed when the containing object is.
- With **aggregation**, aggregate objects are created and destroyed independent of the aggregating object.

Exercise: Identify Likely Aggregations and Compositions



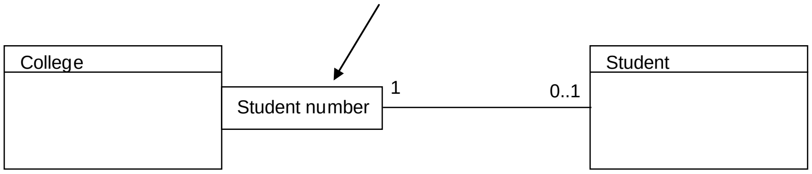
Room
Building
Instructor
Department
College
Meeting
Course Offering
Course
Major
Time Slot
Textbook
Enrollment
Student
Semester
Author

Identify Likely Aggregations and Compositions



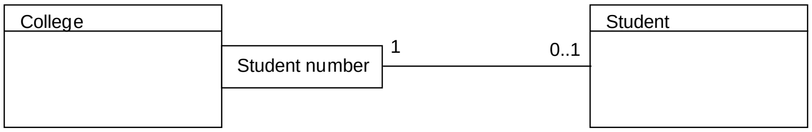
Qualified Association

An attribute indicating how to *locate* the associated object.

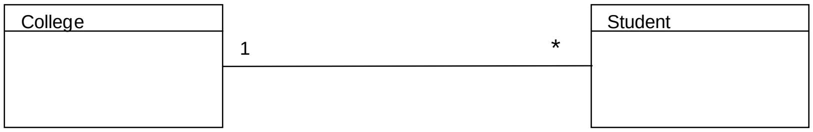


Comparison:
Qualified vs. Unqualified Association

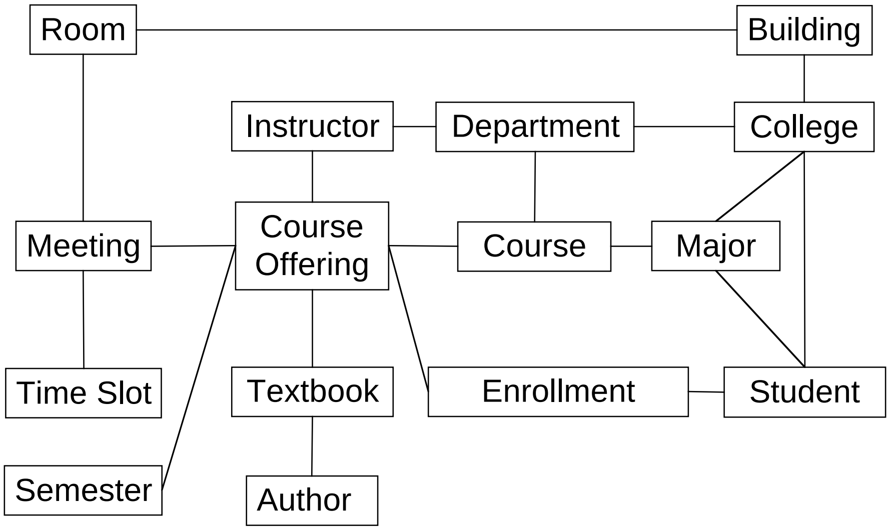
with Qualified Association



without Qualified Association

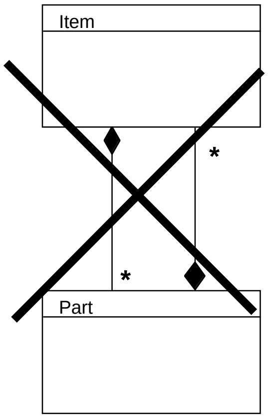


Exercise: Identify Opportunities for Qualified Association



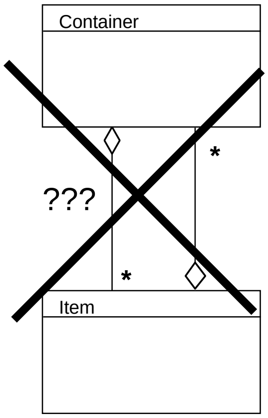
Further Notes on Aggregation and Composition

- Composition cycles are not allowed



Further Notes on Aggregation and Composition

- In some models, aggregation cycles are not allowed either; just why is unclear.



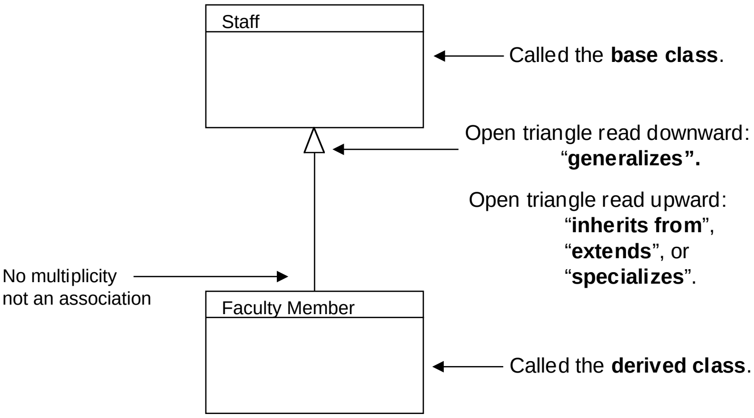
Further Notes on Aggregation and Composition

- Exactly why cycles are not allowed for pure aggregation is unclear (It is clear in the case of composition.)
- We will later see a way to get around this restriction if it is present.

Further Notes on Aggregation and Composition

- From "The Unified Modeling Language Reference Manual" (Rumbaugh, Jacobson, and Booch), p 148:
  - "The distinction between aggregation and association is often a matter of taste… Keep in mind that aggregation is association."
  - "The only real semantics that aggregation adds is the constraint that chains of aggregate links may not form cycles…"
  - "Think of it as a modeling placebo."

Inheritance/Generalization



Called the **base class**.

Open triangle read downward: “**generalizes”.**

Open triangle read upward: “**inherits from**”, “**extends**”, or “**specializes**”.

No multiplicity
not an association

Called the **derived class**.

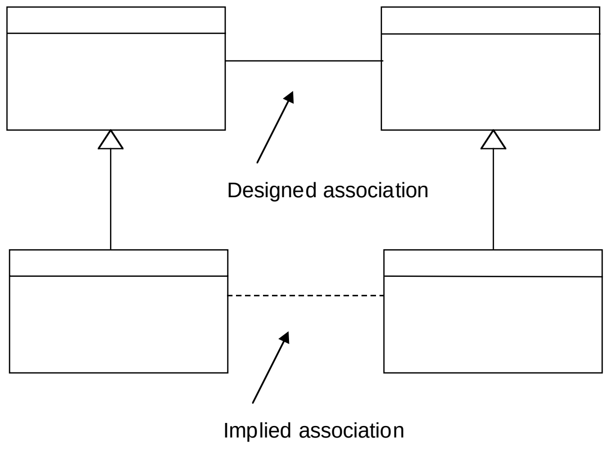
Liskov Substitution Principle (Prof. Barbara Liskov, M.I.T.)

A member of a derived class must also make sense when used as a member of the base class.

For example, if a method has an object of a class as an argument, the same method should be able to work with an object of a derived class.

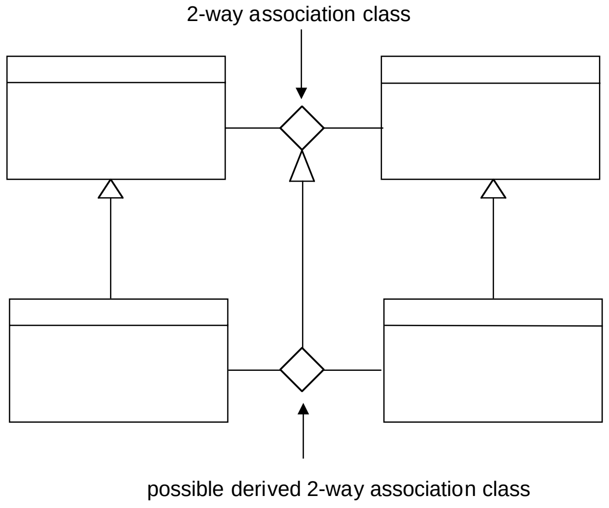
As originally stated: If for each object o1 of type S there is an object o2 of type T such that for all programs P defined in terms of T the behavior of P is unchanged when o1 is substituted for o2, then S is a subtype of T.

Implied Associations
(by the Liskov Substitution Principle)


Designed association

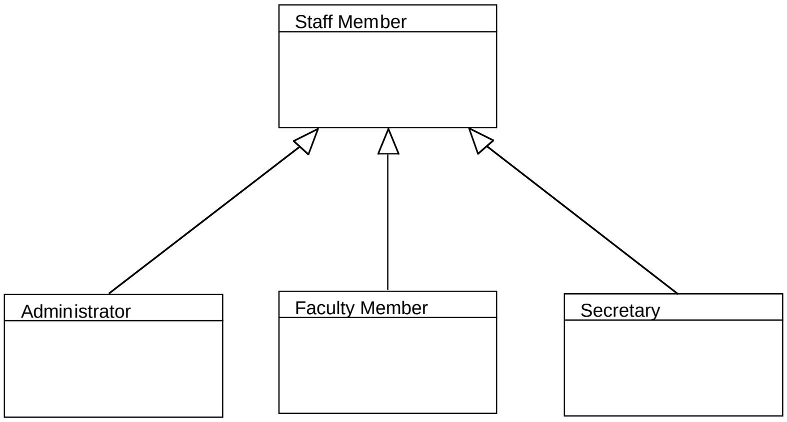
Implied association

Derived Association Classes


2-way association class

possible derived 2-way association class

Usually there will be multiple derived classes



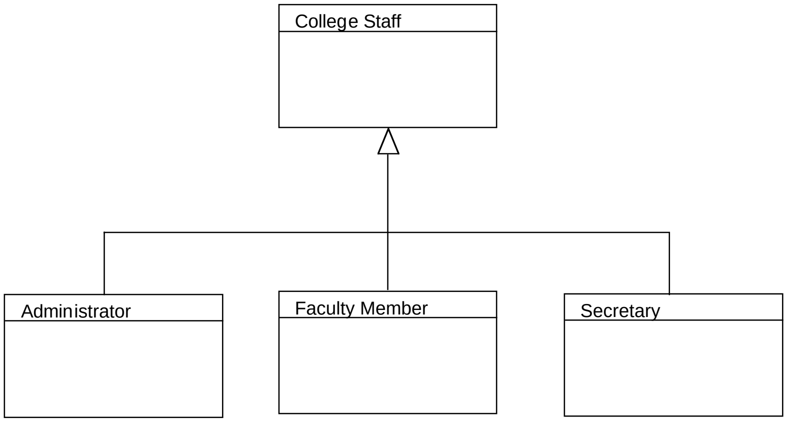
Staff Member

Administrator

Faculty Member

Secretary

This notation is equivalent to that on the preceding slide.



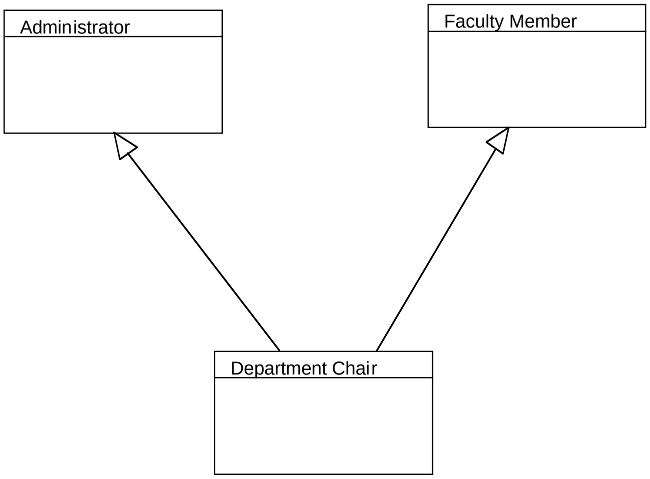
College Staff

Administrator

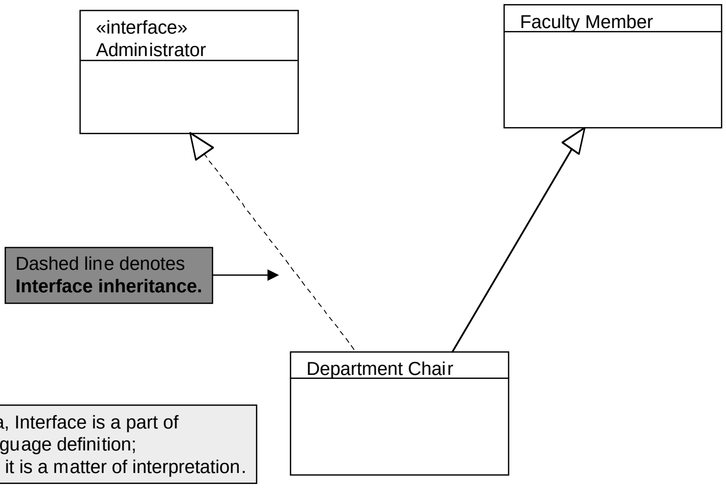
Faculty Member

Secretary

“ Multiple Inheritance” is possible, although should be avoided (not all languages support it)



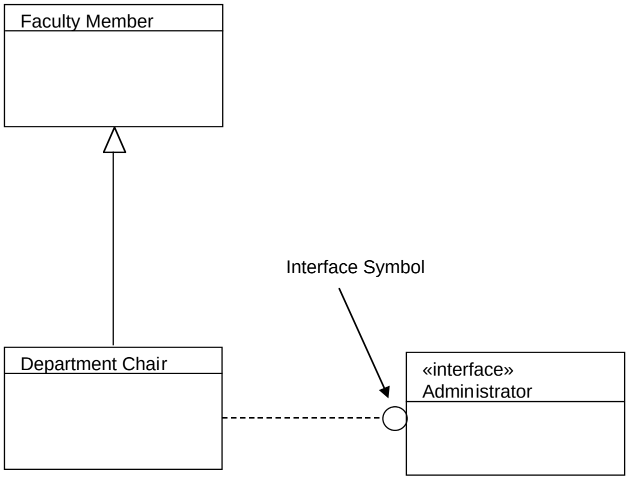
“ Interface Inheritance” alternative



Dashed line denotes **Interface inheritance.**

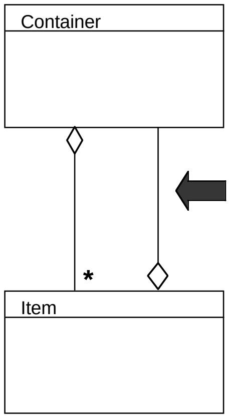
In Java, Interface is a part of
the language definition;
In C++ it is a matter of interpretation.

Alternative Notation for Interface



Recursive Structure (1)

Aggregation cycles: bad in some cases

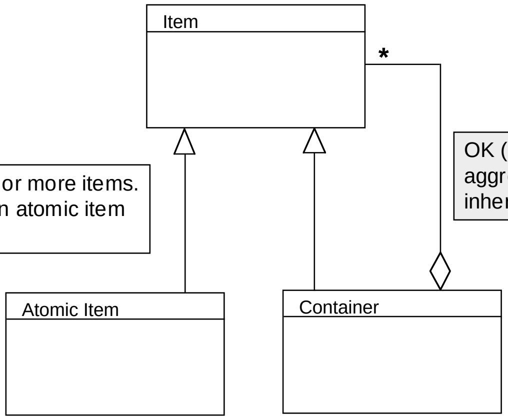


"A container contains zero or more items, each of which contains a container."

At most one of these is regarded as legal.

Recursive Structure (2)

Use inheritance to articulate recursive structures.



"A container contains 0 or more items. An item can be either an atomic item or a container."

OK (One arrow is aggregation, the other inheritance.)

Object vs. Class

- UML uses a notation similar to classes for objects
- Object diagrams are like class diagrams, except that
  - boxes are **objects** rather than classes
  - lines are **links** rather than associations

Object Notation

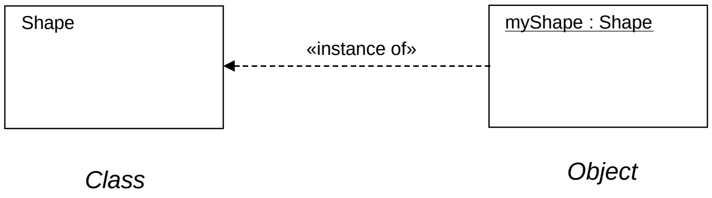
- An object is visually distinguished from a class by an **underline**. The fully named object has the form:

objectName : className

- The class name may be omitted if we don't know it yet.
- The object name may be omitted: anonymous object.

Objects, like classes, are shown by boxes

Objects, like classes, are shown by boxes



Shape

«instance of»

myShape : Shape

Class

Object

Attributes may be listed with values for objects

Shape

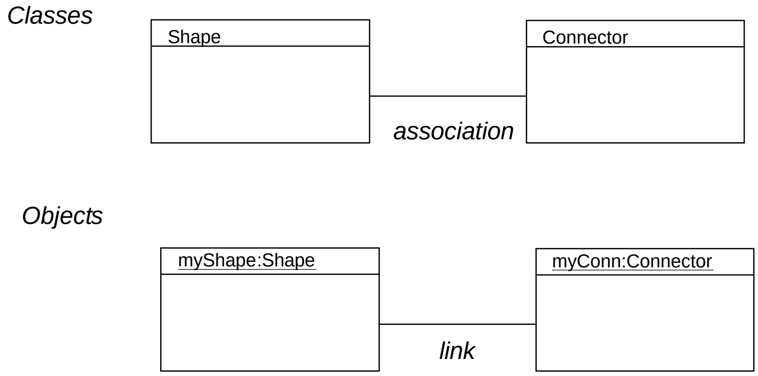
Position
Size
Color

myShape : Shape

Position: [100, 200]
Size: [300, 400]
Color: red

For classes, attributes don’t have values, (*unless* they are class-wide attributes i.e. “static” in C++/Java).

Object Links



Classes

Shape

Connector

association

Objects

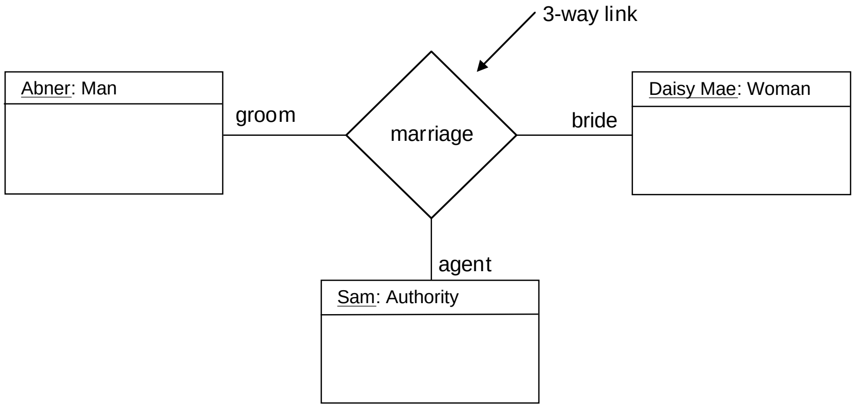
myShape:Shape

myConn:Connector

link

A **link** is an element of an instance of an association.
An instance of an association is a **set** of links.

Multi-way Links



3-way link

Abner: Man

groom

marriage

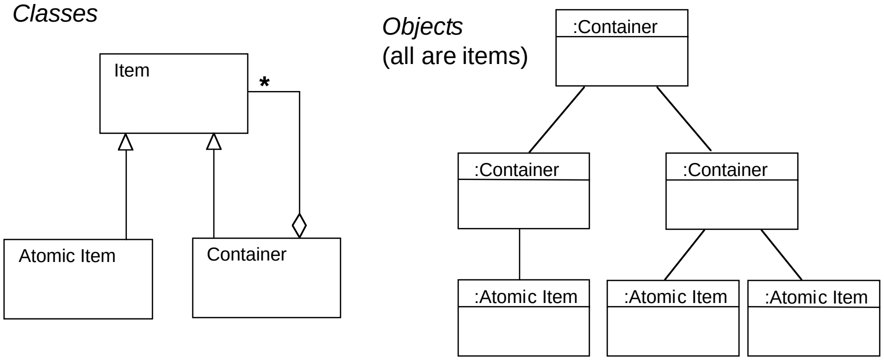
bride

Daisy Mae: Woman

agent

Sam: Authority

Recursive Structures



Classes

Item

*

Atomic Item

Container

Objects
(all are items)

:Container

:Container

:Container

:Atomic Item

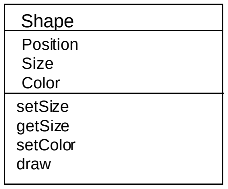
:Atomic Item

:Atomic Item

Scope of Object Notation

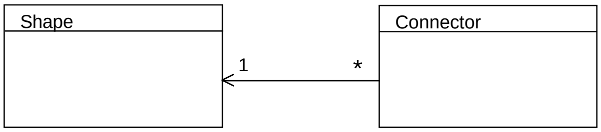
- In addition to object diagrams, the object notation is used in:
  - collaboration diagrams
  - sequence diagrams
  - and others

UML -> C++ Code


Shape
Position
Size
Color
setSize
getSize
setColor
draw

```
class Shape
{
public:
    Shape( );                         // default constructor
    Shape(Shape & orig);              // copy constructor
    ~Shape( );                        // destructor
    void setPosition(Position p);     // setters
    void setSize(Size s);
    void setColor(Color c);
    Size getSize( );                  // getters
    void draw(Graphic g);             // other actions
    Shape& operator=(Shape &original); // assignment
private:
    Position position;
    Size size;
    Color color;
    ...
};
```

UML -> C++:
One-way navigability



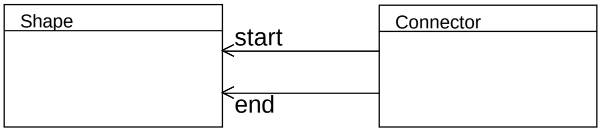
```
class Shape
{
public:
    ...
private:
    ...
};
```

```
class Connector
{
public:
    ...
    setShape(Shape *shape);

private:
    ...
    Shape *shape;
};
```

Disclaimer

- The C++ code examples are samples of what can be done.
- They are generally not the ***only*** way a specific type of association can be implemented.
- A specific tool will generate a specific type of implementation; selection from a a menu of implementations might be possible.
- Use of a standard library, such as STL, is possible.

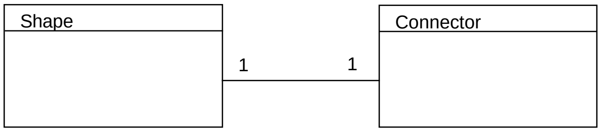
UML -> C++:
Multiple associations with different roles



```
class Shape
{
public:
    ...
private:
    ...
};
```

```
class Connector
{
public:
    ...
    setStart(Shape *start);
    setEnd(Shape *end);

private:
    ...
    Shape *start;
    Shape *end;
};
```

UML -> C++:
1-1 association



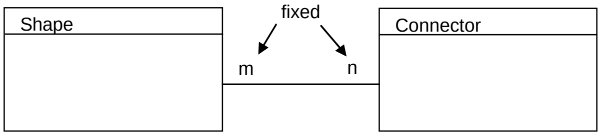
```
class Shape
{
public:
    ...
    setConnector(Connector *connector);

private:
    ...
    Connector *connector;
};
```

```
class Connector
{
public:
    ...
setShape(Shape *shape);
private:
    ...
    Shape *shape;
};
```

Generally choose one, not both.
Each calling the other would be a problem.

UML -> C++ Exercises

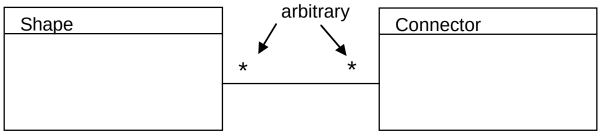
UML -> C++



```
class Shape
{
public:
    ...

private:
    ...




};
```

```
class Connector
{
public:
    ...

private:
    ...




};
```

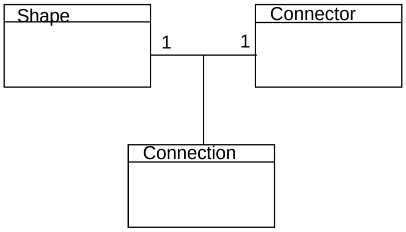
UML -> C++



```
class Shape
{
public:
    ...

private:
    ...




};
```

```
class Connector
{
public:
    ...

private:
    ...




};
```

UML -> C++

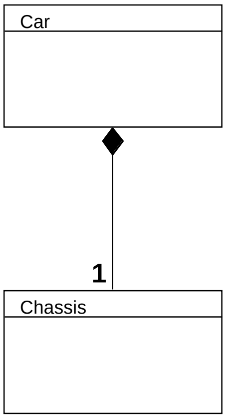


```
class Shape
{
public:
    ...

private:
    ...

};
```

```
class Connector
{
public:
    ...

private:
    ...

};
```

```
class Connection
{
public:
    ...

private:
    ...

};
```

UML -> C++



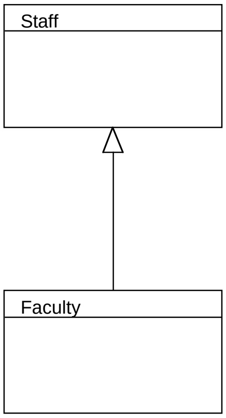
```
class Car
{
public:
    Car( );
    ...

private:
    Chassis &chassis;
    ...

};
```

reference notation

```
Car::Car()        // constructor
      : chassis(new Chassis( ))
  {
  }
```

initializer notation

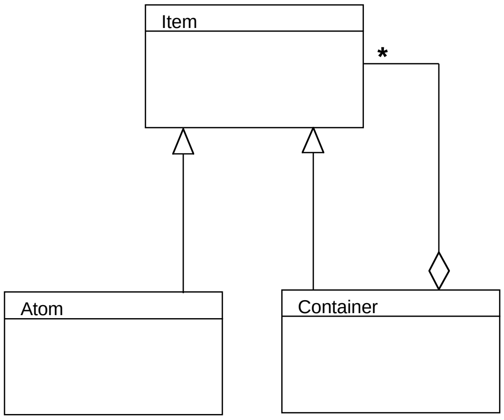
Inheritance/Generalization



```
class Staff
{
public:

Staff(String name);          // constructor

    ...

};


class Faculty : public Staff
{
public:

Faculty(String name);        // constructor
};


Faculty::Faculty(String name)
          : Staff(name)
  {
    ...
  }
```

initializer notation

Recursive Structure, C++



```
// The base class

class Item
{
protected:
    char *name;

public:

    // construct an Item, copying name into it

    Item(char *name)
      {
      this->name = strcpy(new char[strlen(name)+1], name);
      }

    // destroy the item

    virtual ~Item()
      {
      delete [ ] name;
      }

};  // class Item
```

See turing: `/cs/cs121/codeExamples/virt.cc` for more details.

```
// Atom is an Item that cannot contain others

class Atom : public Item
{
public:

    // construct an Atom

    Atom(char *name)
      : Item(name)
      {
      }

};  // class Atom
```

```
// ItemCells are used to construct an open linked-list of Items

class ItemCell
{
private:

    Item &item;        // the first item in a list represented by this cell
    ItemCell *next;    // the next cell in the list, i.e. the rest of the items

public:

    // construct an ItemCell based on a first Item and next ItemCell

    ItemCell(Item &newItem, ItemCell *next)
      : item(newItem)
      {
      this->next = next;
      }
```

```
class Container : public Item
{
private:

    ItemCell* items;                        // list of Items

public:

    // construct a Container with a given name

    Container(char *name)
      : Item(name)
      {
      items = 0;                            // empty list
      }


    // add an Item to a Container

    void add(Item &item)
      {
      items = new ItemCell(item, items);
      }
}
```