UML Class Diagrams

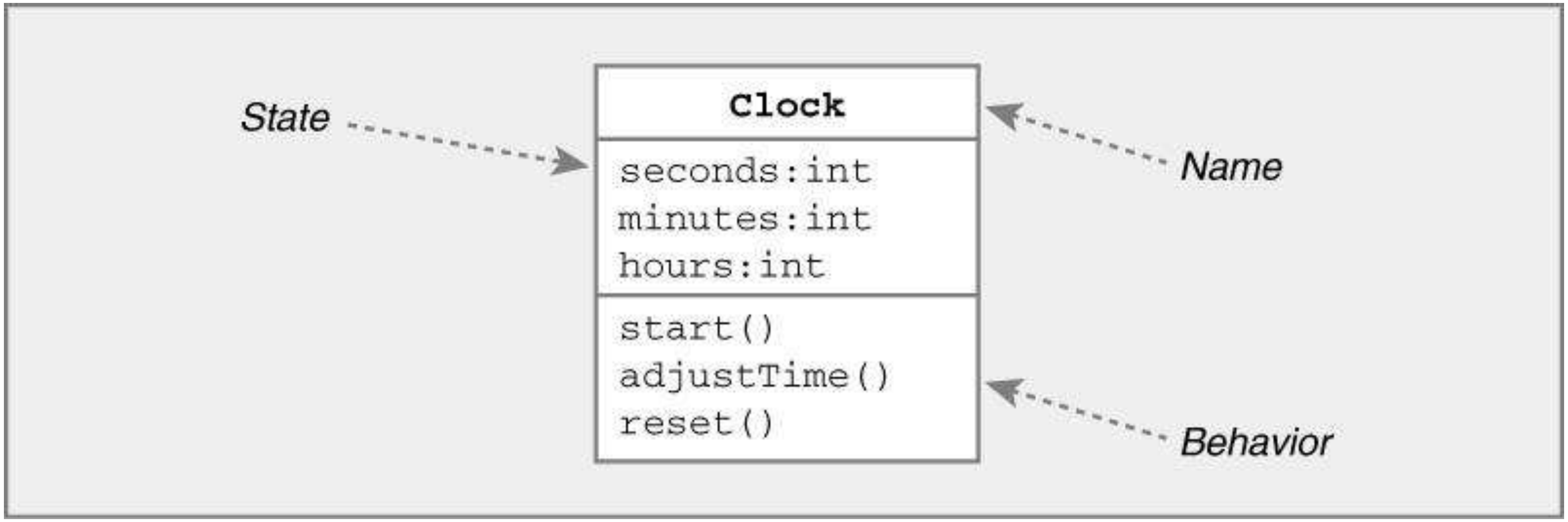
Class

- Template for object creation:
  - Instantiated into objects
  - An abstract data type (ADT)
- Examples: Employees, Books, etc.
- Sometimes not intended to produce instances:

UML Class Diagrams

- Represent the (static) structure of the system

General	In Java	In C++
Name	Name	Name
State	Variables	Members
Behavior	Methods	Functions

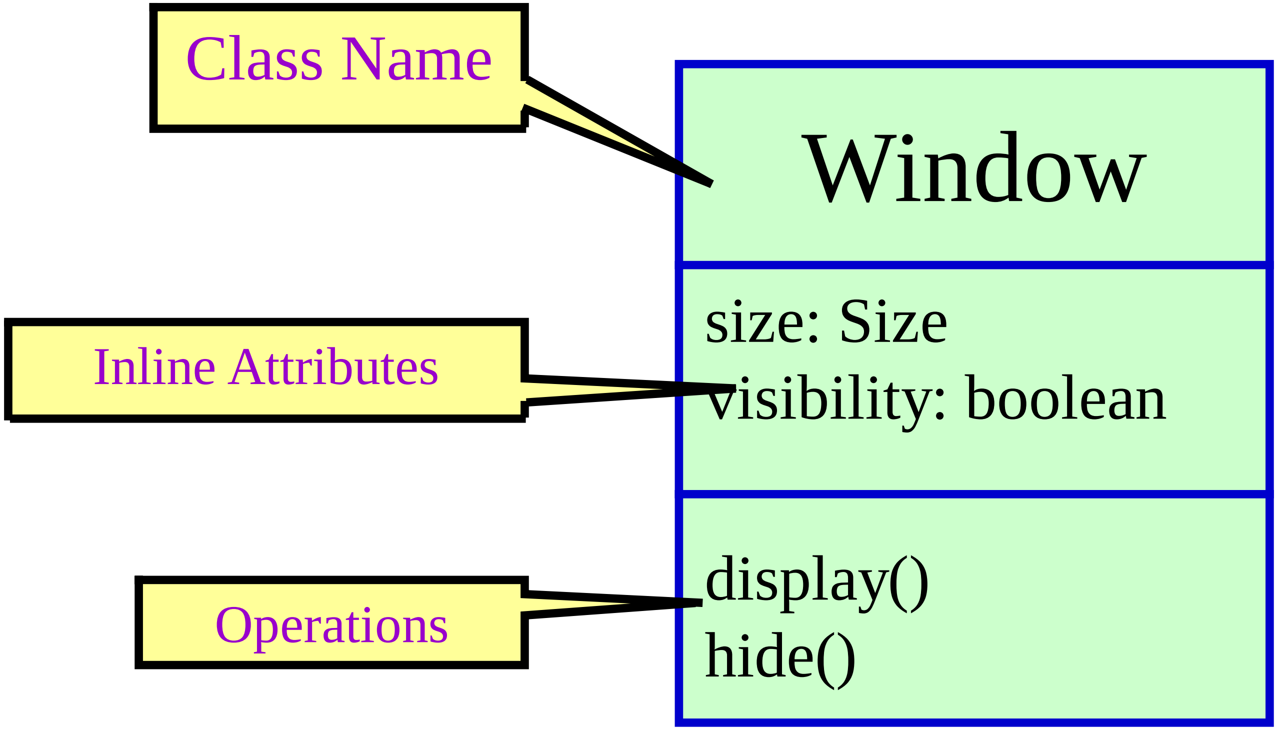


Class Attribute Examples

Java Syntax	UML Syntax
Date birthday	Birthday:Date
Public int duration = 100	+duration:int = 100
Private Student students[0..MAX_Size]	-Students[0..MAX_Size]:Student

UML Class Representation

- **A class represents a set of objects having similar attributes, operations, relationships and behavior.**



Class Name

Inline Attributes

Operations

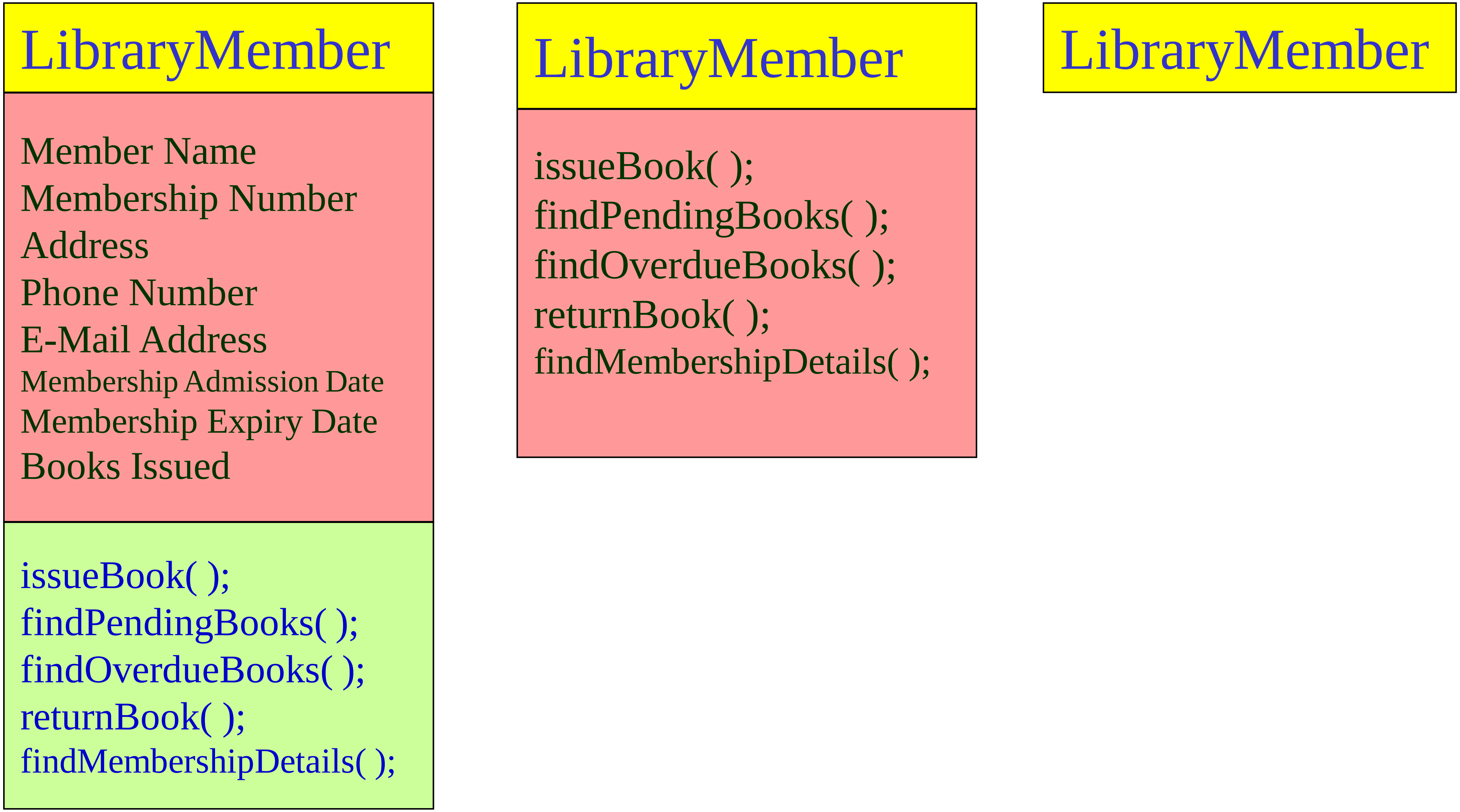
Window

size: Size
visibility: boolean

display()
hide()

A class can implicitly have a few association attributes

Example UML Classes



LibraryMember

Member Name
Membership Number
Address
Phone Number
E-Mail Address
Membership Admission Date
Membership Expiry Date
Books Issued

issueBook( );
findPendingBooks( );
findOverdueBooks( );
returnBook( );
findMembershipDetails( );

LibraryMember

issueBook( );
findPendingBooks( );
findOverdueBooks( );
returnBook( );
findMembershipDetails( );

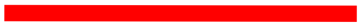
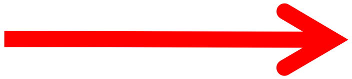
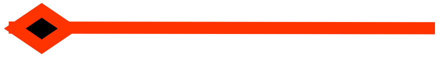
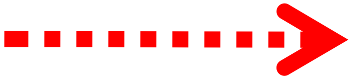
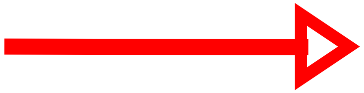
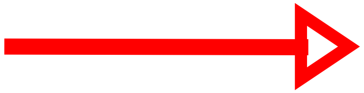
LibraryMember

Different representations of the LibraryMember class

Visibility Syntax in UML

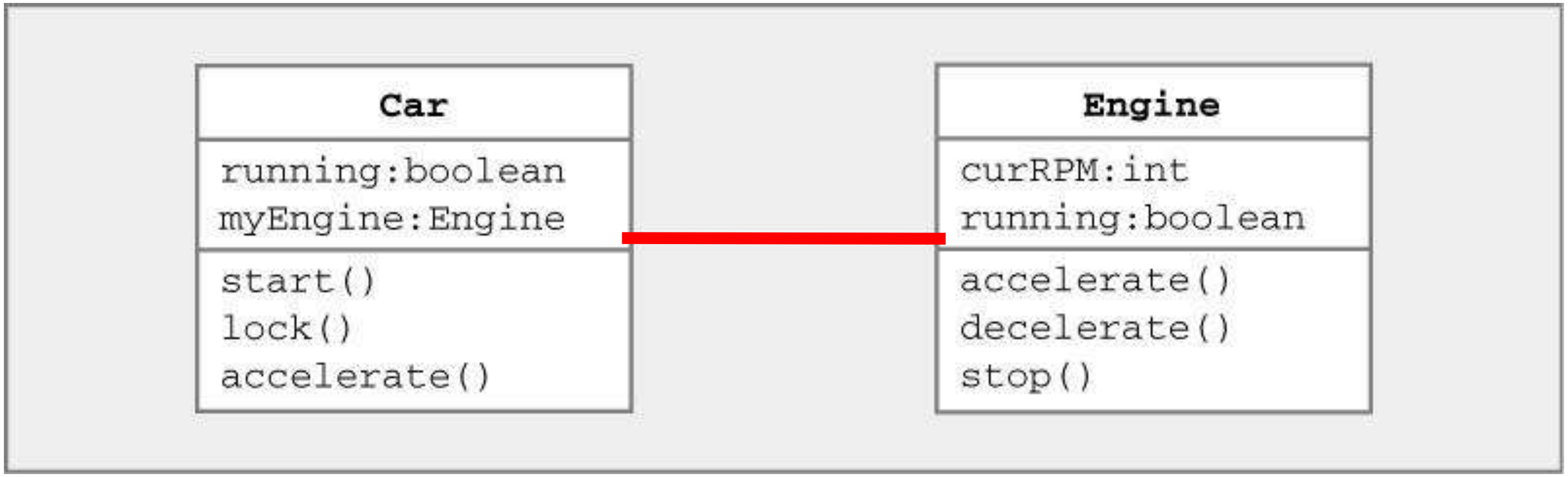
Visibilty	Java Syntax	UML Syntax
public	public	+
protected	protected	#
package		~
private	private	-

Relationships Between Classes

- Association  OR 
  - Permanent, structural, “has a”
  - Solid line (arrowhead optional)
- Aggregation 
  - Permanent, structural, a whole created from parts
  - Solid line with diamond from whole
- Dependency 
  - Temporary, “uses a”
  - Dotted line with arrowhead
- Generalization 
  - Inheritance, “is a”
  - Solid line with open (triangular) arrowhead
- Implementation 
  - Dotted line with open (triangular) arrowhead

Association

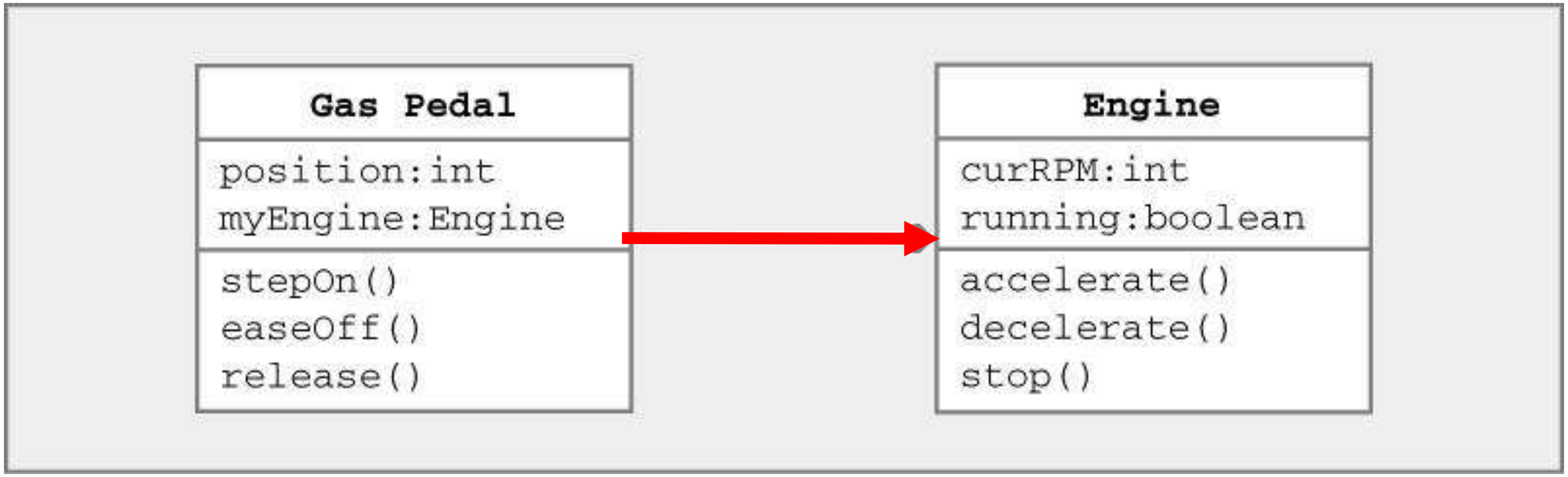
- Denotes permanent, structural relationship
- State of class A contains class B
- Represented by solid line (arrowhead optional)



Car and Engine classes know about each other

Associations w/ Navigation Information

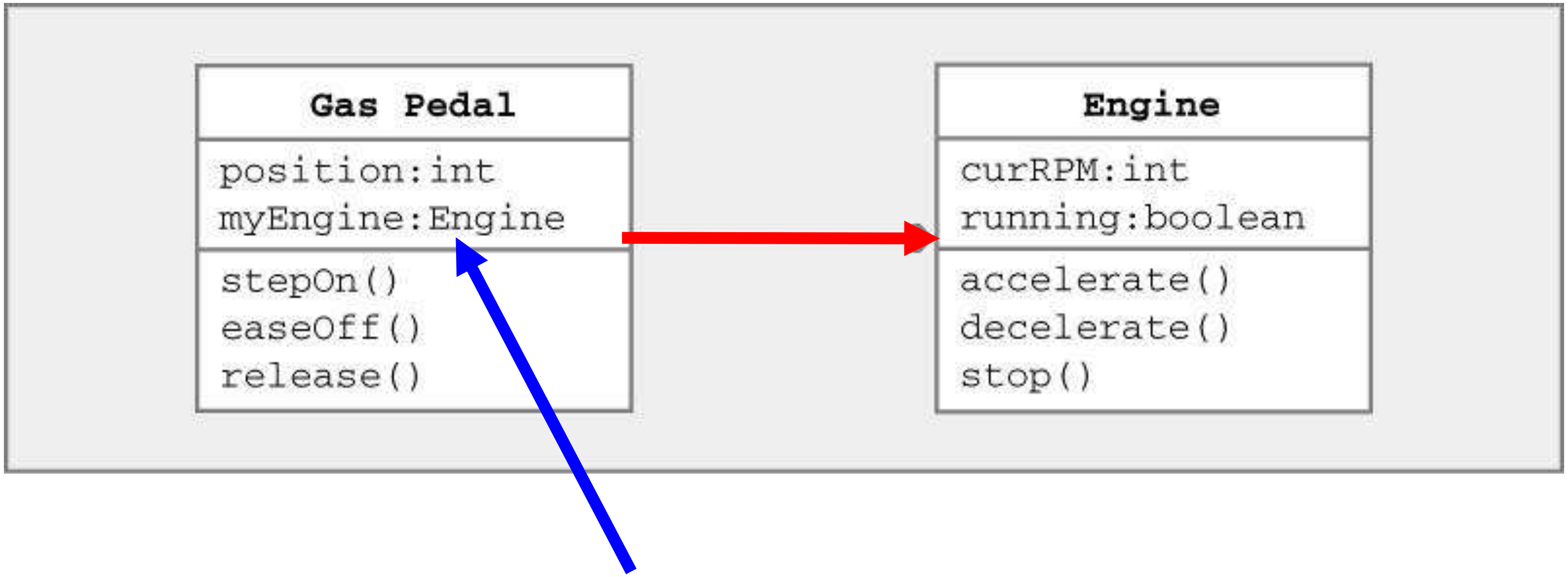
- Can indicate direction of relationship
- Represented by solid line with arrowhead



Gas Pedal class knows about Engine class
Engine class doesn't know about Gas Pedal class

Associations w/ Navigation Information

- Denotes “has-a” relationship between classes
- “Gas Pedal” has an “Engine”

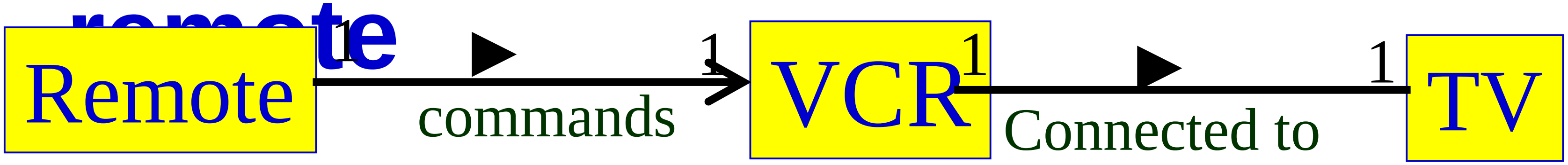


State of Gas Pedal class contains instance of Engine class ⇒ can invoke its methods

Association – example

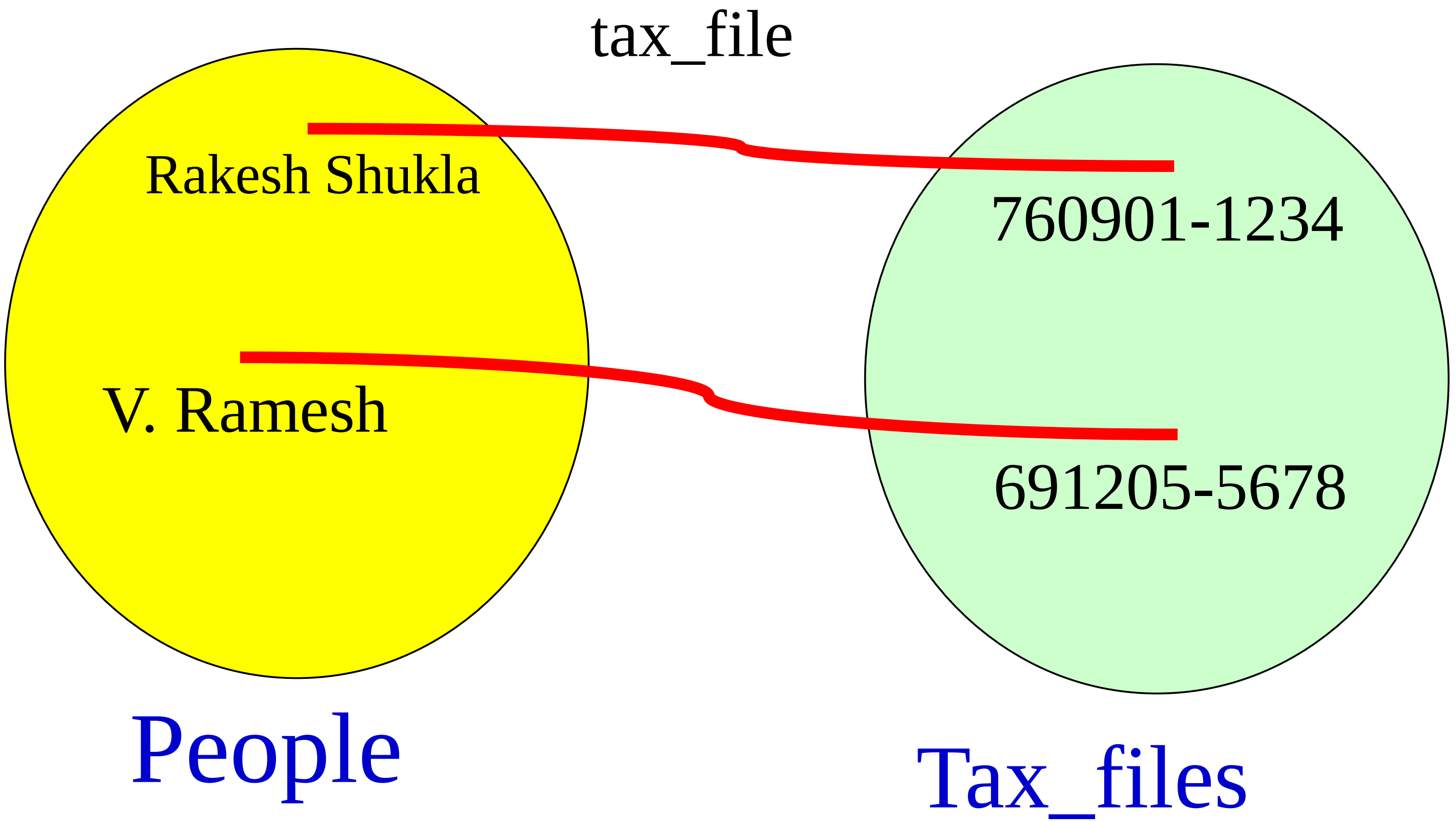
- In a home theatre system,
  - A TV object has an association with a VCR object

    - It may receive a signal from the VCR
  - VCR may be associated with remote



    - It may receive a signal (command)

1-1 Association – example



tax_file

Rakesh Shukla

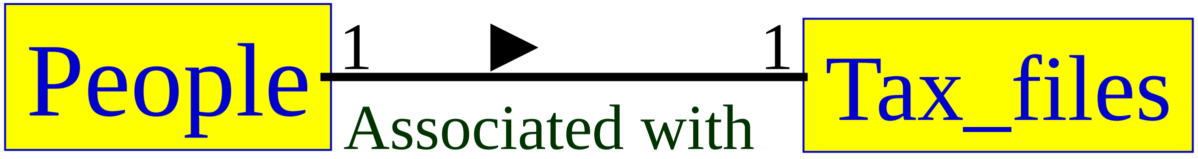
V. Ramesh

760901-1234

691205-5678

People

Tax_files



People

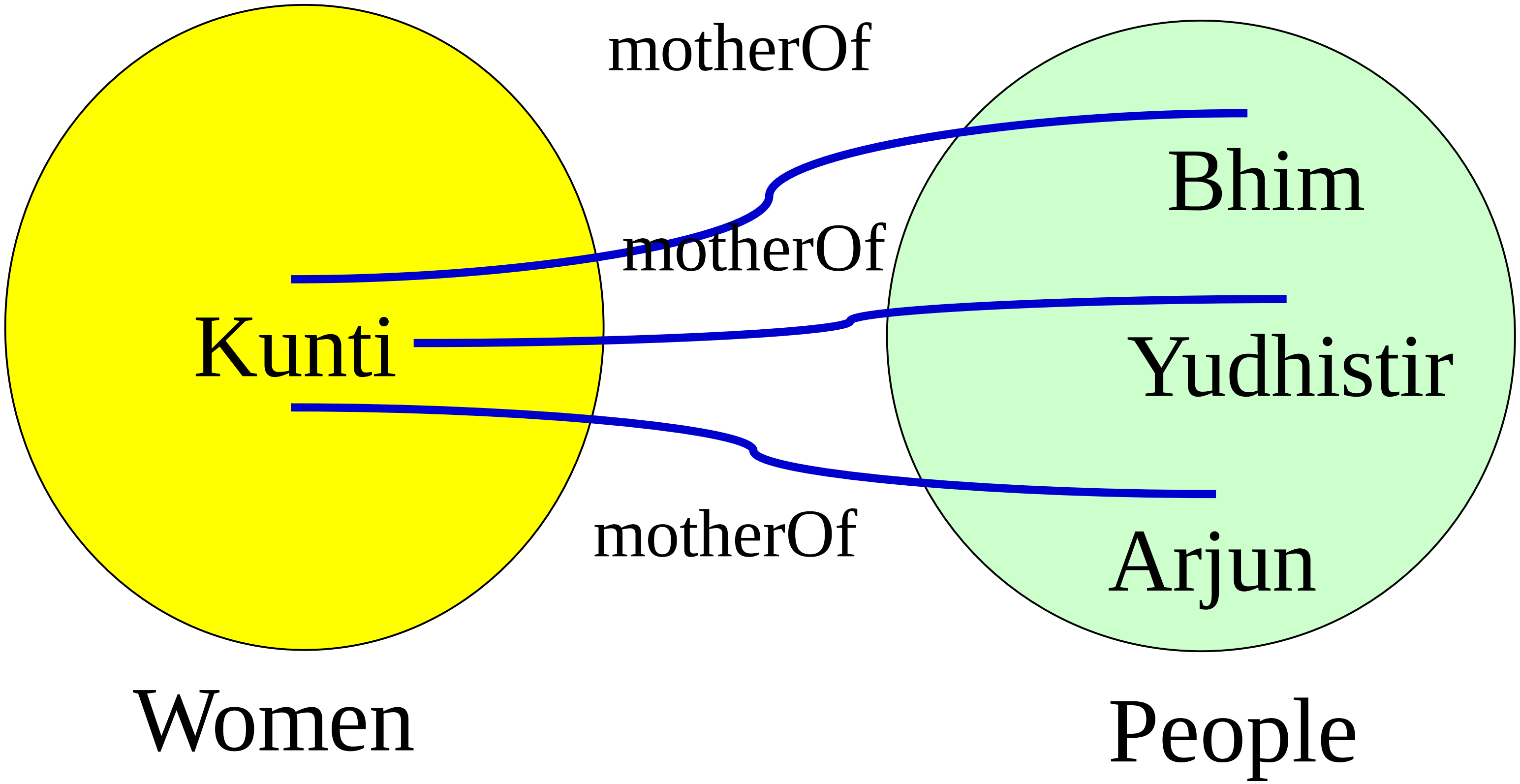
1

1

Associated with

Tax_files

Multiple Association – example



motherOf

motherOf

motherOf

Kunti

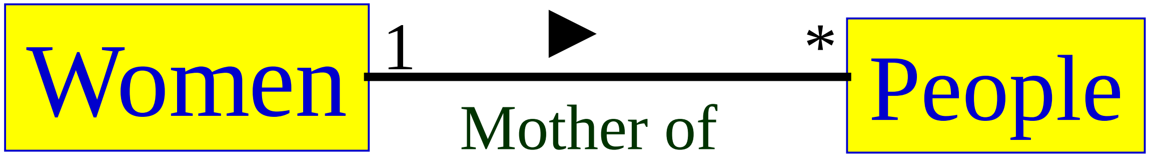
Bhim

Yudhistir

Arjun

Women

People



Women

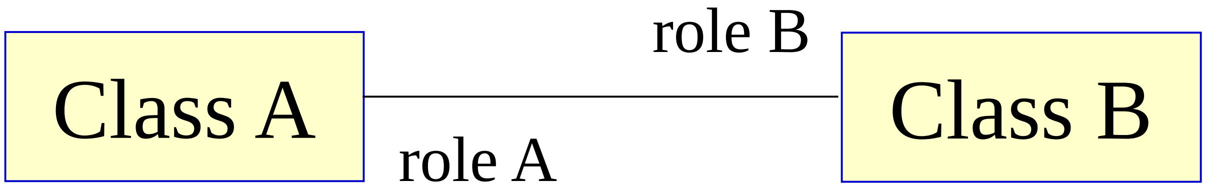
1

*

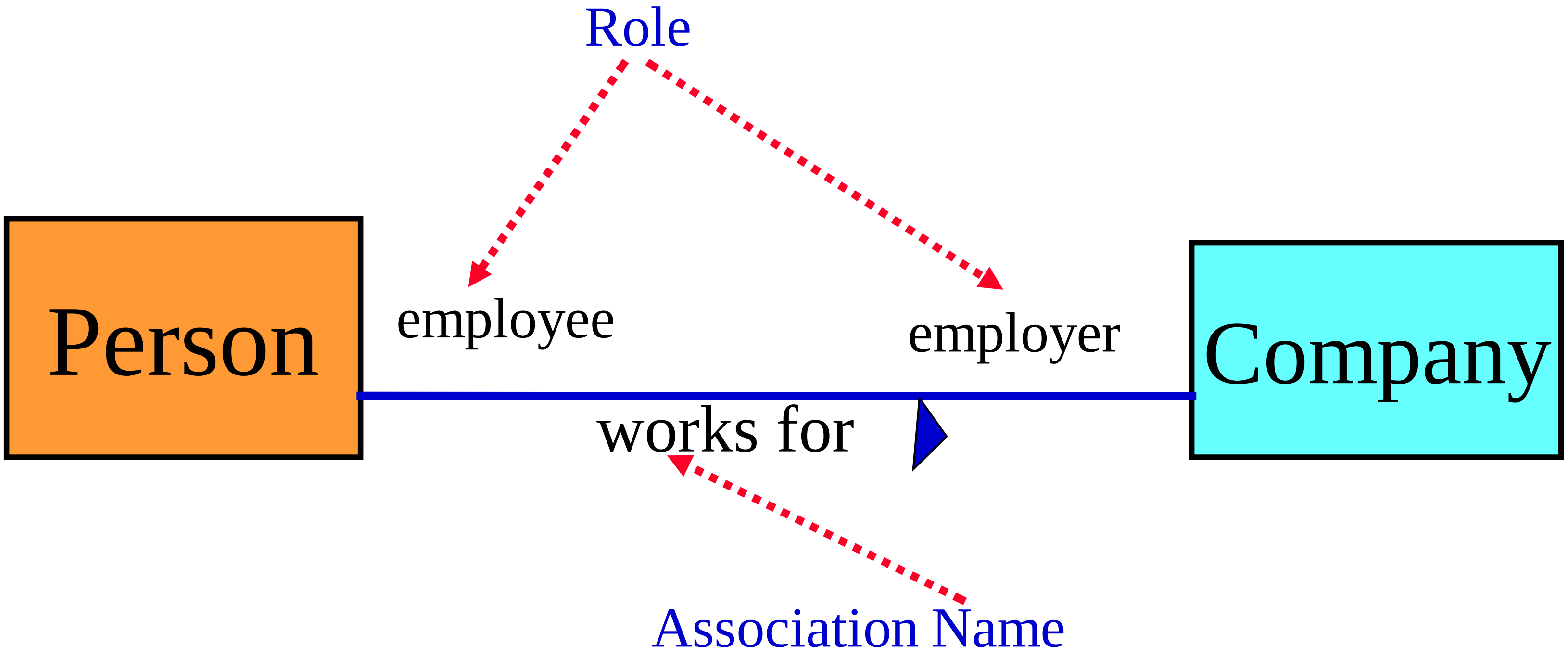
People

Mother of

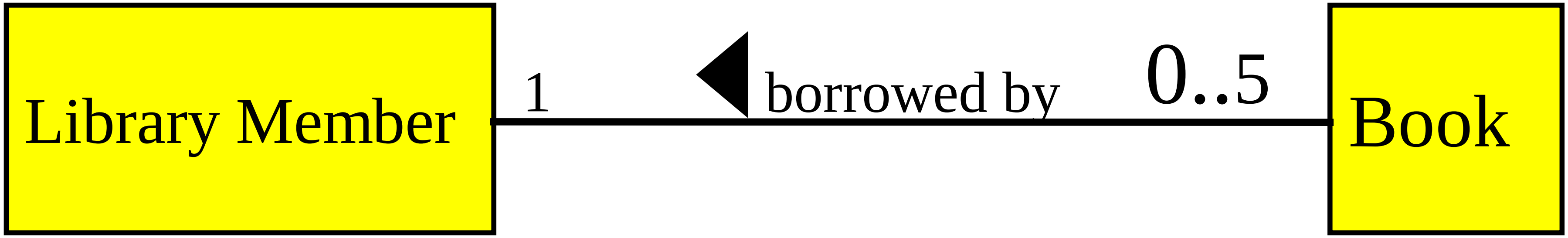
Association UML Syntax

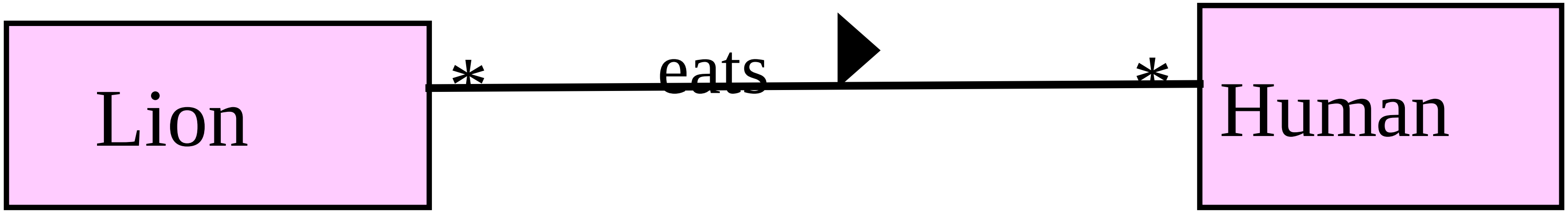


- **A Person works for a Company.**

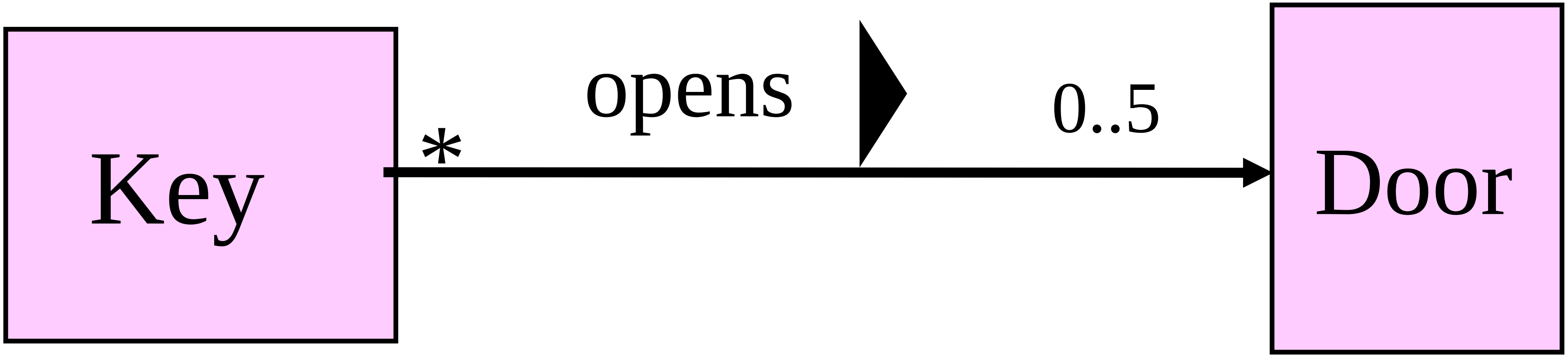


Association - More Examples



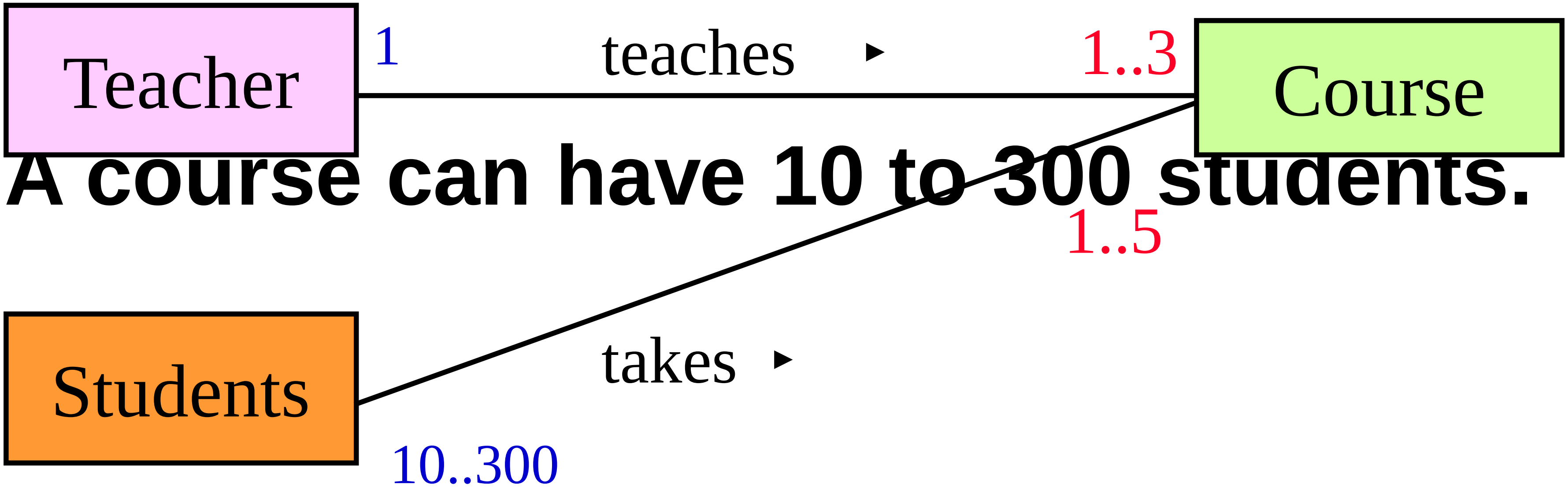


Navigability



Association – Multiplicity

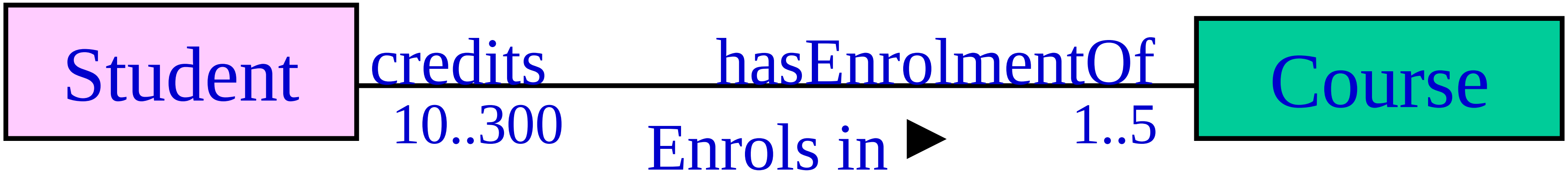
- **A teacher teaches 1 to 3 courses (subjects)**
- **Each course is taught by only one teacher.**
- **A student can take between 1 to 5**



- **A course can have 10 to 300 students.**

Quiz: Draw Class Diagram

- A Student can take up to five Courses.
- A student has to enroll in at least one course.
- Up to 300 students can enroll in a course.
- A class should have at least 10



Student

credits

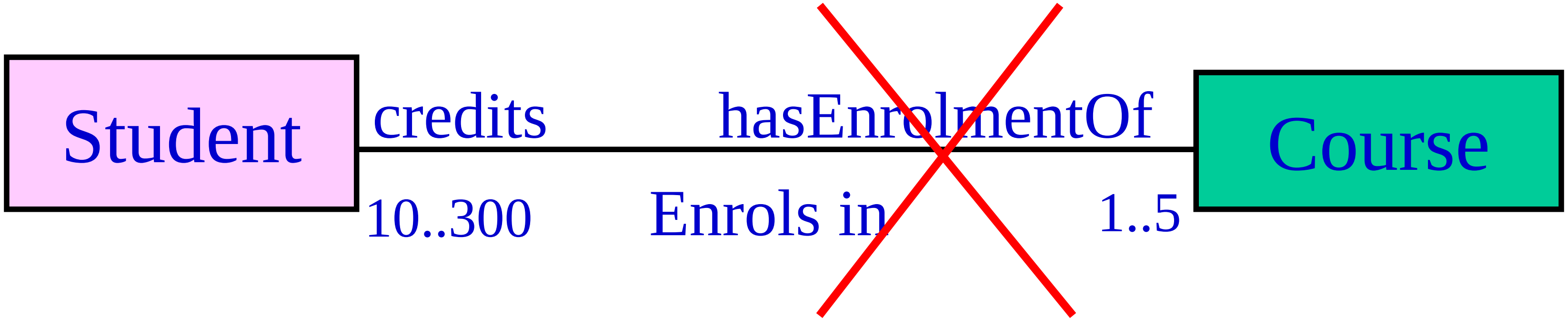
10..300

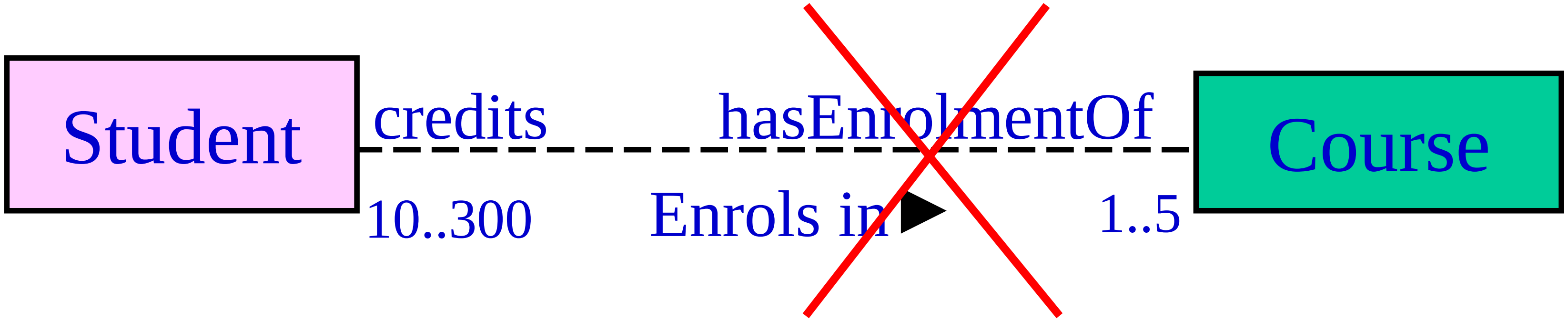
Enrols in ▶

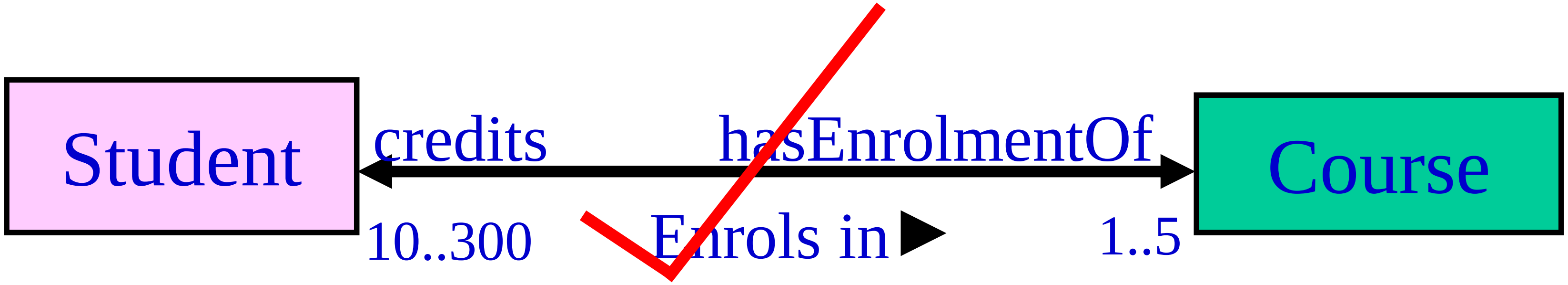
hasEnrolmentOf

1..5

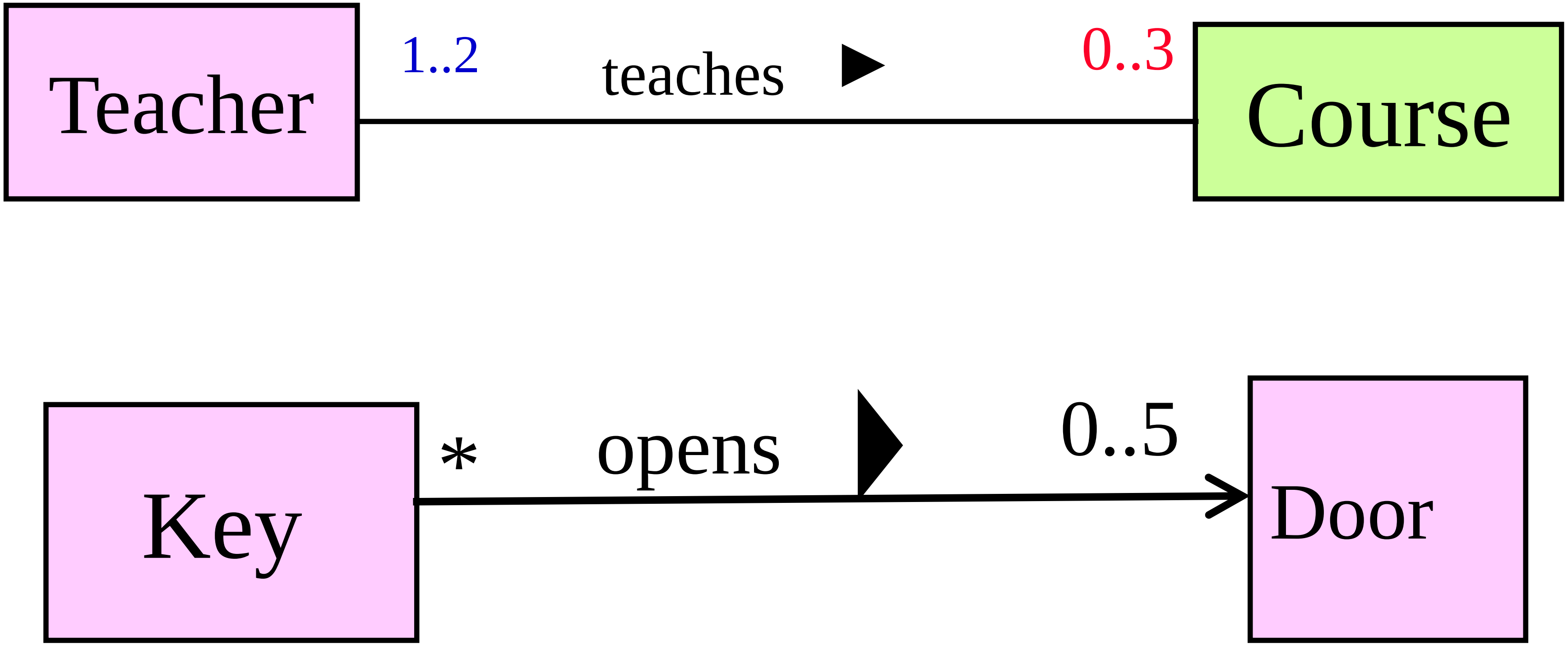
Course


Student
credits
10..300
Enrols in
hasEnrolmentOf
1..5
Course


Student
credits
10..300
Enrols in ▶
hasEnrolmentOf
1..5
Course


Student
credits
10..300
Enrols in ▶
hasEnrolmentOf
1..5
Course

Quiz: Read the Diagram?



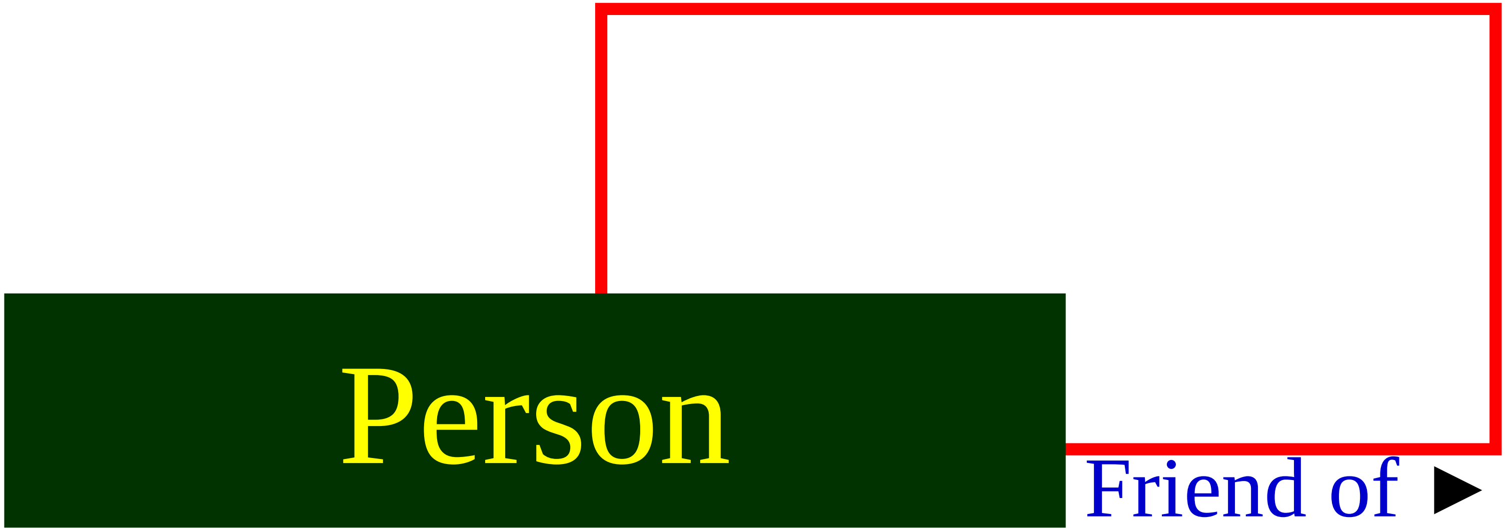
Association and Link

- A link:
  - An instance of an association
  - Exists between two or more objects
  - Dynamically created and destroyed as the run of a system proceeds
- For example:
  - An employee joins an organization.
  - Leaves that organization and joins a new organization etc.

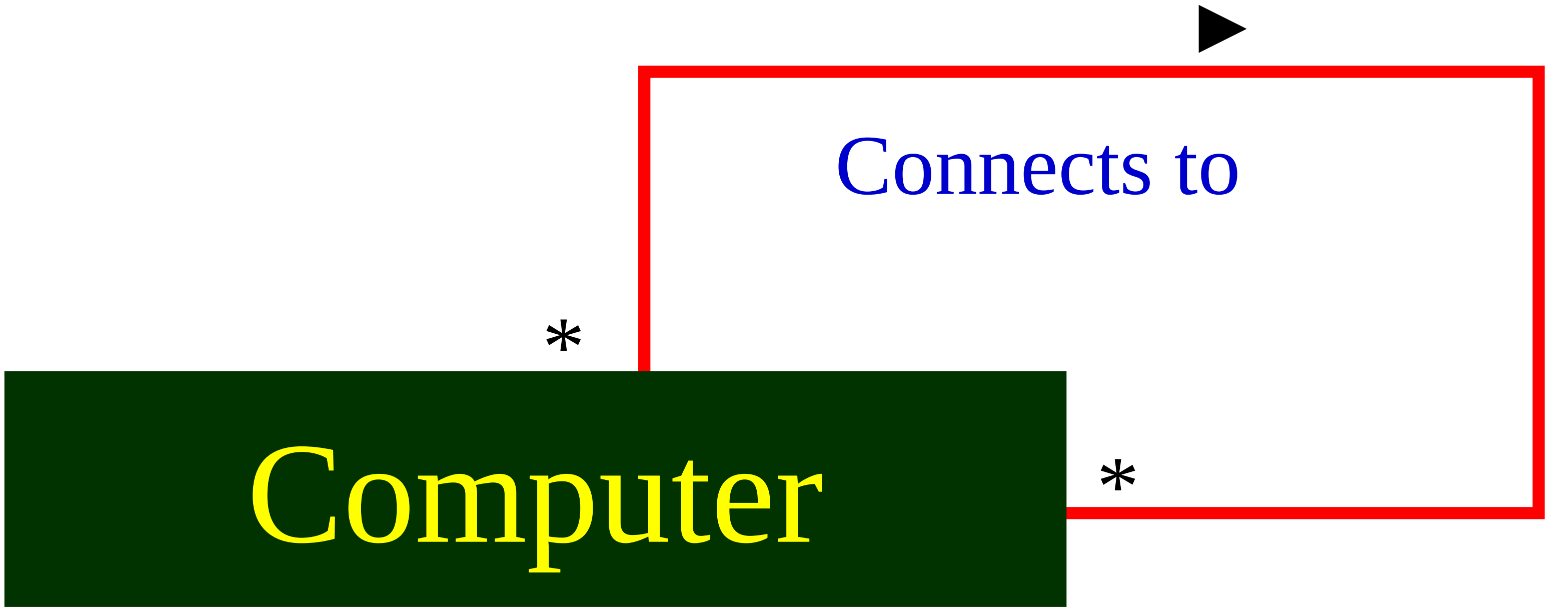
Association Relationship

- A class can be associated with itself (recursive association).
  - Give an example?
- An arrowhead used along with name:
  - Indicates direction of association.
- Multiplicity indicates # of instances taking part in the association.

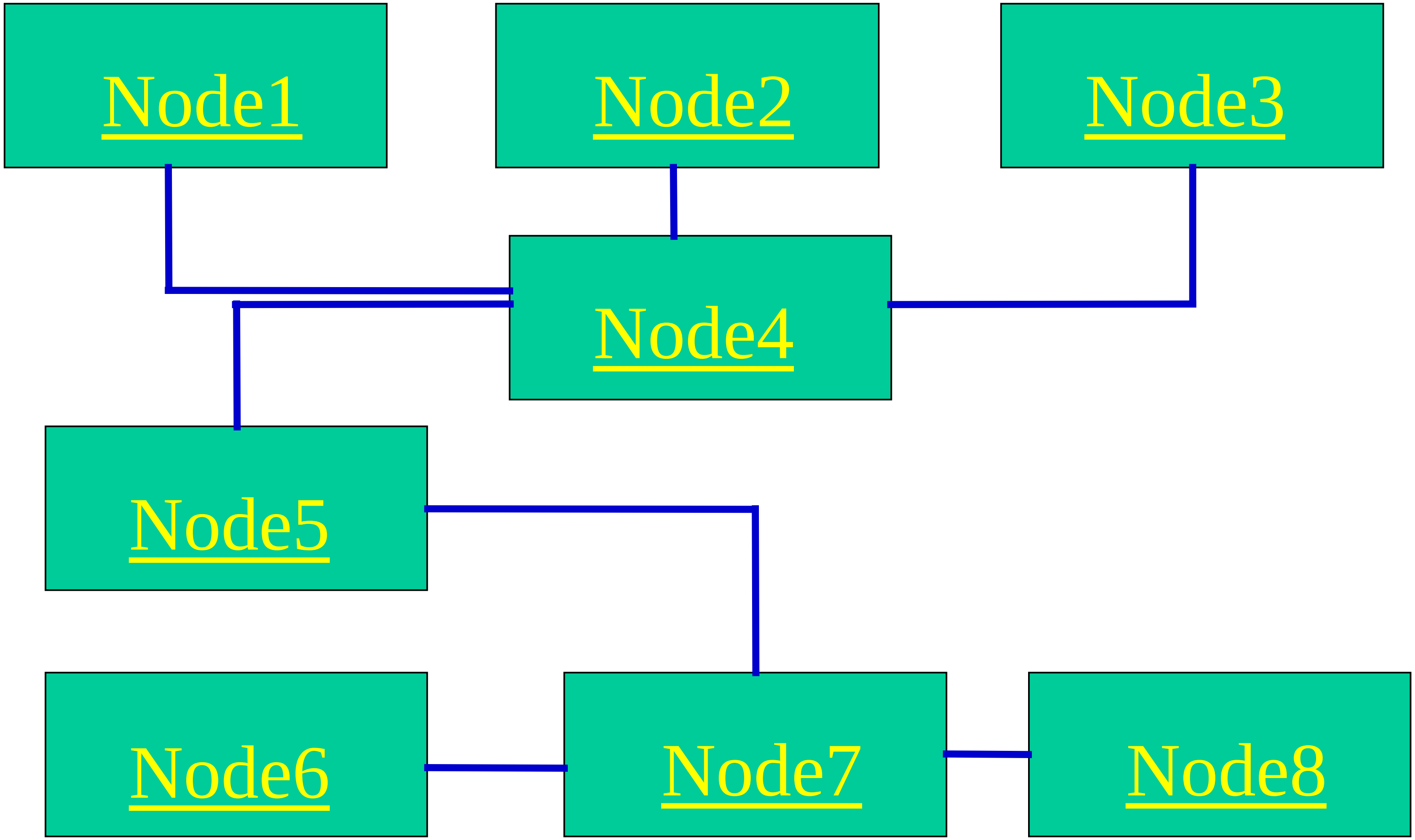
Self Association: Example 0



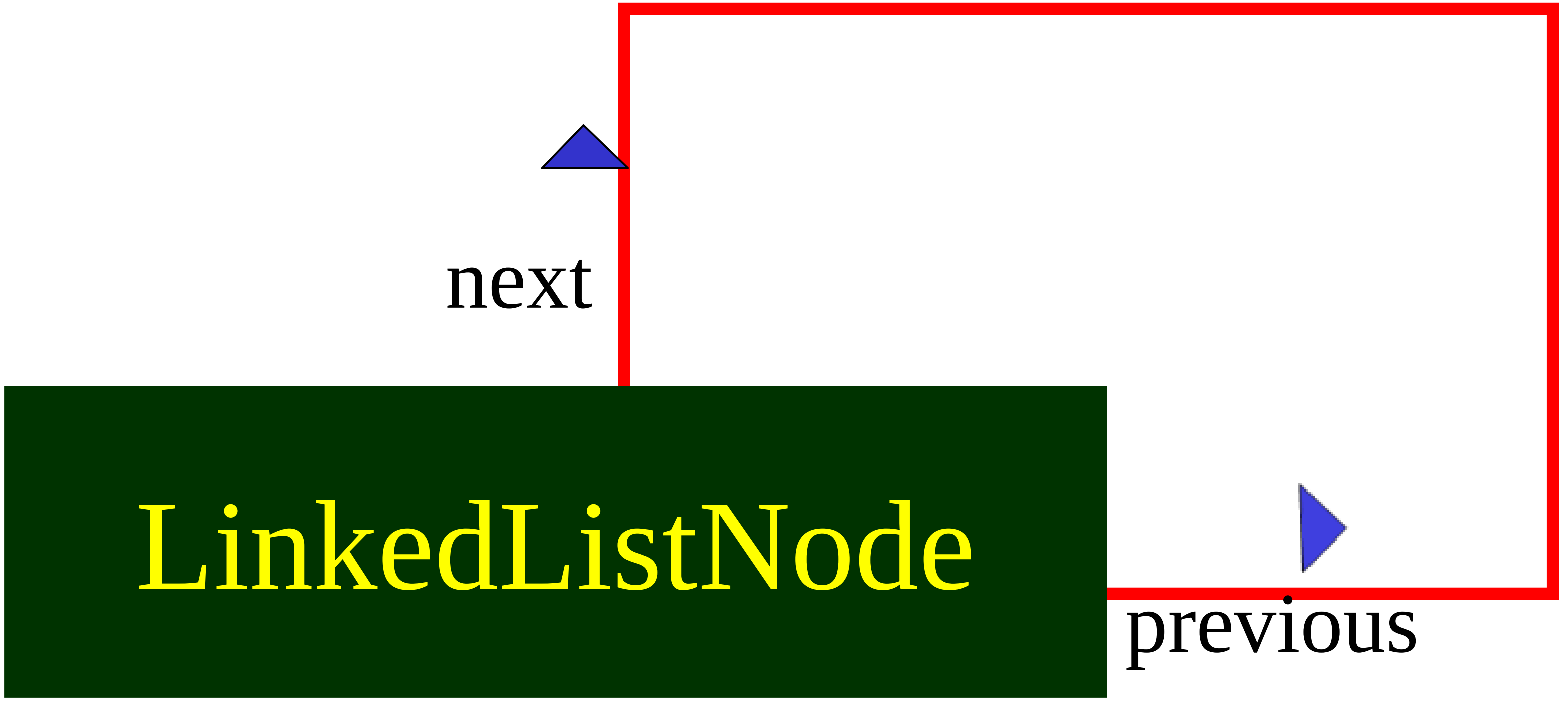
Self Association: Example 0
Computer Network



Computer Network: Object Diagram



Self Association: Example 1

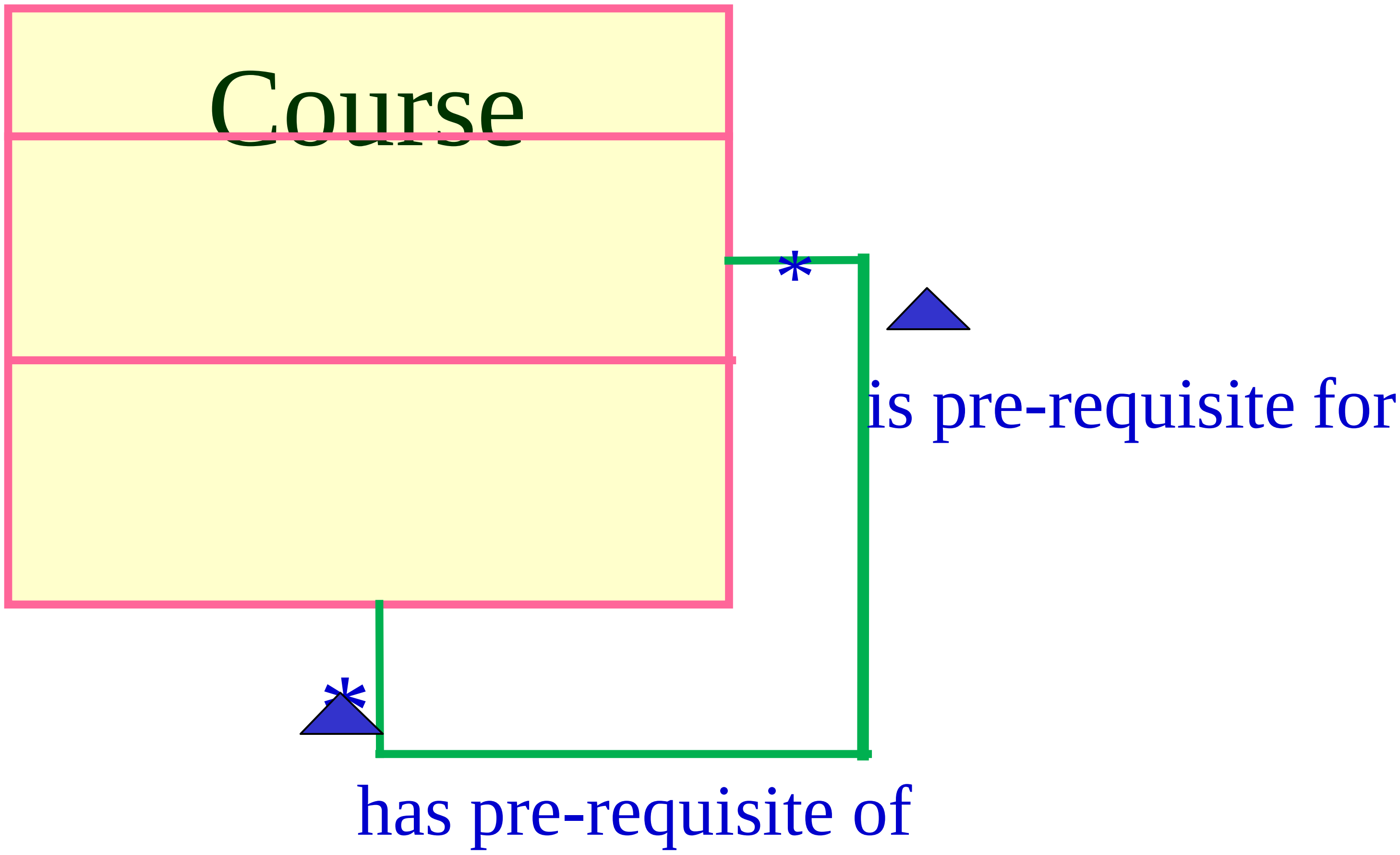


next

LinkedListNode

previous

Reflexive Association: Example 2

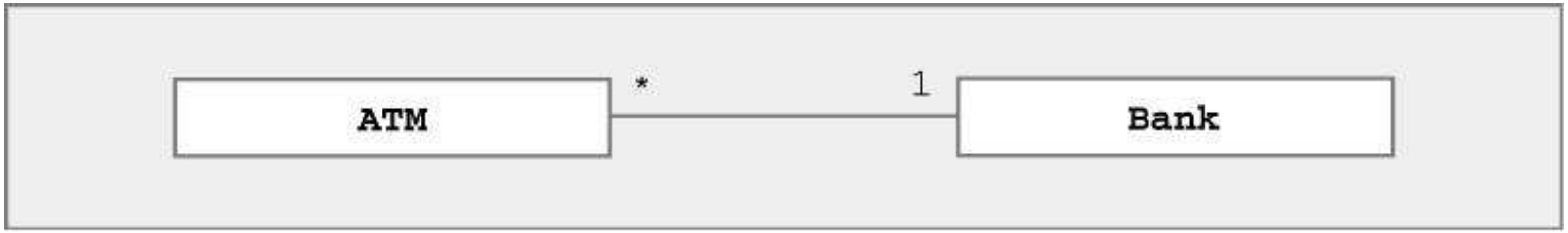


Multiplicity of Associations

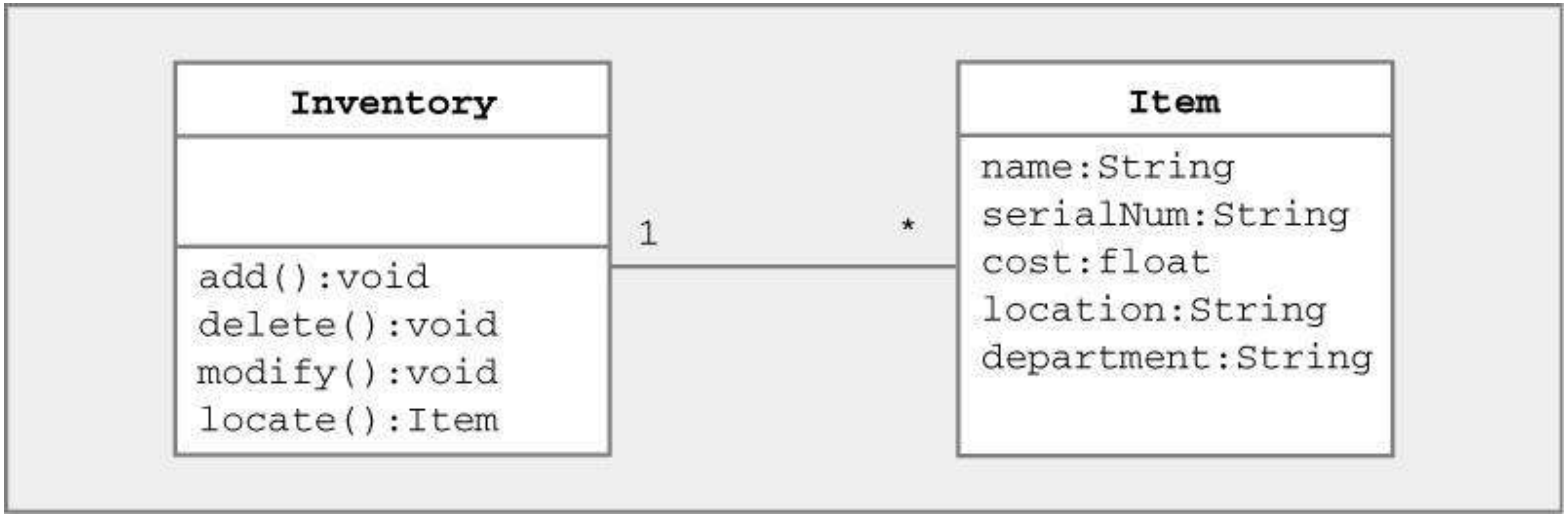
- Some relationships may be quantified
- Multiplicity denotes how many objects the source object can legitimately reference
- Notation
  - * ⇒ 0, 1, or more
  - 5 ⇒ 5 exactly
  - 5..8⇒ between 5 and 8, inclusive
  - 5..*⇒ 5 or more

Multiplicity of Associations

- Many-to-one
  - Bank has many ATMs, ATM knows only 1 bank



- One-to-many
  - Inventory has many items, items know 1 inventory

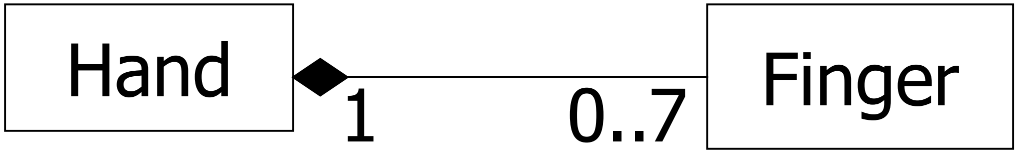


Aggregation and Composition

- **A special kind of association**
- **Models whole-part relationship between things**
- **Whole is usually referred to as *composite***

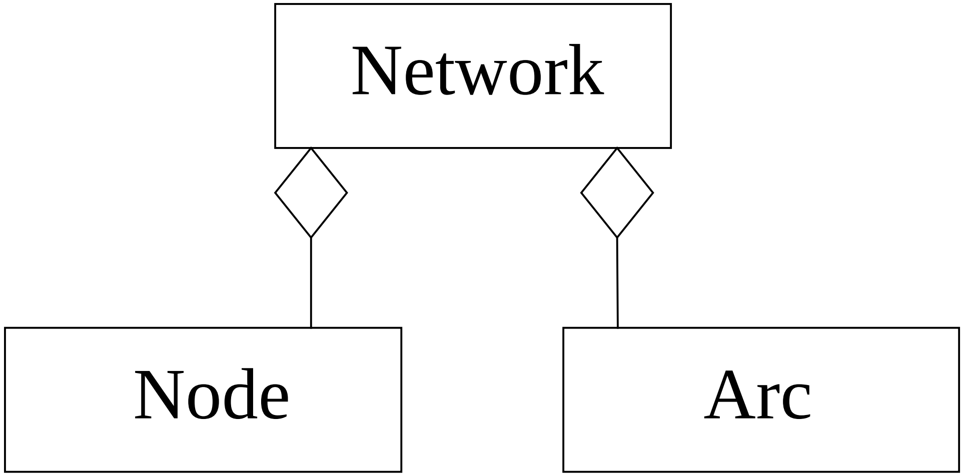
Composite aggregation

- Also referred to as composition
- Composite solely owns the part and they are in a tree structure parts hierarchy
- Most common form of aggregation
- In UML, represented by filled diamond



Shared Aggregation

- Part may be in many composite instances
- In UML, represented as hollow diamond



How to identify aggregation

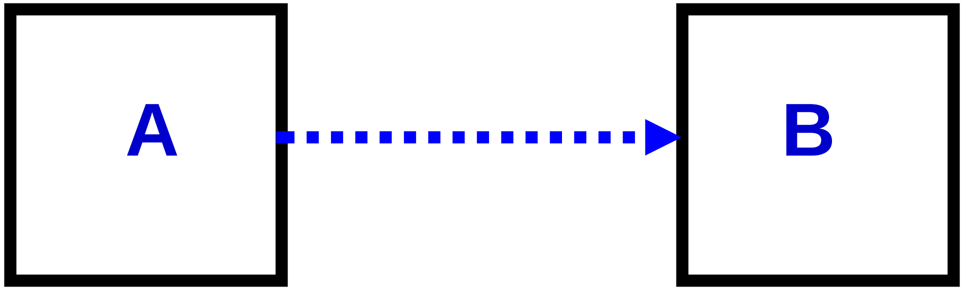
- Lifetime of part is bound within lifetime of composite
  - There is a create-delete dependency
- There is an obvious whole-part physical or logical assembly
- Some properties of composite propagate to parts (e.g., location)
- Operations applied to composite propagate to parts (e.g., destruction, movement, recording)

Why show aggregation

- **Clarifies domain constraints regarding part-whole relationship**
- **Assists in identification of a *creator***
- **Operations applied to whole should usually propagate to parts**
- **Identifying whole wrt a part supports encapsulation**

Dependency

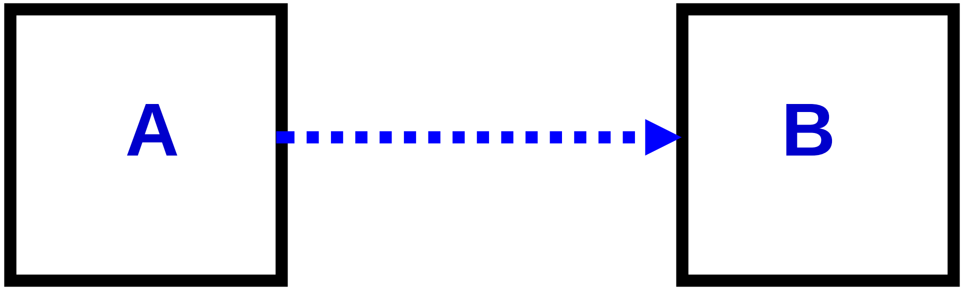
- Denotes dependence between classes
- Always directed (Class A depends on B)
- Represented by dotted line with arrowhead



A depends on B

Dependency

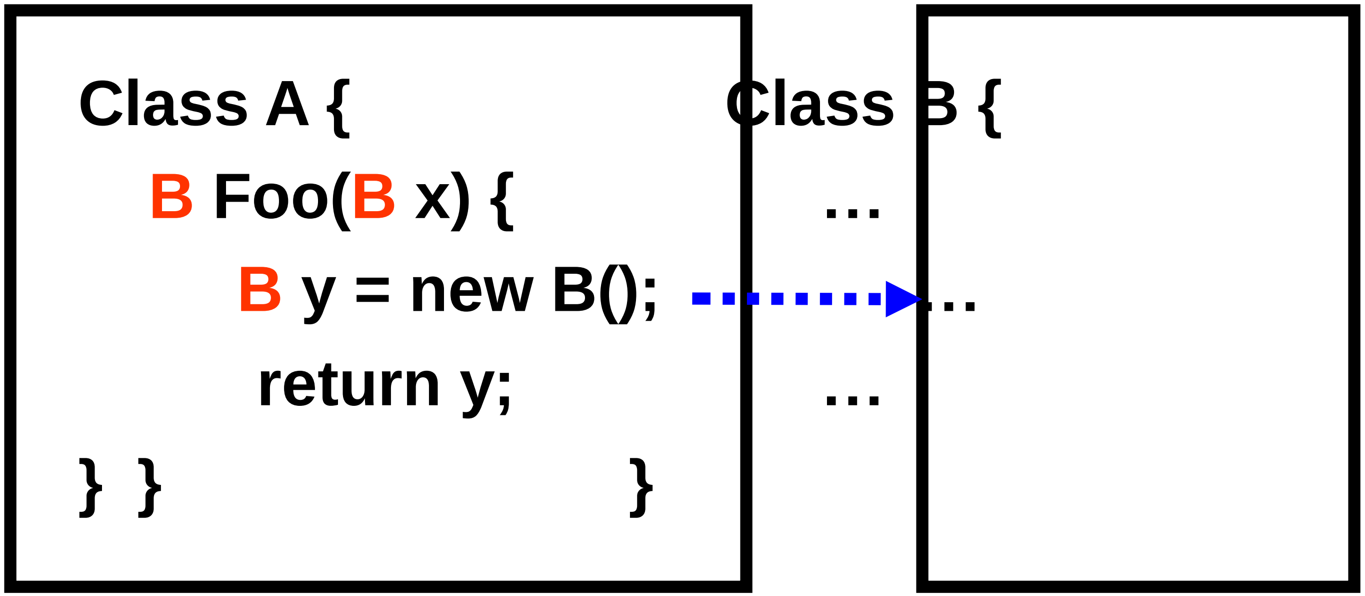
- Caused by class methods
- Method in Class A temporarily "uses a" object of type Class B
- Change in Class B may affect class A



A uses object of class B

Dependency

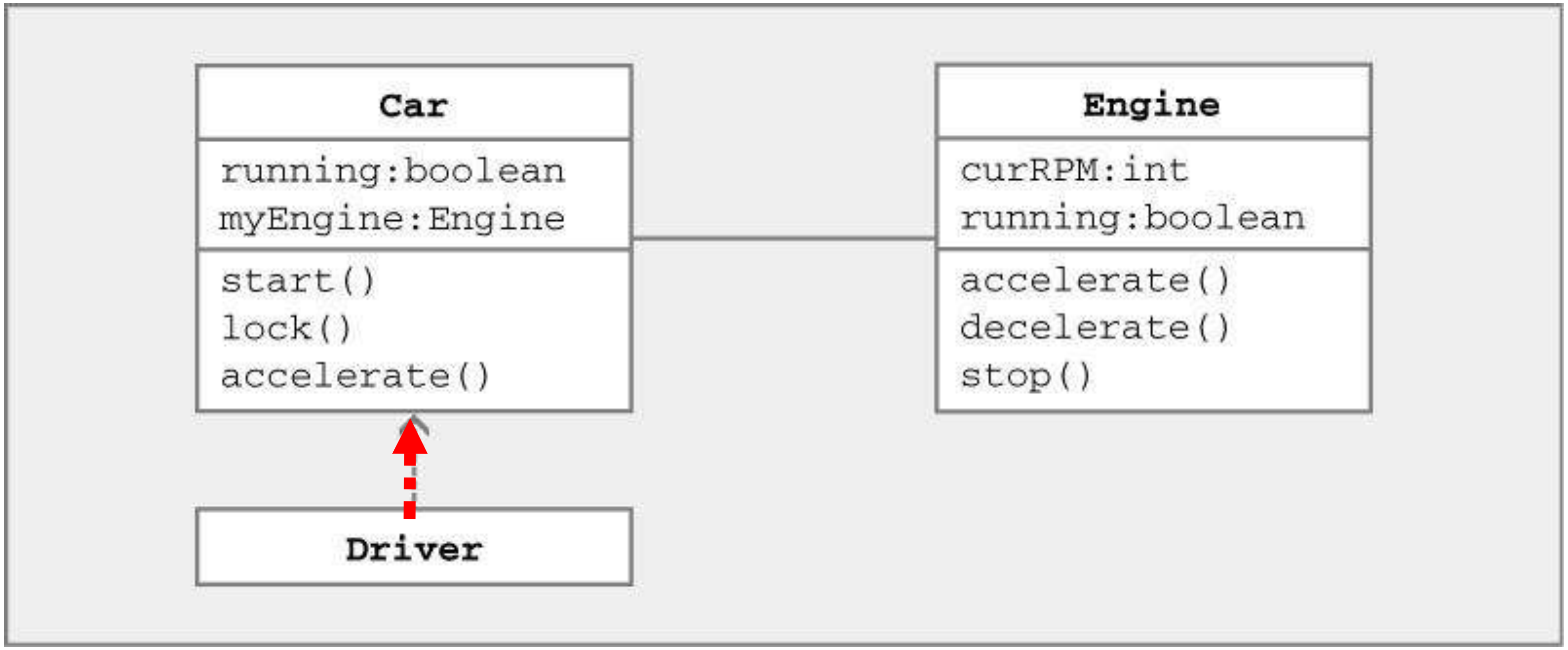
- Dependence may be caused by
  - Local variable
  - Parameter
  - Return value
- Example



```
Class A {
    B Foo(B x) {
        B y = new B();
        return y;
} }
```

```
Class B {
    …
    …
    …
}
```

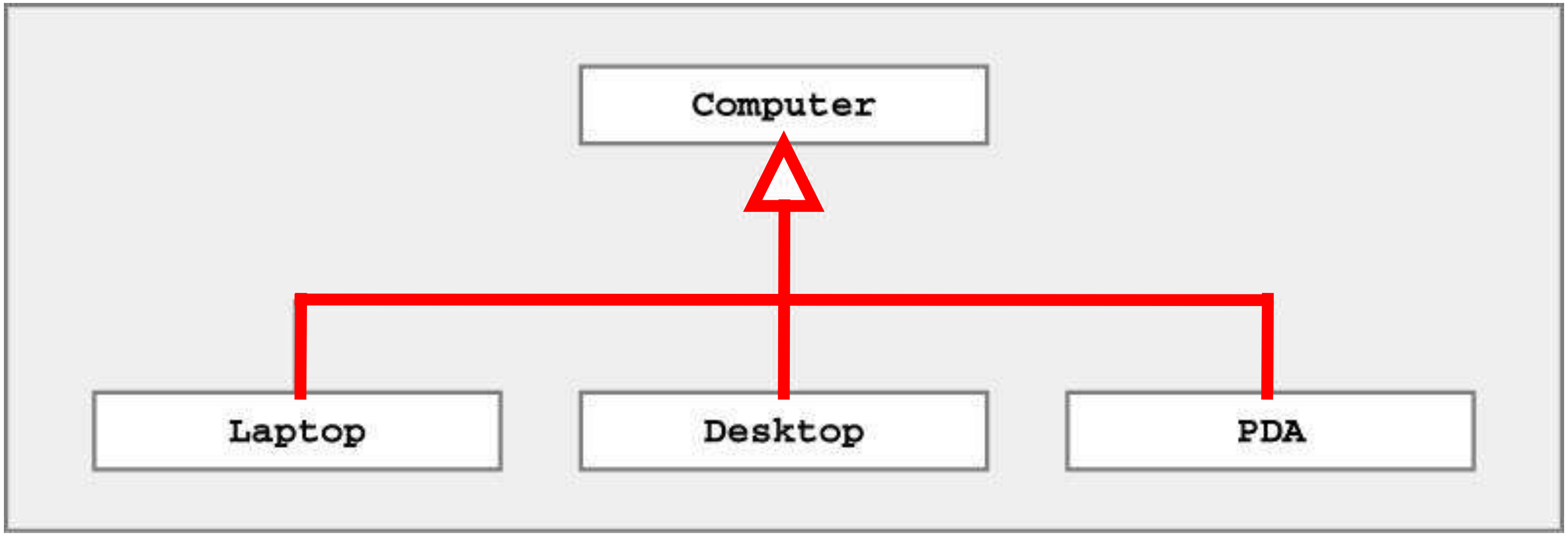
Dependency Example



Class Driver depends on Class Car

Generalization

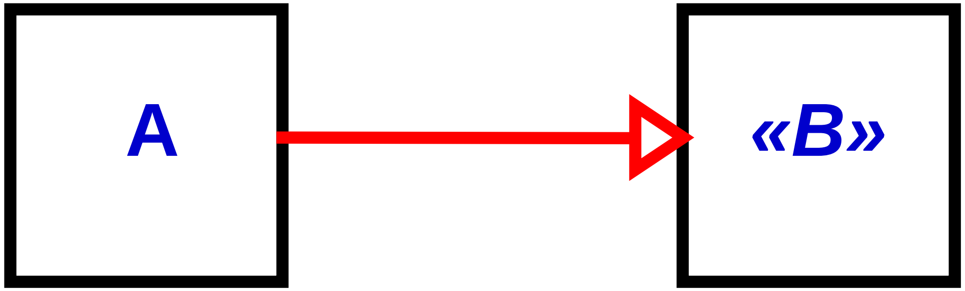
- Denotes inheritance between classes
- Can view as “is-a” relationship
- Represented by line ending in (open) triangle



Laptop, Desktop, PDA inherit
state & behavior from Computers

Implementation

- Denotes class implements Java interface
- Represented by dotted line ending in (open) triangle



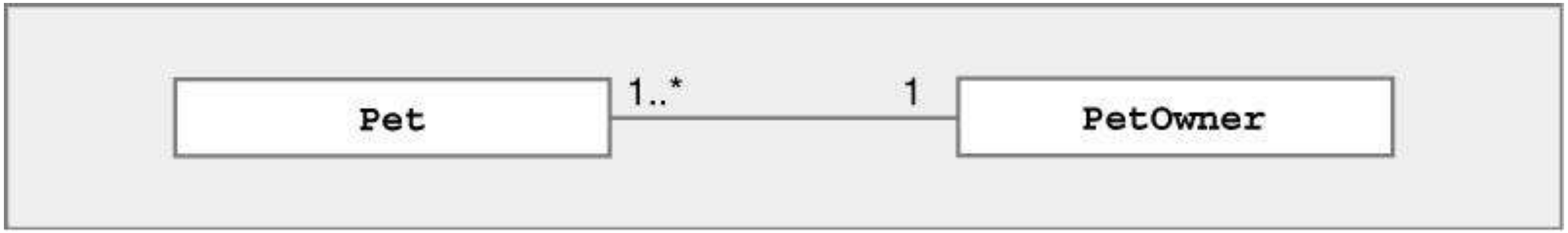
A implements interface B

UML Examples

- Read UML class diagram
- Try to understand relationships
- Examples
  - Pets & owners
  - Computer disk organization
  - Banking system
  - Home heating system
  - Printing system

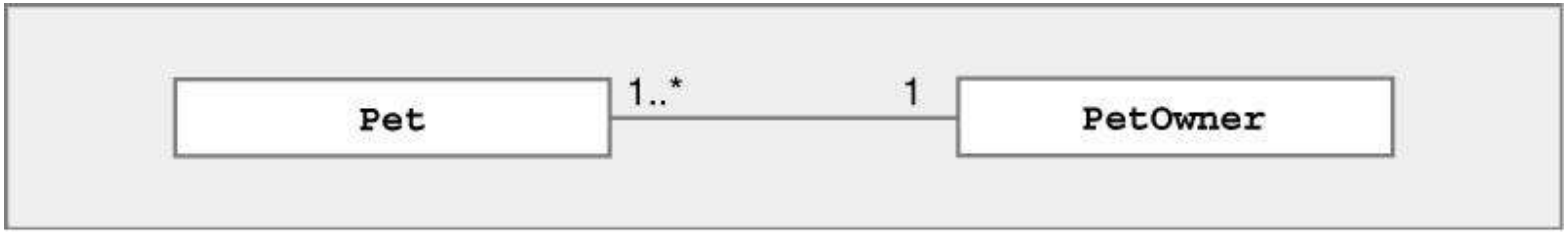
UML Example – Veterinary System

- **Try to read & understand UML diagram**



UML Example – Veterinary System

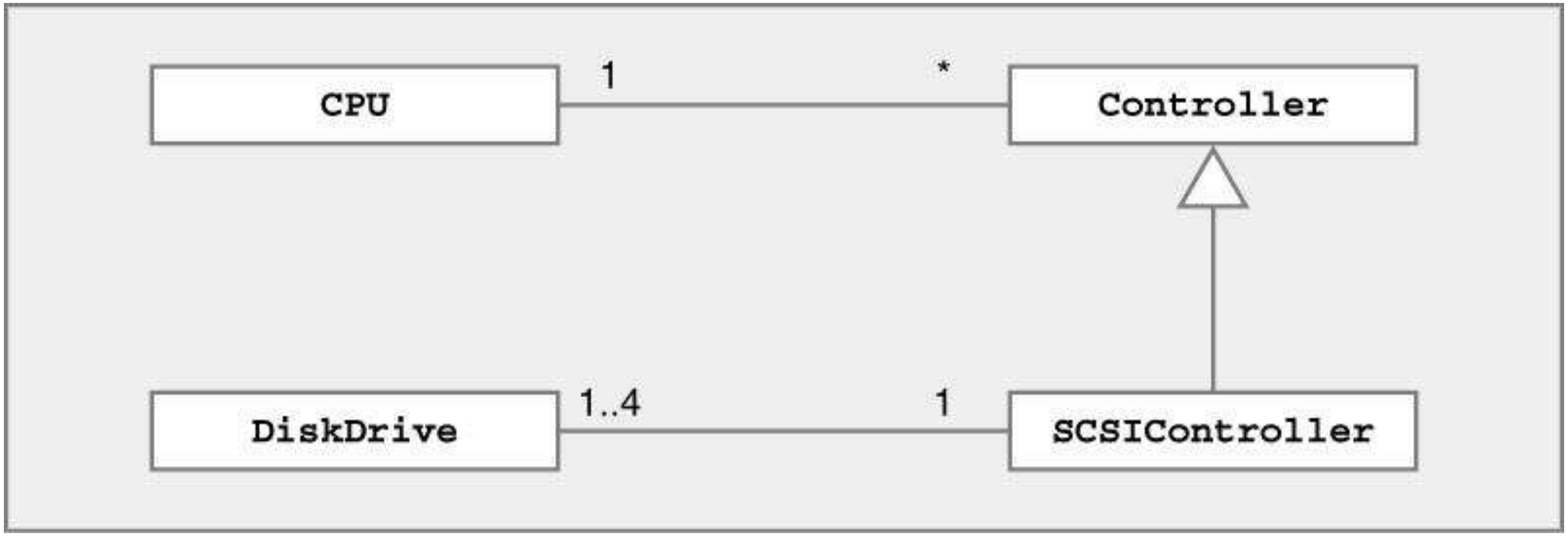
- Try to read & understand UML diagram



- 1 or more Pets associated with 1 PetOwner

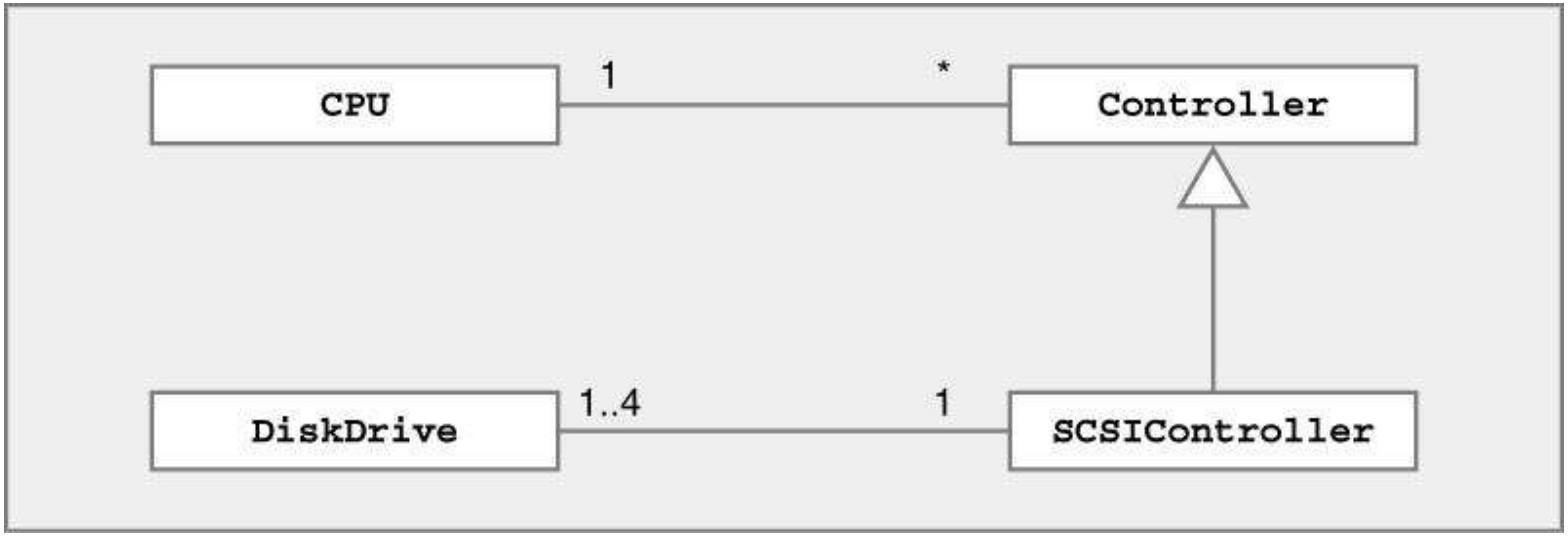
UML Example – Computer System

- Try to read & understand UML diagram



UML Example – Computer System

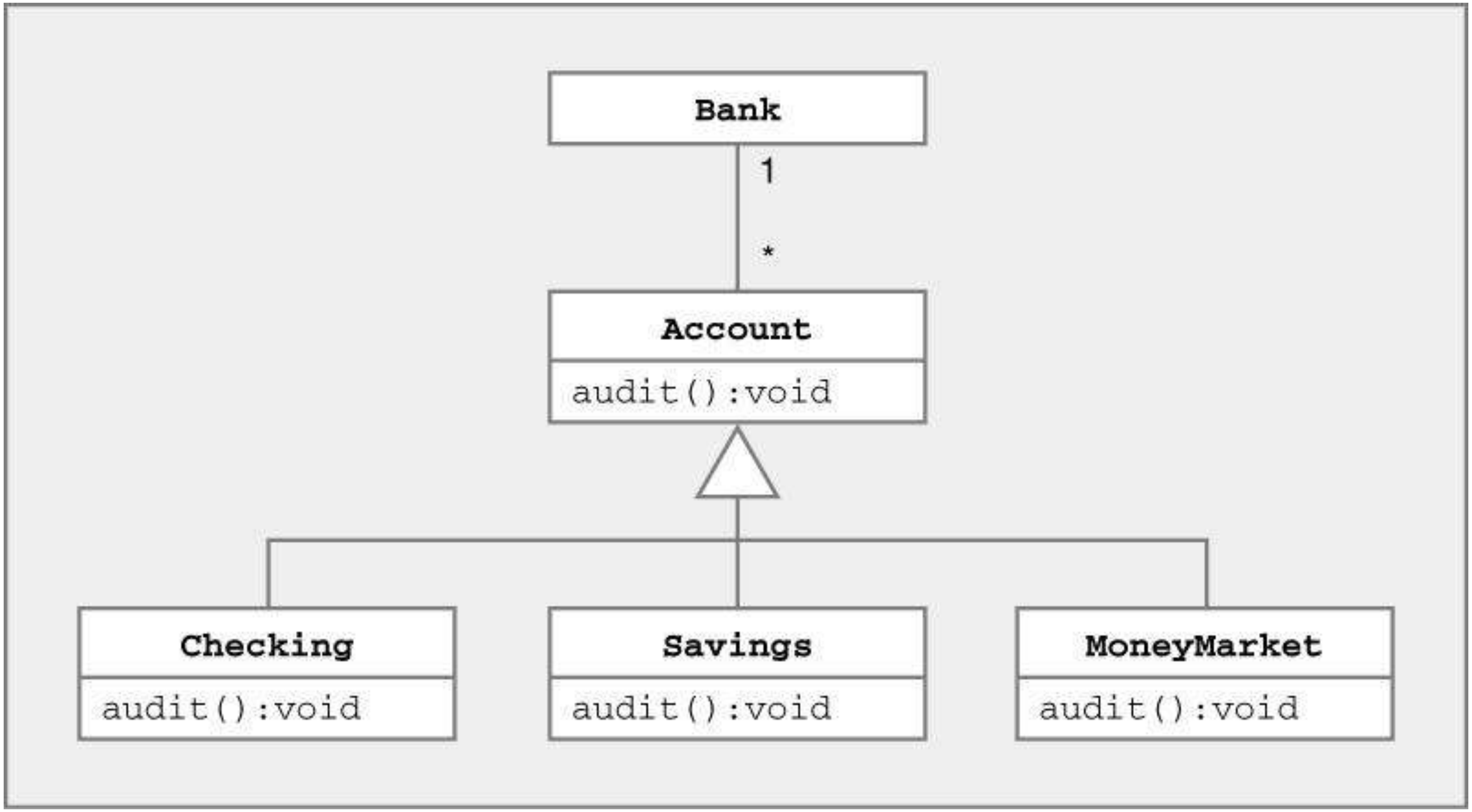
- Try to read & understand UML diagram



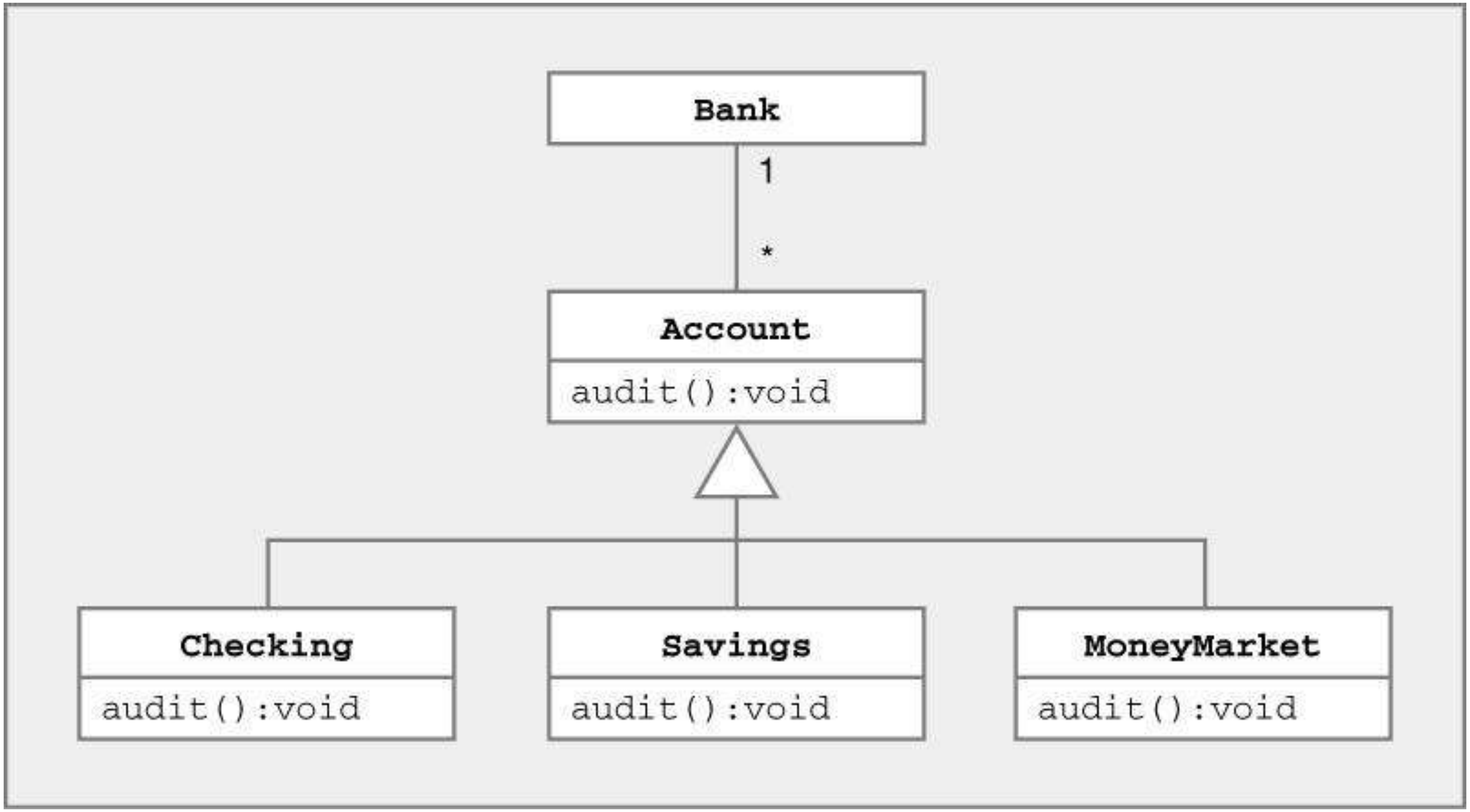
- 1 CPU associated with 0 or more Controllers
- 1-4 DiskDrives associated with 1 SCSIController
- SCSIController is a (specialized) Controller

UML Example – Banking System

- **Try to read & understand UML diagram**



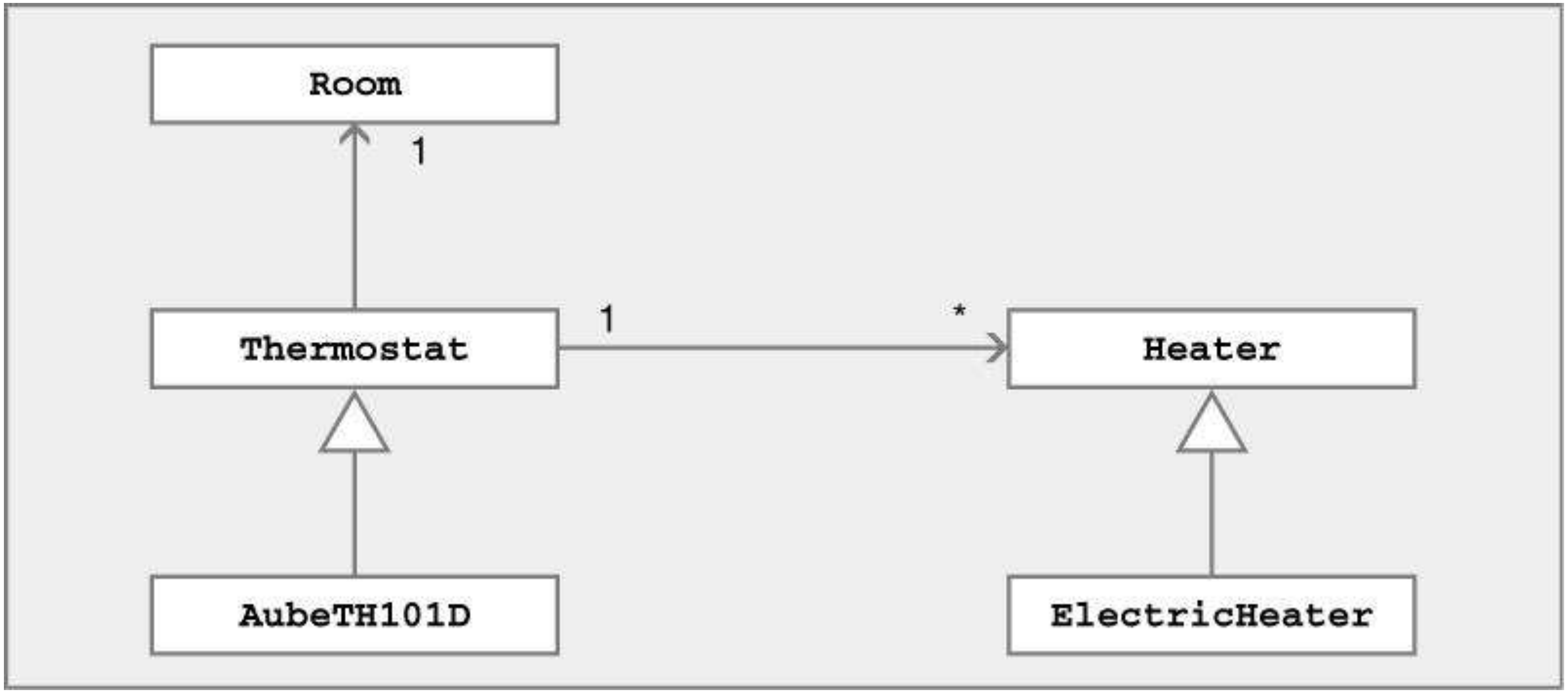
UML Example – Banking System



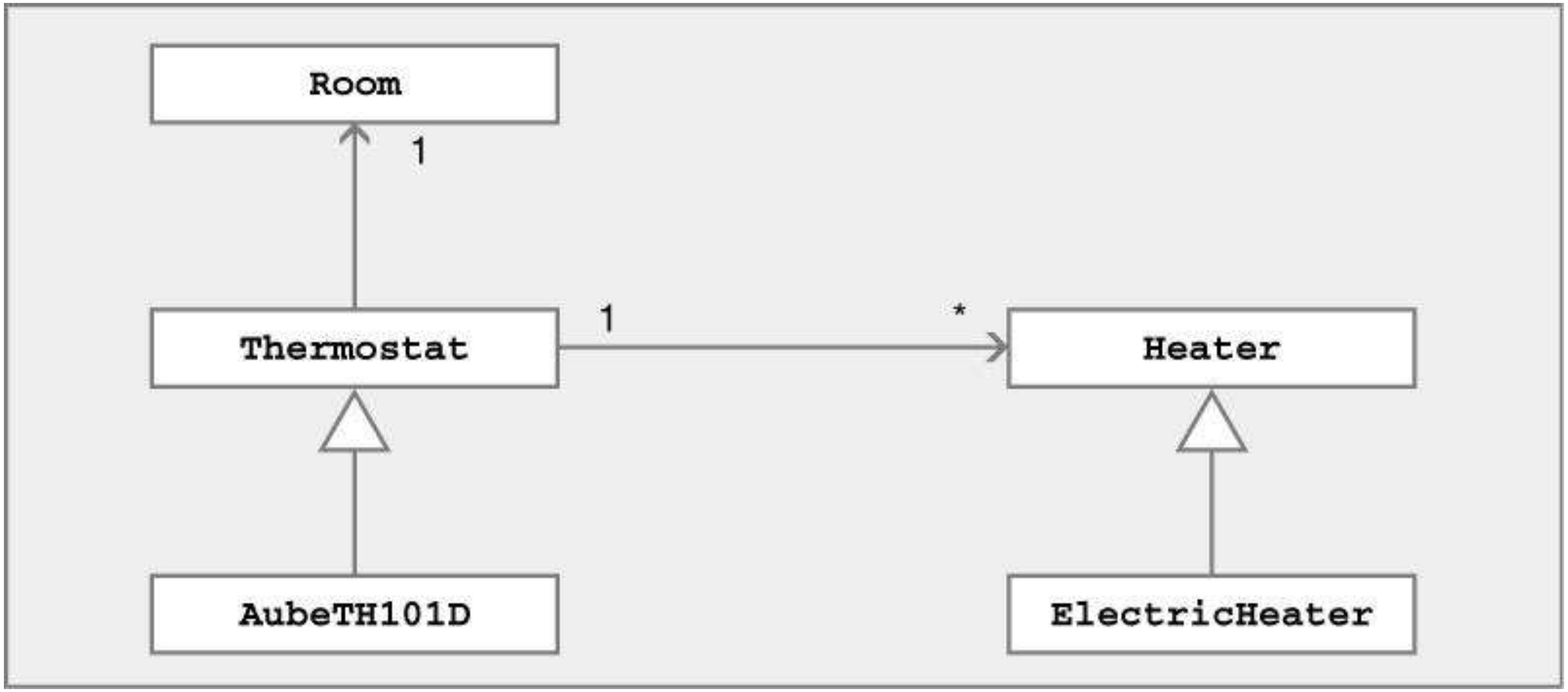
- 1 Bank associated with 0 or more Accounts
- Checking, Savings, MoneyMarket are Accounts

UML Example – Home Heating System

- **Try to read & understand UML diagram**



UML Example – Home Heating System



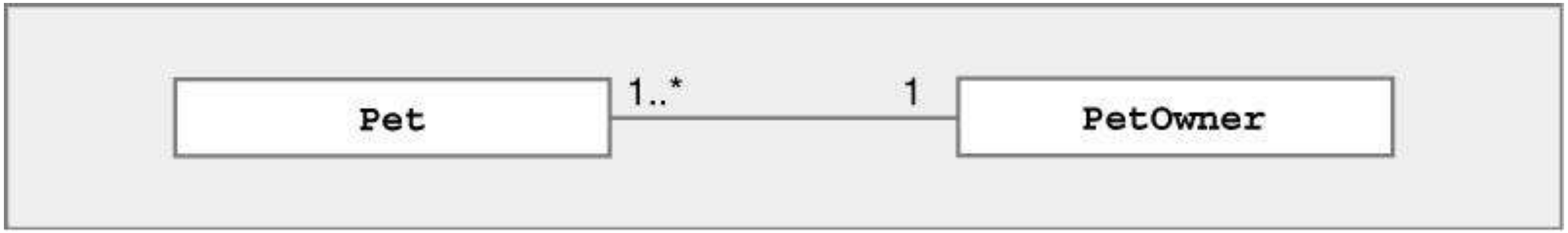
- Each Thermostat has 1 Room
- Each Thermostat associated with 0 or more Heaters
- ElectricHeater is a specialized Heater
- AubeTH101D is a specialized Thermostat

UML Class Diagrams ↔ Java

- Different representation of same information
  - Name, state, behavior of class
  - Relationship(s) between classes
- Practice deriving one from the other
  - Accurately depicting relationship between classes

UML → Java : Veterinary System

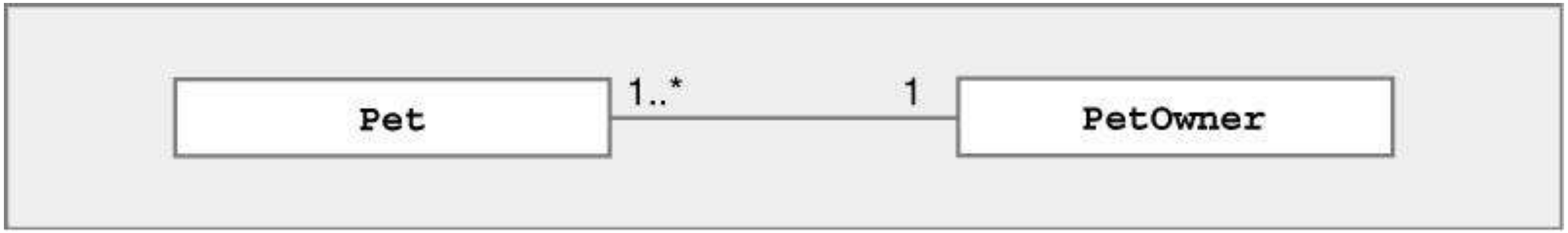
- UML



- Java

UML → Java : Veterinary System

- UML



- Java

```
class Pet {
   PetOwner myOwner;   // 1 owner for each pet
}
class PetOwner {
   Pet [ ] myPets;   // multiple pets for each owner
}
```

Java → UML : Veterinary System

- Java

```
class Pet {
   PetOwner myOwner;   // 1 owner for each pet
}
class PetOwner {
   Pet [ ] myPets;   // multiple pets for each owner
}
```

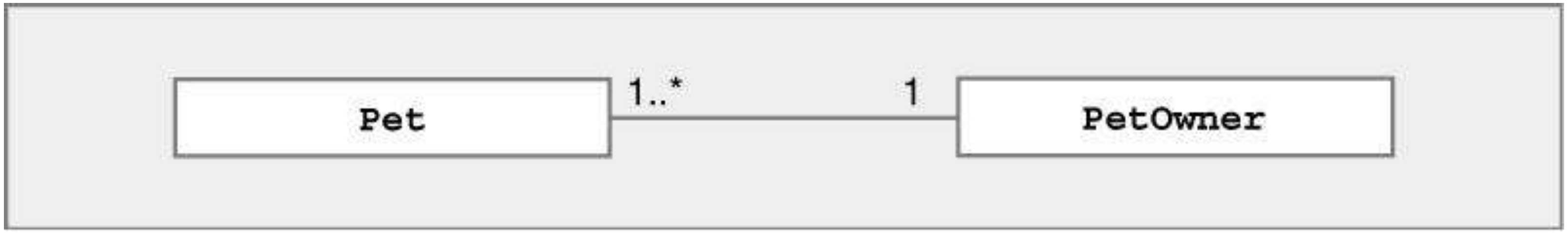
- UML

Java → UML : Veterinary System

- Java

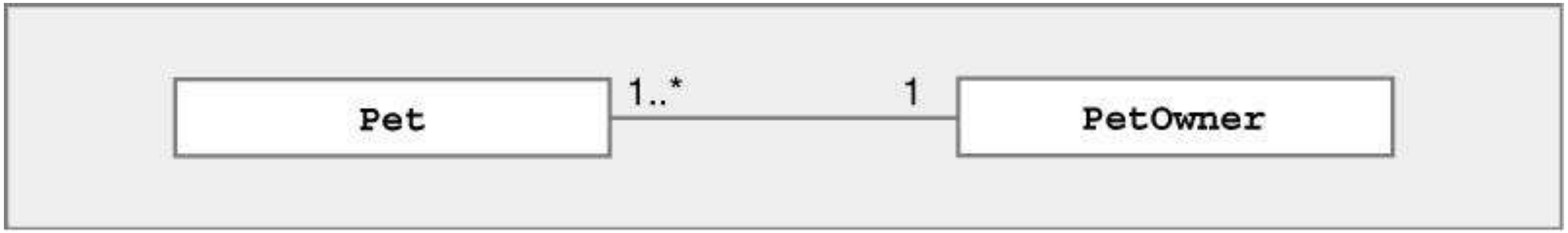
```
class Pet {
   PetOwner myOwner;   // 1 owner for each pet
}
class PetOwner {
   Pet [ ] myPets;   // multiple pets for each owner
}
```

- UML



UML Class Diagrams ↔ Java

- UML

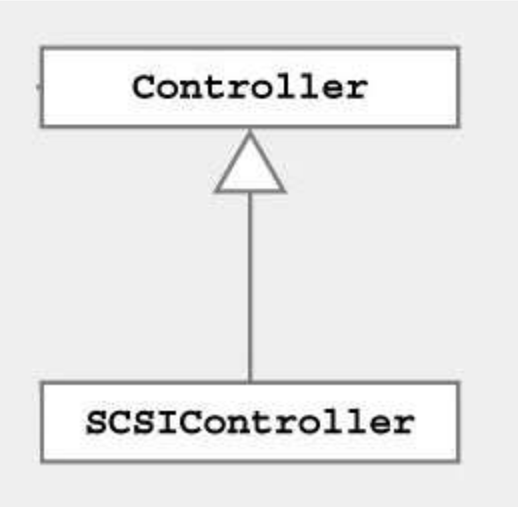


- Java

```
class Pet {
   PetOwner myOwner;   // 1 owner for each pet
}
class PetOwner {
   Pet [ ] myPets;   // multiple pets for each owner
}
```

UML → Java : Computer System

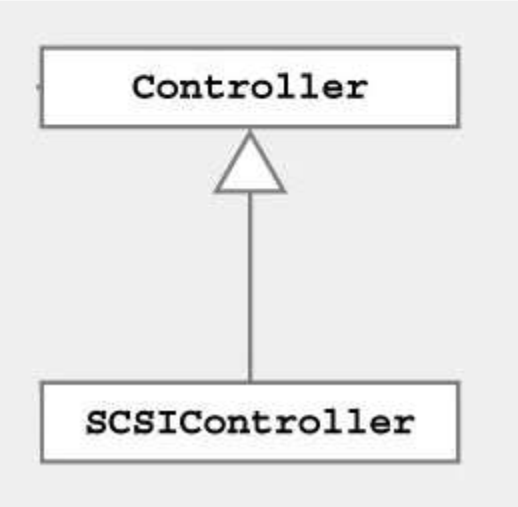
- UML



- Java

UML → Java : Computer System

- UML

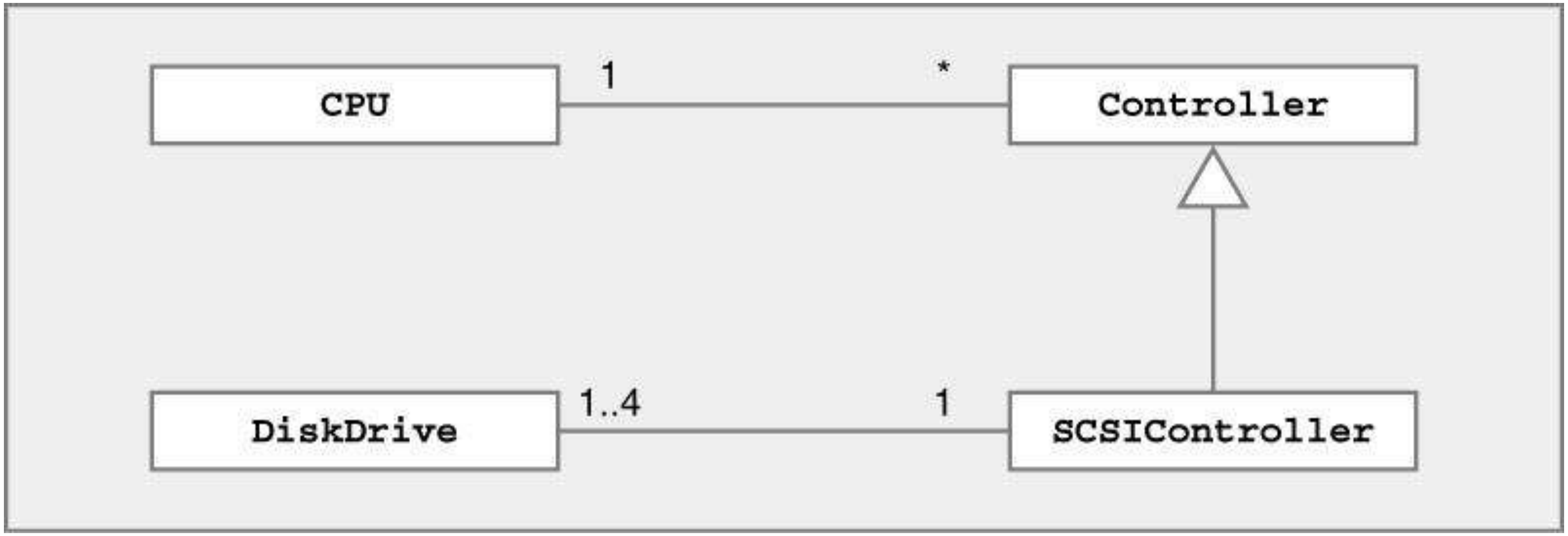


- Java

```
class Controller {
}
class SCSIController extends Controller {
}
```

UML → Java : Computer System

- UML

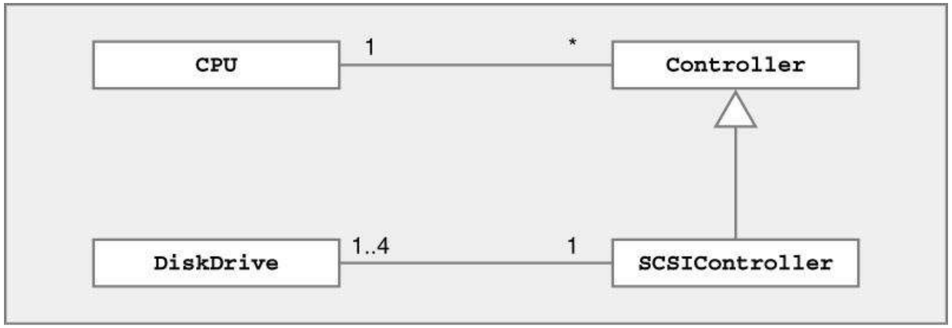


- Java
  - Design code using all available information in UML…

UML → Java : Computer System

- **Java**

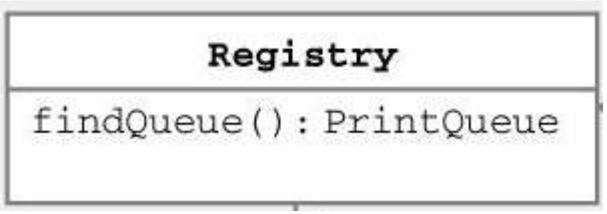
```
class CPU {
   Controller [ ] myCtlrs;
}
class Controller {
   CPU myCPU;
}
class SCSIController extends Controller {
   DiskDrive [ ] myDrives = new DiskDrive[4];
}
Class DiskDrive {
    SCSIController mySCSI;
}
```



Java → UML : Printing System

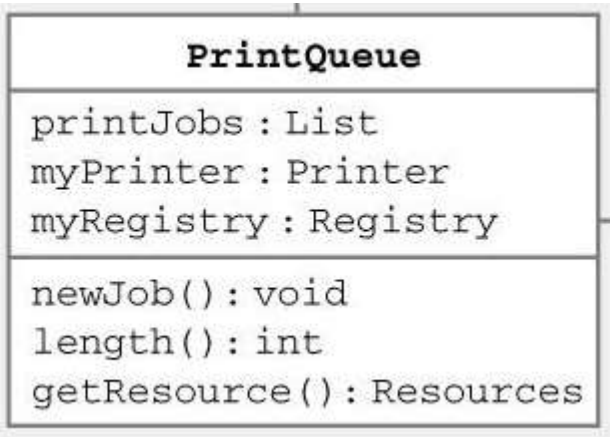
- **Java**

```
class Registry {
   PrintQueue findQueue();
}
class PrintQueue {
   List printJobs;
   Printer myPrinter;
   Registry myRegistry;
   void newJob();
   int length();
   Resources getResource();
}
```



Registry

findQueue() : PrintQueue



PrintQueue

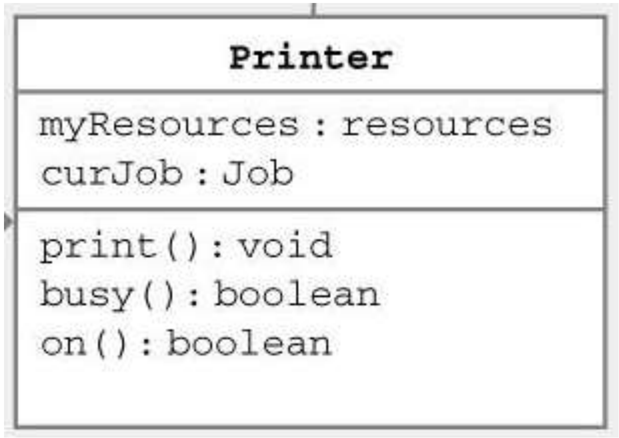
printJobs : List
myPrinter : Printer
myRegistry : Registry

newJob() : void
length() : int
getResource() : Resources

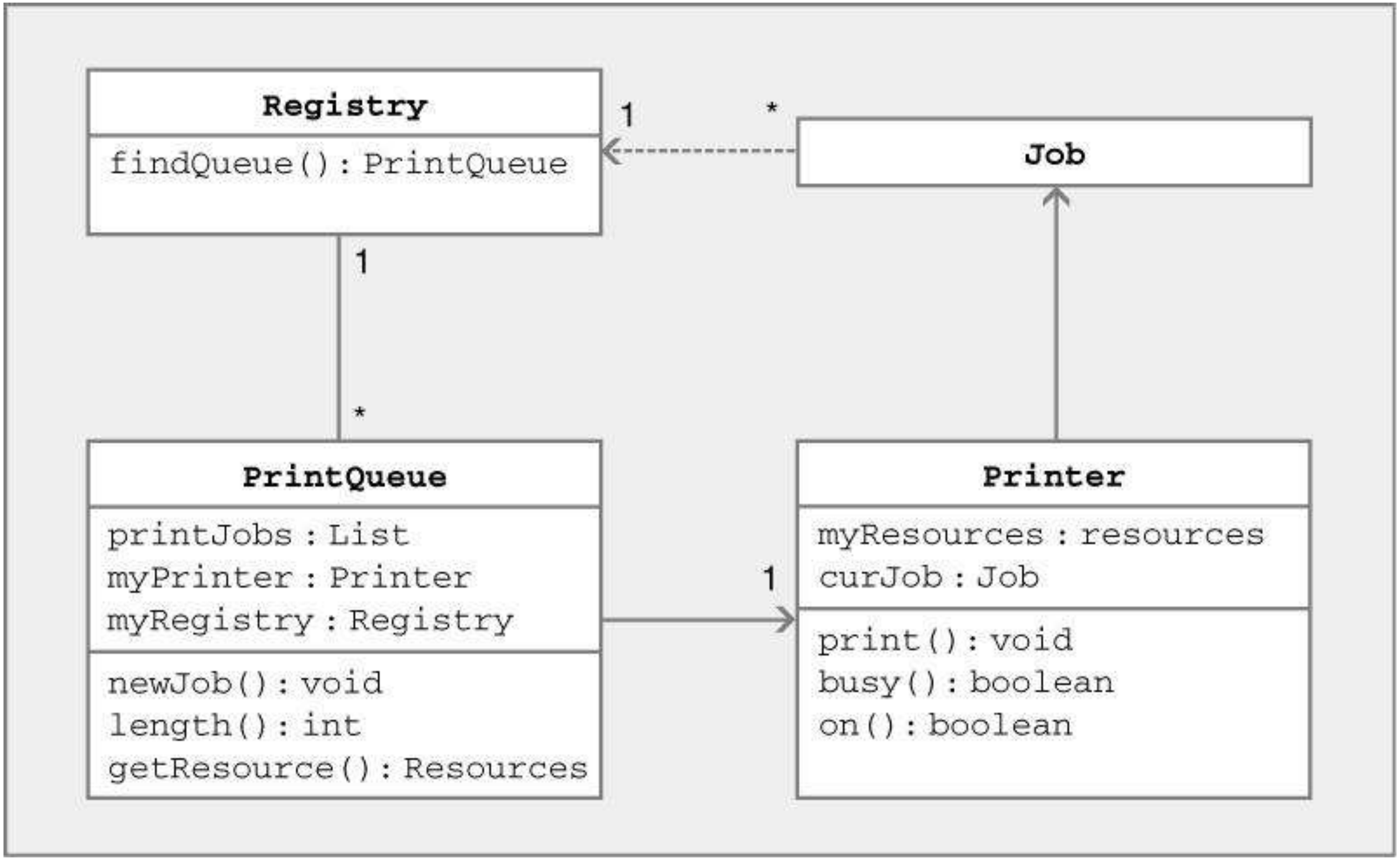
Java → UML : Printing System

- Java

```
Class Printer {
    Resources myResources;
    Job curJob;
    void print();
    boolean busy();
    boolean on();
}
class Job {
    Job(Registry r) {
     …
    }
}
```

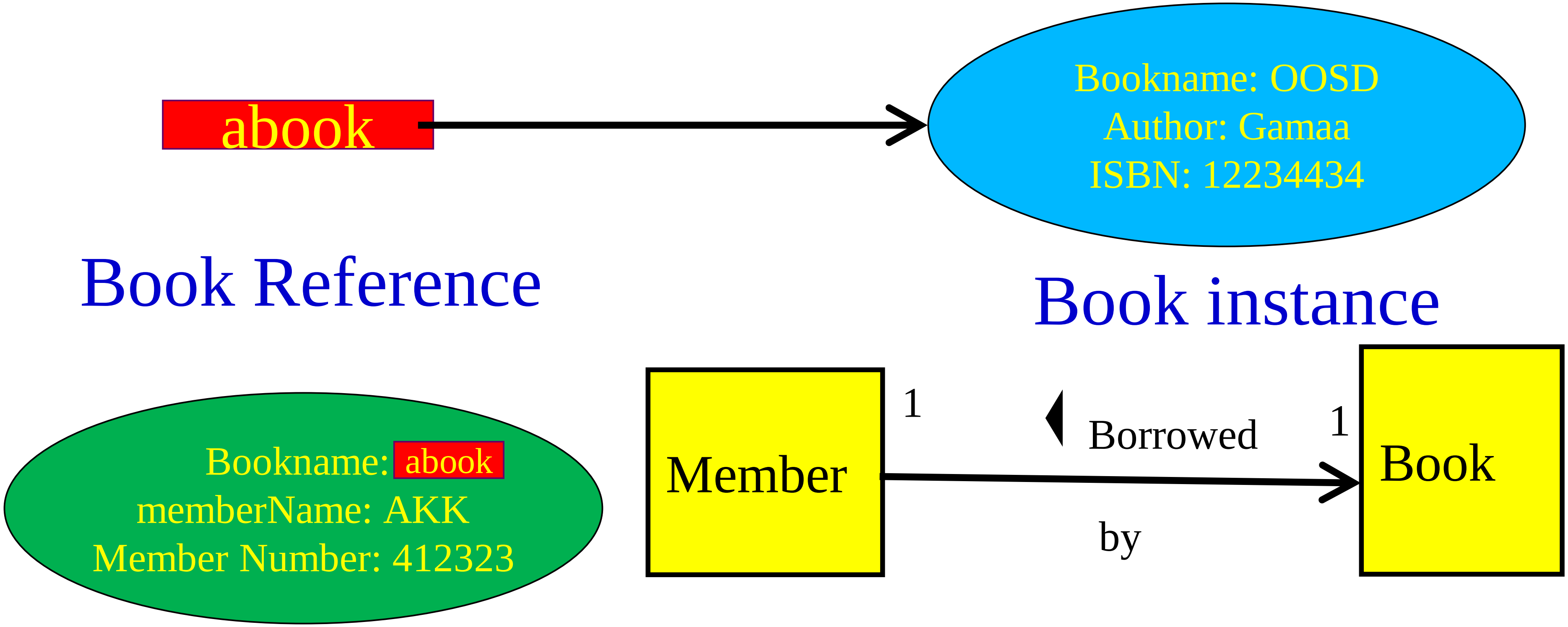


Java → UML : Printing System



Implementing Association Relationship: Example 1

- **To implement in Java:**
  - **Use a reference variable of one class as an attribute of another class**



abook

Bookname: OOSD
Author: Gamaa
ISBN: 12234434

Book Reference

Book instance

Bookname: abook
memberName: AKK
Member Number: 412323

Member

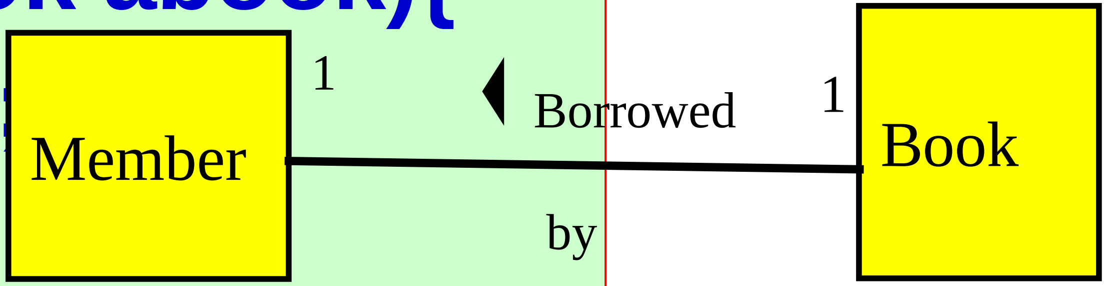
1

◀ Borrowed by

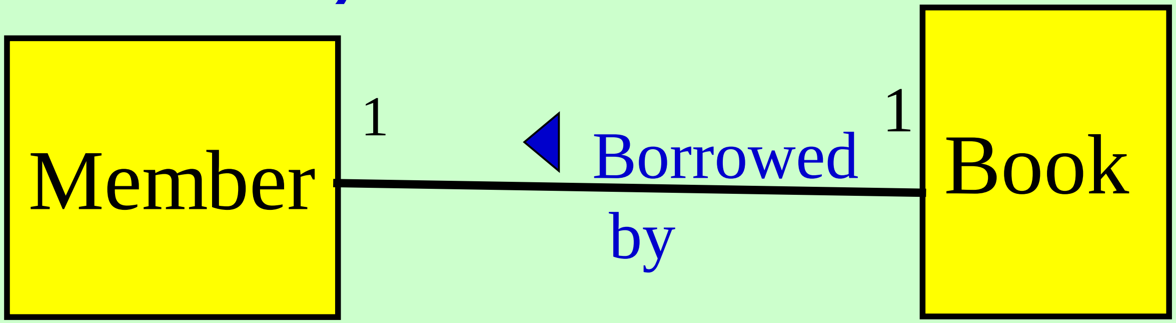
1

Book

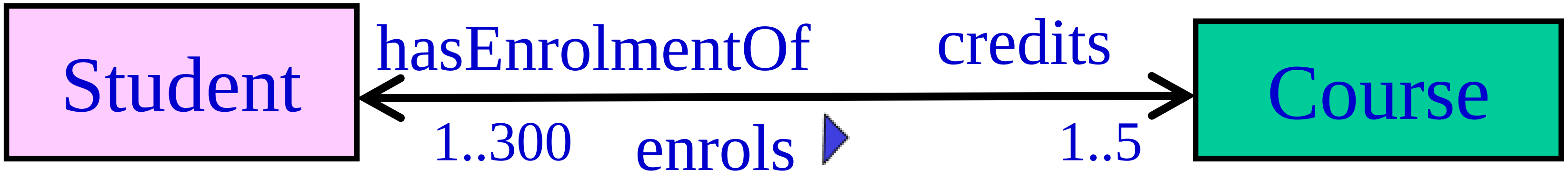
```
public class Member{
private Book book;
public issueBook(Book
  abook){
    setBook(abook);
    abook.setLender(this);
    }
    setBook(Book abook){
    book=abook;
  }
  ...
}
```



```
public class Book{
private Member member;
setLender(Member aLender){
    member=aLender;
  }
  ...
}
```



Association Implementation: Example 2

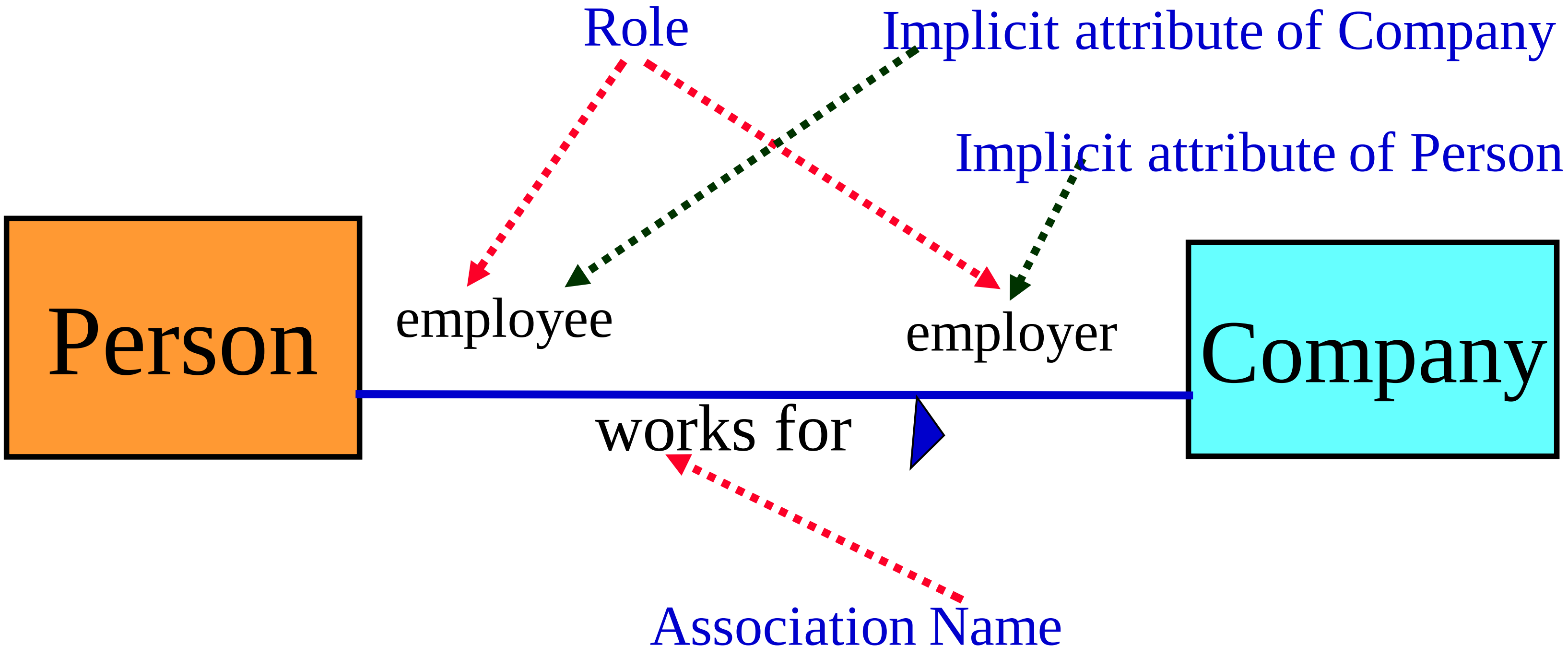


```
Class Student {
    Course credits[5];
    …
}
Class Course {
   Student hasEnrolmentOf[300];
   …
}
```

Observe the Navigation

Association Example 2

- A Person works for a Company.



Role

Implicit attribute of Company

Implicit attribute of Person

Person

employee

employer

Company

works for

Association Name

Observe: Implicit bidirectional navigation

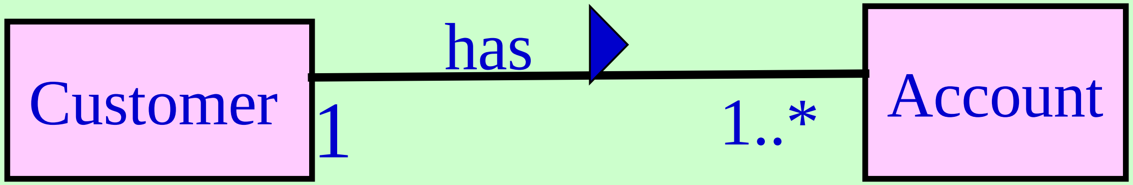
Implementation?

Example 2 Implementation

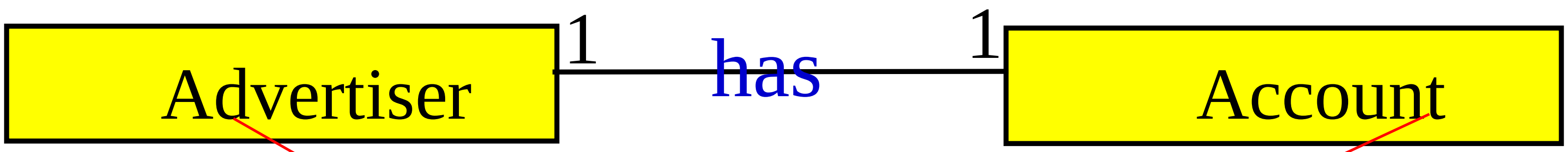
```
 public class Company {
      private Person employee;
      public void setCompany(Person p){ employee=p;}
 }
public class Person {
  private Company employer;
  public Company getWorksFor() {
     return employer;
  }
 public void setWorksFor(Company c) {
     employer=c;
  }
```

Code for Association Multiplicity

```
class Customer{

        private ArrayList <Account> accounts =
                            new ArrayList<Account>();

   public Customer() {

       Account defaultAccount = new Account();

         accounts.add(defaultAccount);

    }

}
```



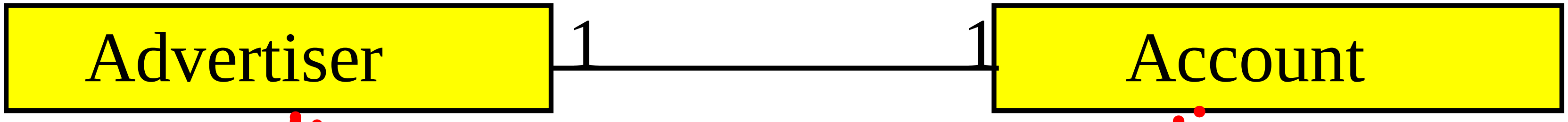
1-1 Association Example 3



```
public class Advertiser {
private Account account;
public Advertiser() {
      account = new Account(this);
}
public Account getAccount() {
      return account;
}
}
```

Now, Write code for

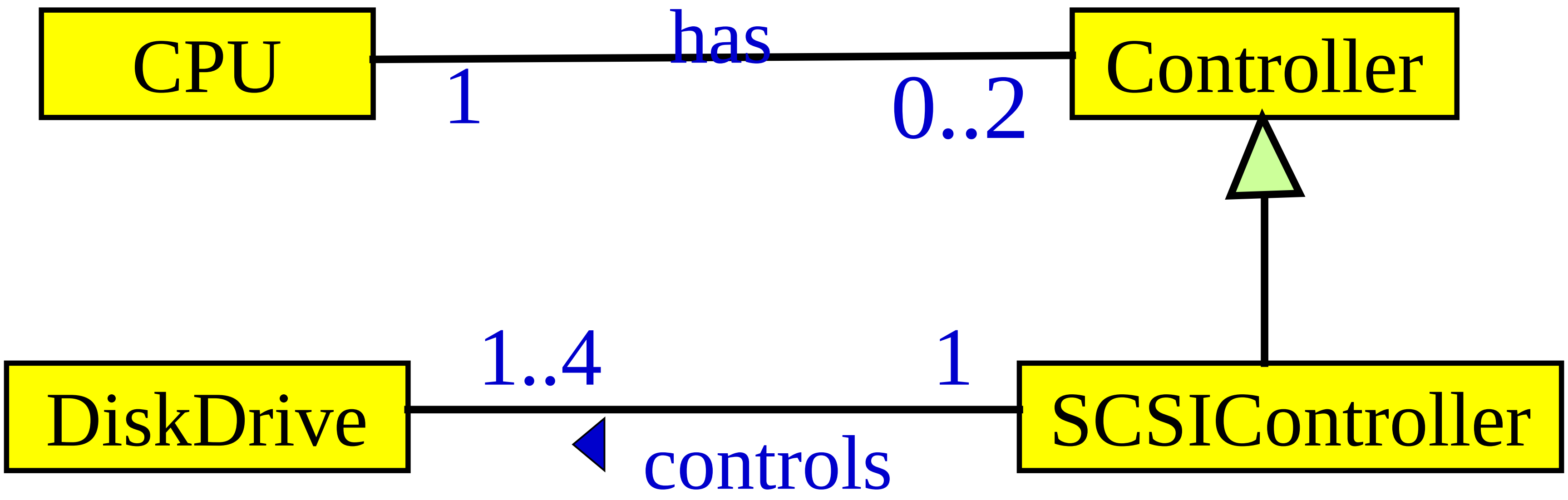
1-1 Association



```
public class Advertiser {
   private Account account;
   public Advertiser() {
      account = new
   Account(this);
   }
   public Account
   getAccount() {
      return account;
```

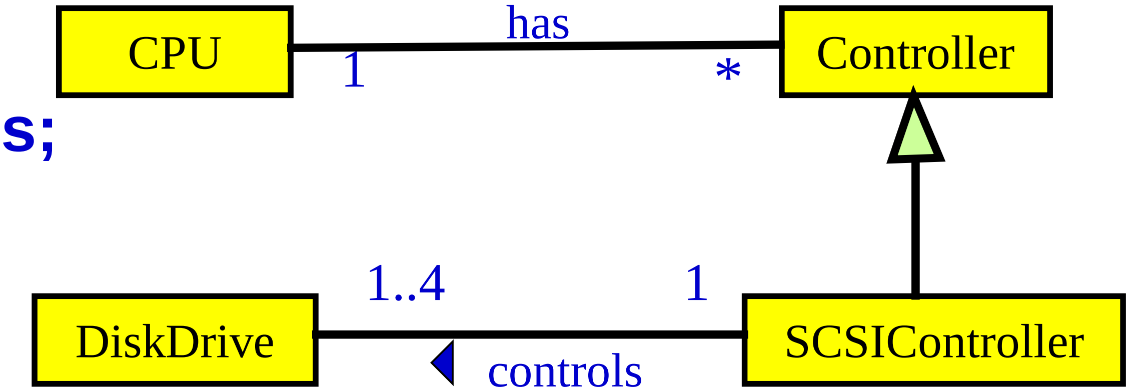
```
public class Account {
      private Advertiser owner;
   publicAccount(Advertiser
   owner) {
      this.owner = owner;
   }
   public Advertiser getOwner()
   {
      return owner;
   }
```

Quiz: Read and understand UML class diagram



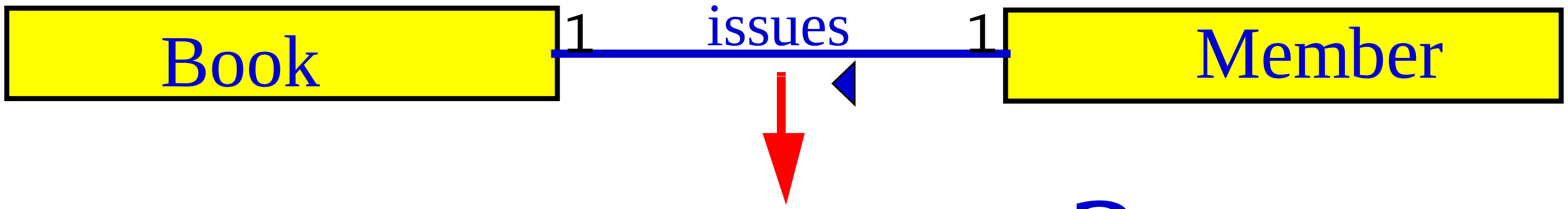
- 1 CPU has 0 to two Controllers
- 1-4 DiskDrives controlled by 1 SCSIController
- SCSIController is a (specialized) Controller

Java Code?



```
class CPU {
   Controller [ ] myCtlrs;
}
class Controller {
   CPU myCPU;
}
class SCSIController extends Controller {
   DiskDrive [ ] myDrives = new DiskDrive[4];
}
Class DiskDrive {
    SCSIController mySCSI;
}
```

Quiz 1: Write Java Code



Book

1

issues

1

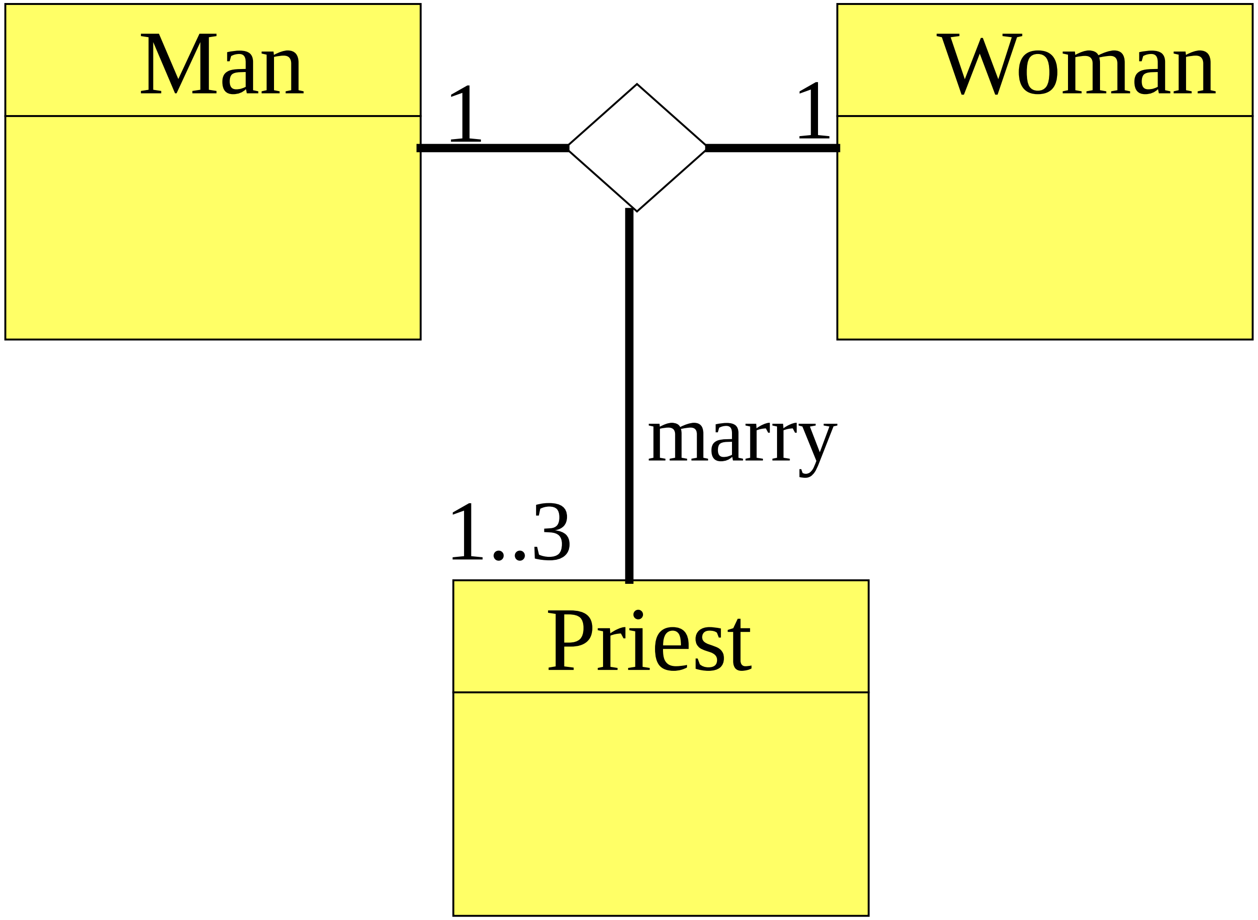
Member

Source code? ? ?

Quiz 2: Draw UML Class Diagram

```
public class TreeMap {
  TreeMapNode topNode = null;
  public void add(Comparable key, Object value)
{…}
  public Object get(Comparable key) {…}
}

class TreeMapNode {
  private Comparable itsKey;
  private Object itsValue;
  private TreeMapNode nodes[] = new
TreeMapNode[2];

  public TreeMapNode(Comparable key, Object
value) {…}
```

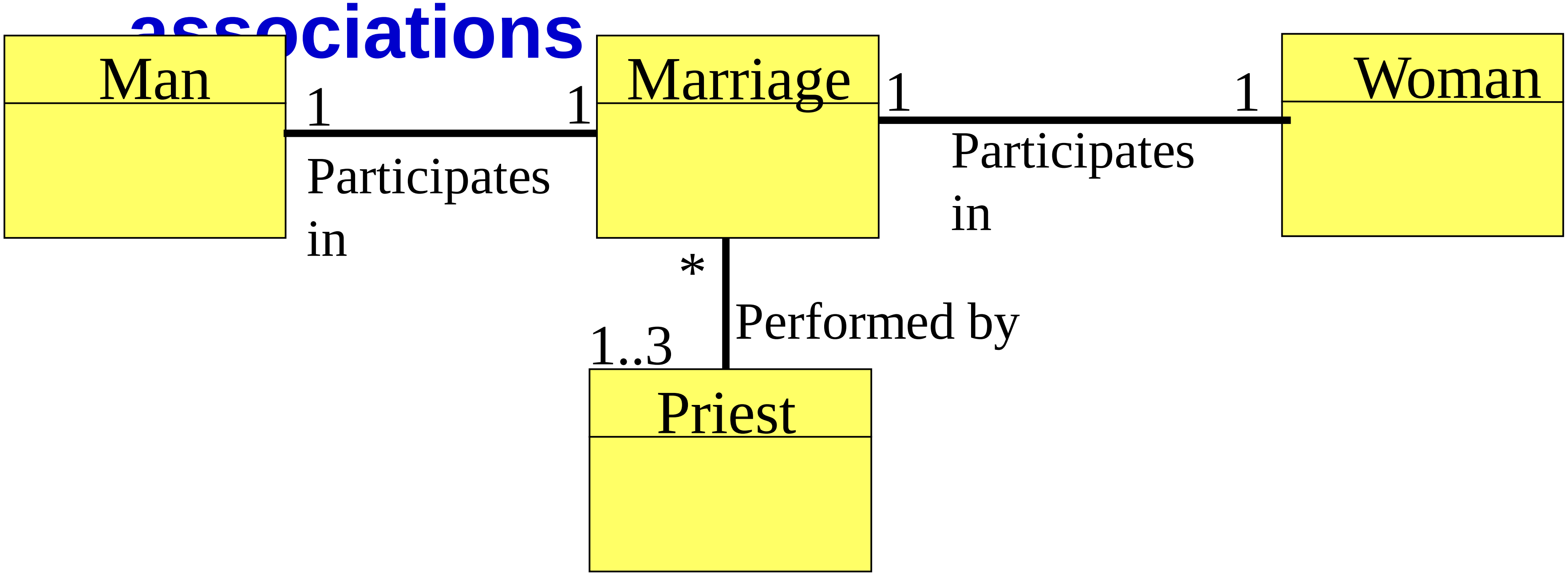
Ternary Association

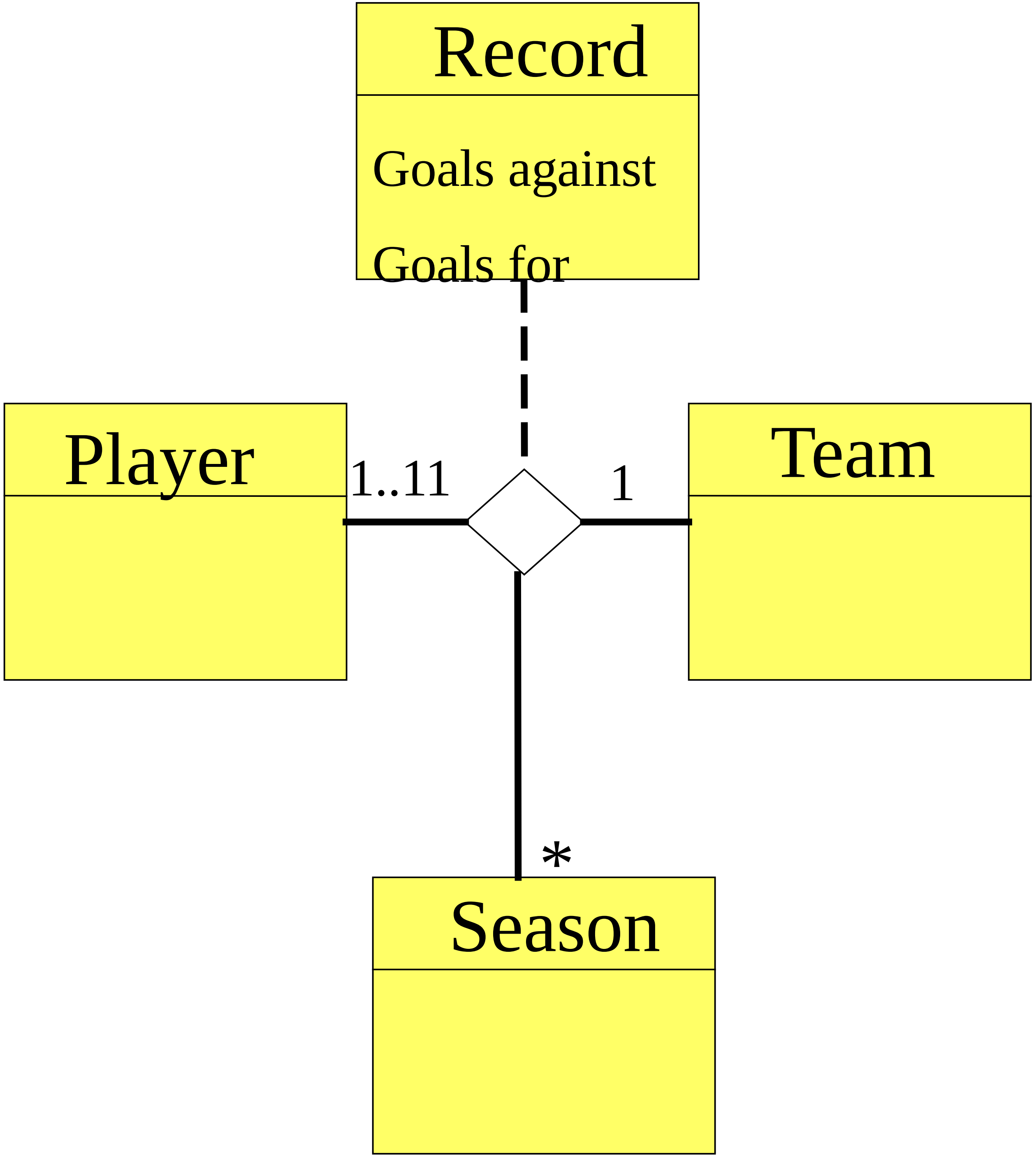


and we can add more classes to the diamond…

Implementation of Ternary Association

- There are several ways in which ternary association can be implemented.
  - One is to decompose it to a set of binary associations





Record

Goals against

Goals for

Player

1..11

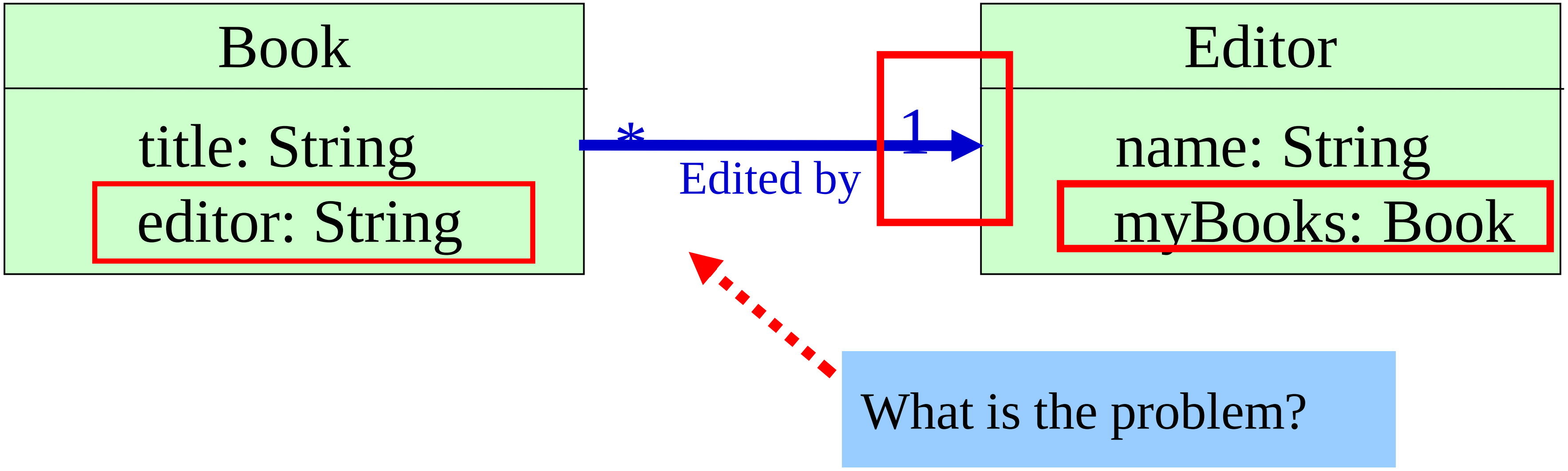
1

Team

*

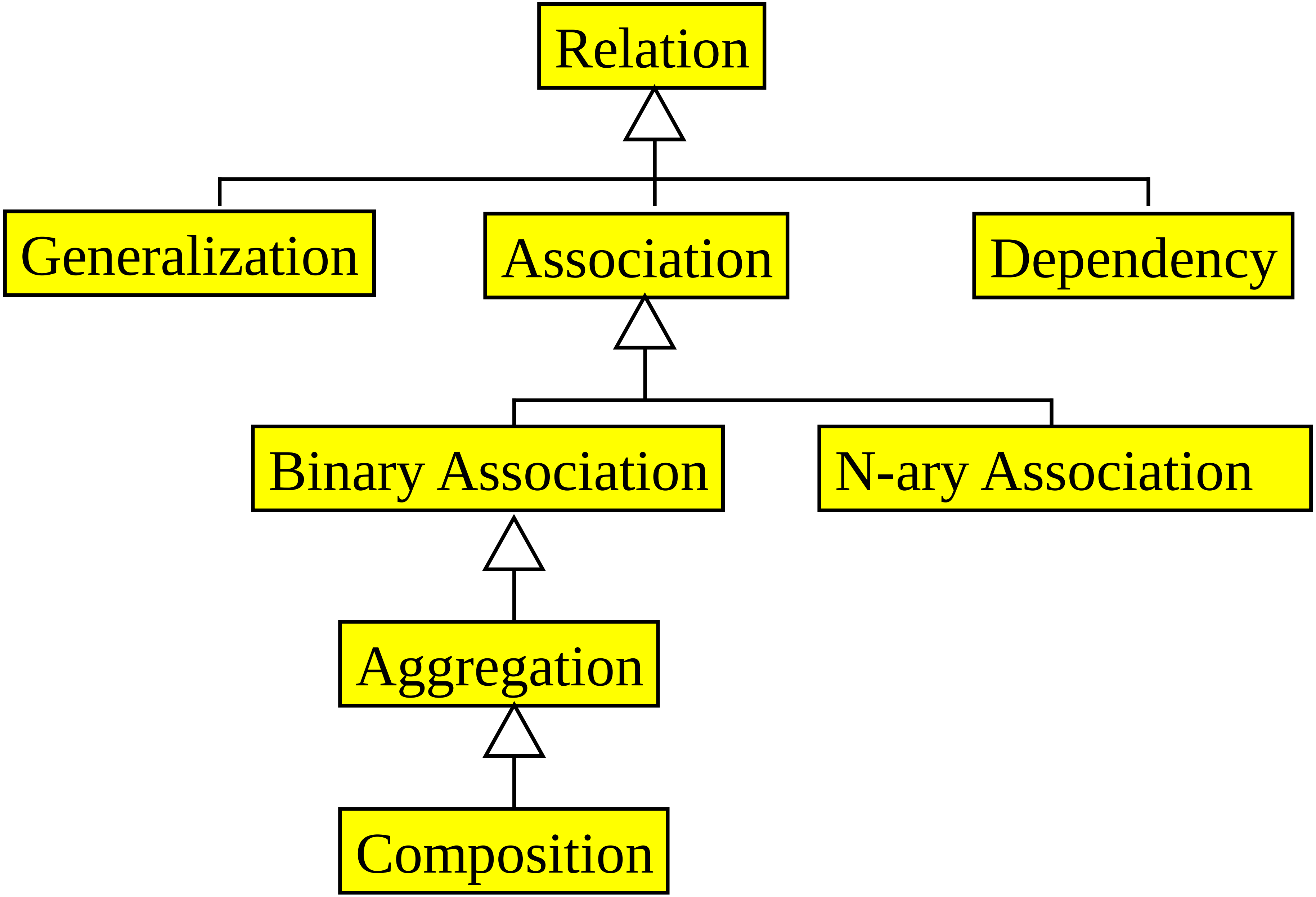
Season

Association Quiz



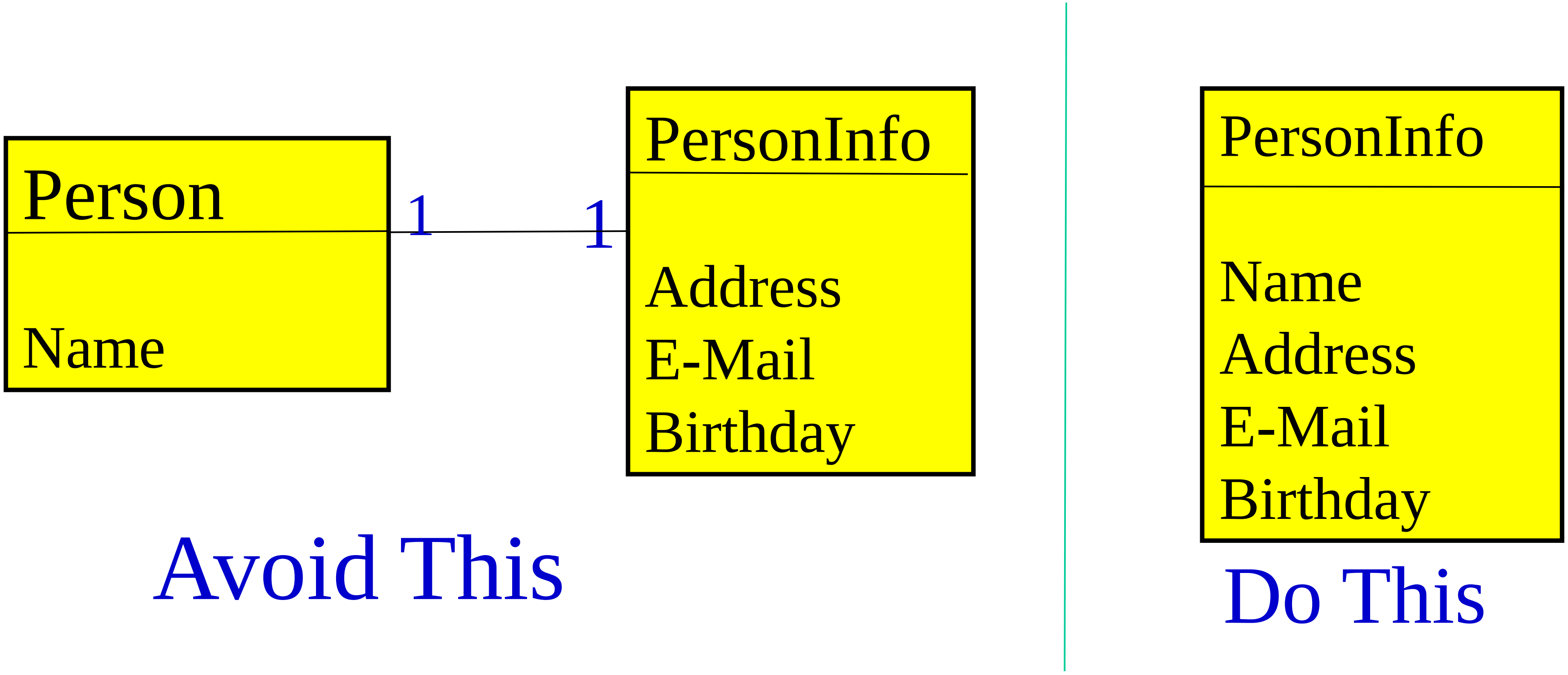
- **Association denoted by symbol not attributes.**
- **Implementation (pointers, arrays, vectors, ids etc) is left to the detailed design phase.**
- **Wrong arrow type**

Types of Class Relationships

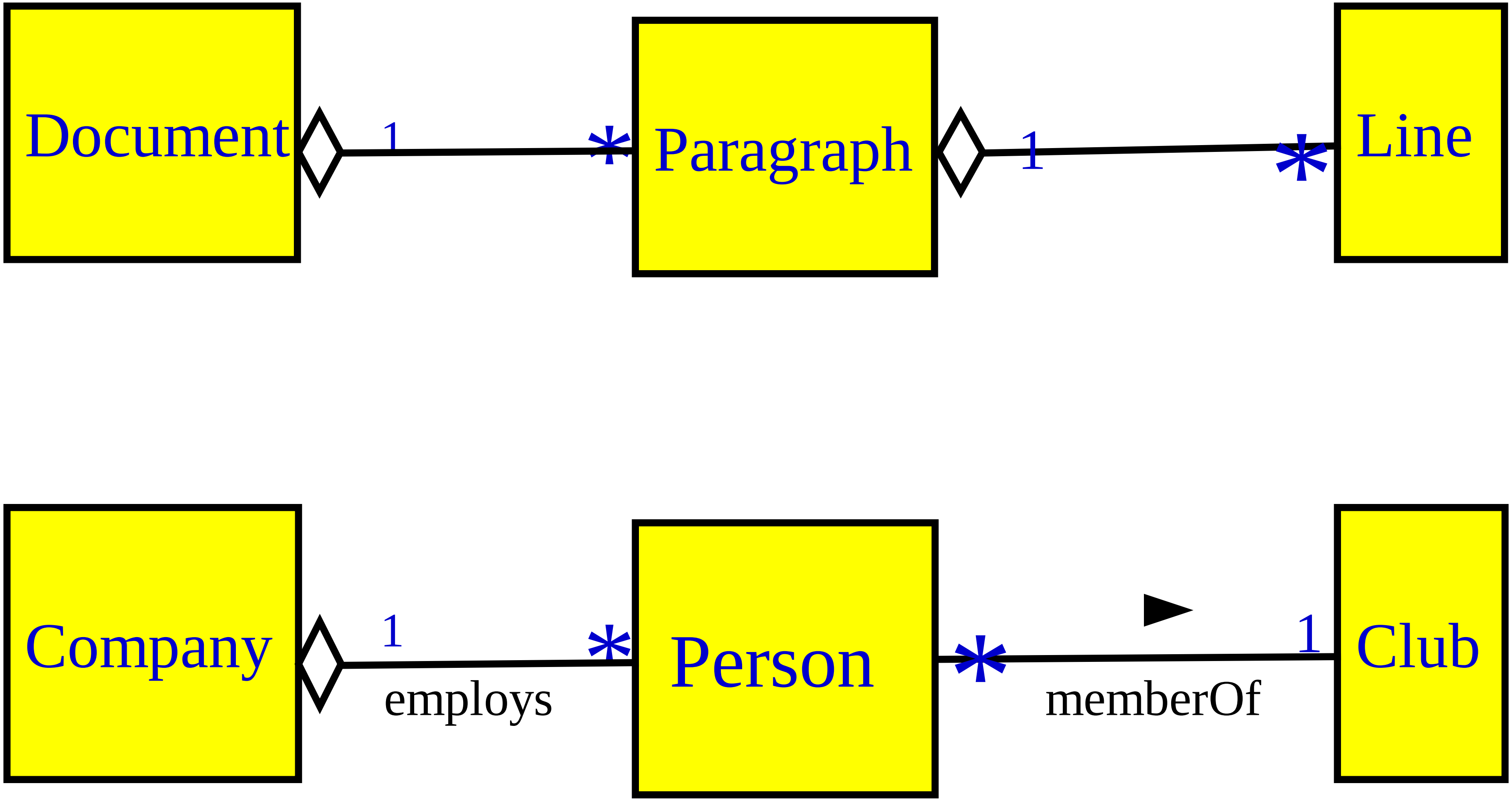


Overdoing Associations

- **Avoid unnecessary Associations**



Aggregation Relationship



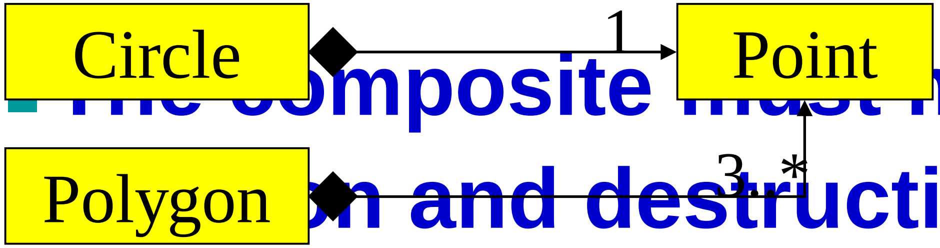
Aggregation

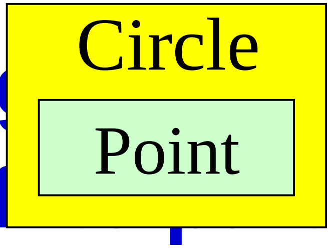
cont…

- An aggregate object contains other objects.
- Aggregation limited to **tree hierarchy**:
  - No circular inclusion relation.

Composition

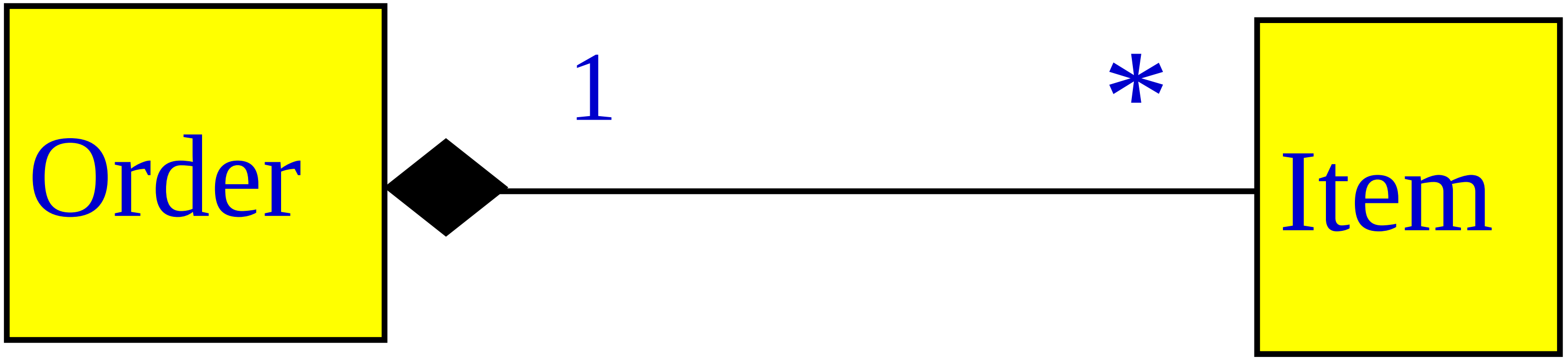
- A stronger form of aggregation
  - The whole is the sole owner of its part.
    - A component can belong to only one whole
  - The life time of the part is dependent upon the whole.
    - The composite must manag
    on and destruction of s.





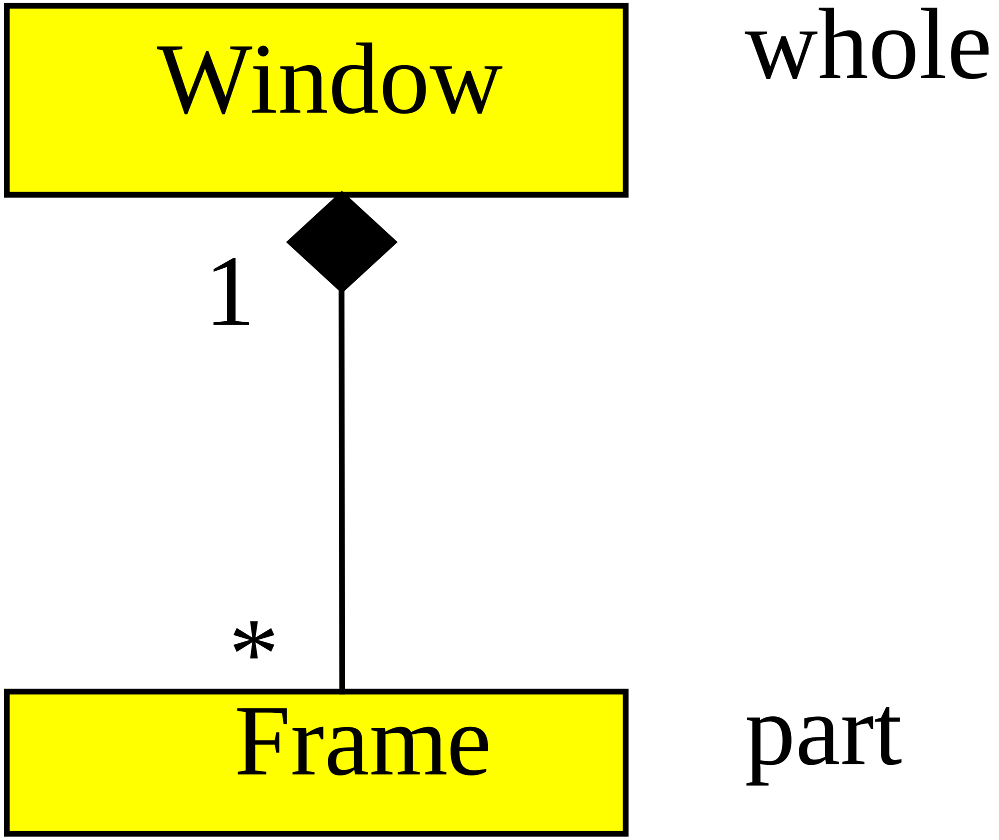
Composition Relationship

- Life of item is same as the order



Composition

- An object may be a part of ONLY one composite at a time.
  - Whole is responsible for the disposition of its parts.



Window

whole

1

*

Frame

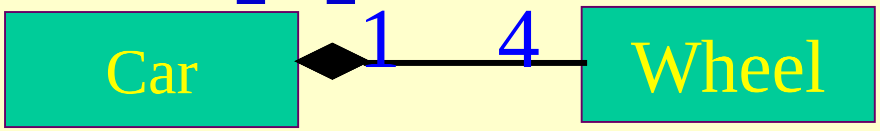
part

Aggregation vs. Composition

- Composition:
  - Composite and components have the same life.
- Aggregation:
  - Lifelines are different.
- Consider an order object:
  - Aggregation: If order items can be changed or deleted after placing the order.

Implementing Composition

```
public class Car{
  private Wheel wheels[4];
  public Car (){
        wheels[0] = new Wheel();
        wheels[1] = new Wheel();;
           wheels[2] = new Wheel();;
        wheels[3] = new Wheel();;
      }
```



Summary

- Focus: Class diagrams
  - Contents of a class
  - Relationship between classes
- You should be able to
  - Draw UML class diagram given code
  - Write code given UML class diagram