Association, Aggregation, and Composition

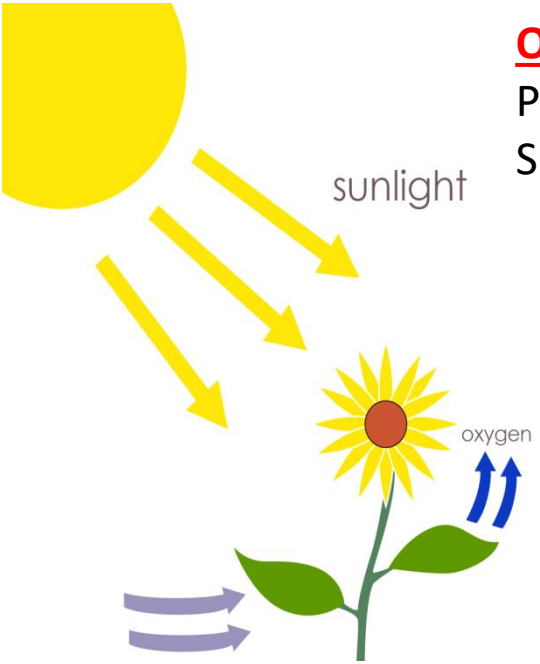
Department of Software Engineering

National University of Computer & Emerging Sciences, Islamabad Campus

Part 1
Identifying relationships and their types

Identifying objects

- **Identifying** objects / classes in real life
- How is this identification possible?



Objects

Plant (Flower, Leaves)
Sunlight

Objects

Car (Body, Steering wheel, tires, engine)
Driver

Interaction between objects

Plant Example

- Plant **is composed** of leaves and flowers
- Leaves **interact** with the sunlight (even if you don't know how, exactly),
- Flower's **existence depends on** the plant.

Car Example

- Car **is composed** of body, steering wheel, tires, engine etc.
- Driver **interacts** with the car

Relationship b/w objects

- **What** is a **relationship** between **objects**?
  - Whenever an object **interacts** with another…
- In real life
  - **Object** in **real life** have **relationships** with each other
  - Only by understanding these we **understand** the **behavior** of these **objects**
- In programming
  - **Objects** also have **relationship**, **hierarchies** among them
  - Understanding these relationships help in writing **reusable** and **extensible** code – **HOW**?

Identifying relationships b/w objects

- In case of real life we identify these relationships with experience and years of training
- How can we identify relationships between programming objects?
  - Same as in real life!
  - Class Responsibility Collaborator (CRC) Cards (CRC)

CRC Cards

- CRC card is divided into three sections: **Class Name**, **Responsibilities**, and **Collaborators**
  - **Class** represents collection of similar objects
  - **Object** is a person, thing, place, event, concept, screen or report
  - **Responsibility** – is anything that **a class knows** or **does**
  - **Collaborator** – when **a class doesn't have information** to fulfill a responsibility it needs to collaborate

Sample CRC Card

Class Name	
Responsibilities	**Collaborators**

CRC Modelling - example

Inventory Item	
Item number Name Description Unit Price Give price	

Order	
Order number Date ordered Date shipped Order items Calculate order total Print invoice Cancel	Order Item Customer

Order Item	
Quantity Inventory item Calculate total	Inventory item

Customer	
Name Phone number Customer number Make order Cancel order Make payment	Order Surface address

Surface Address	
Street City State Zip Print label	

CRC Cards - Example

- CRC cards helped in identifying relationships:
  - Order item – Inventory item
  - Order – Order item
  - Order – Customer
  - Customer – Street address
  - Customer – Order
- How are these converted into interactions between programming objects?

Relationship type words

- There are special "**relationship type**" words to describe these relationships. These are:
  - part-of
  - has-a
  - uses-a
  - depends-on
  - member-of
  - is-a

Can we use these words to describe relationships we identified?

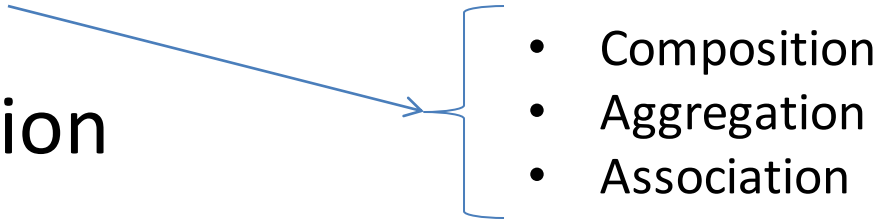
How are these words useful in context of C++ classes?

Other examples of relationship words

- For example:
  - a square "**is-a**" shape
  - a car "**has-a**" steering wheel
  - a computer programmer "**uses-a**" keyboard
  - a flower "**depends-on**" a bee for pollination
  - a student is a "**member-of**" a class
  - Your brain exists as "**part-of**" you
- All of these **relation types** have useful analogies in **C++.**

Types of Relationships

- Association
- Generalization

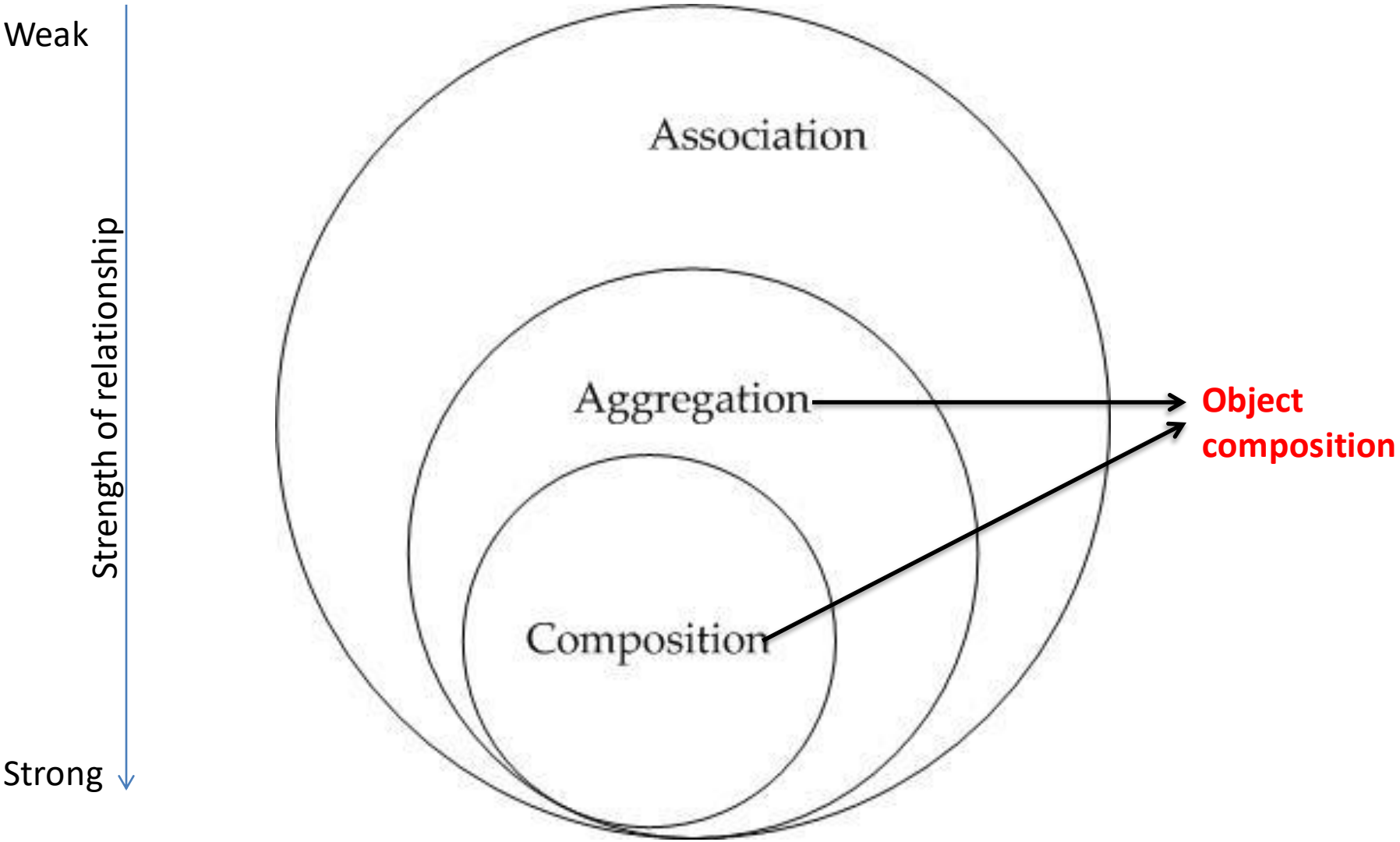


and

In these two objects are not really related!

- Dependency
- Realization

Relationships between Objects



Part 2
Composition

Object composition

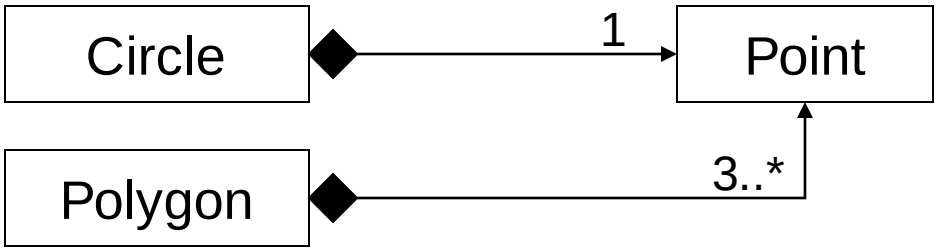
- Process of building **complex objects** from **simpler ones** is called **object composition**
- This relationship is described using "**has-a**" word
  - Car – engine, steering wheel, frame etc.
  - Computer – CPU, motherboard, memory etc.
- Complex part is called the whole
- Simpler object is called the part

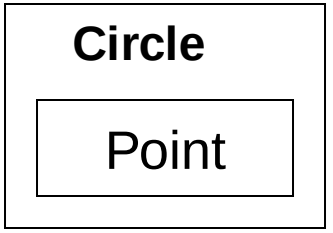
Types of object composition

- Two types
  - Composition
  - Aggregation

Composition

- Composition models "**part-of**" relationships
- These relationships are **part-whole** relationships
- Composition is often used to model **physical relationships**, where one object is physically contained inside another.
  - Heart is **part-of** body
  - Fish are **part-of** pond





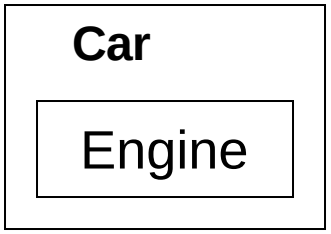
Composition tests

- The **part** (member) is part of the object (class)
- The **part** (member) can only belong to **one object** (class) at a time
- The **part** (member) has its **existence** managed **by the object** (class)
- The **part** (member) does not know about the **existence of the object** (class) - **Directional**

Fraction Class (Example)

```
class Fraction
{
    private:
        int c_num;
        int c_den;
    public:
        Fraction(int n=0, int d=1): c_num{n}, c_den{d}
        {}
};
```

Engine is a part-of Car (Example)



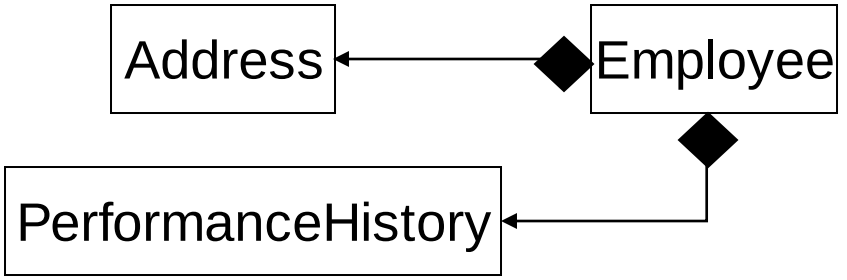

```
class Car
{
    public:
        Car(char* e_No){
            cout << "Car created" << endl;
            ptr_engine = new Engine(e_No); //Engine created
        }
        void disp(){
            cout << ptr_engine->getEngineNumber() << endl;
        }
        ~Car() {
            cout << "\nCar destroyed" << endl;
            delete ptr_engine; //engine destroyed/deleted
        }
    private:
        Engine* ptr_engine;
};
```

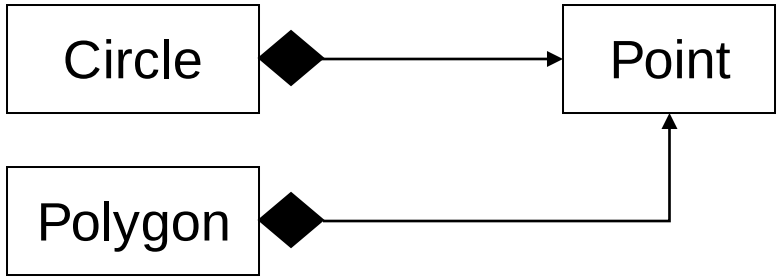
Composition variants

- Whole **creates** the parts and **destroy** them **BUT** it can do it **indirectly** as well
  - **Deferring creation** of parts For example, a string class may not create a dynamic array of characters
  - Instead of creating part, whole can opt to **use a part** that has been **given to it as input**
  - Whole can **delegate destruction** of its parts (e.g. to a garbage collection routine).
- The key point here is that the composition should manage its parts.

Composition and subclasses

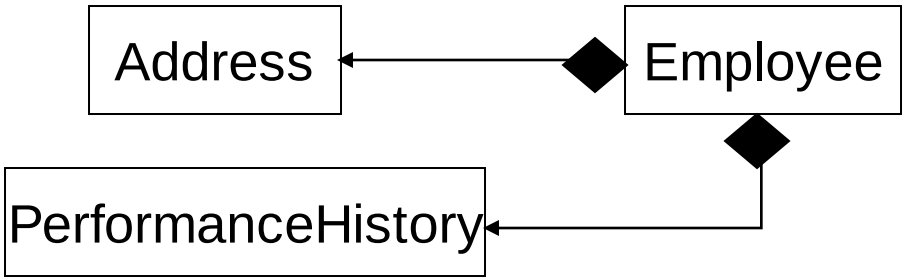
- When/why create a subclass instead of direct implementation of a feature?
  - Car (whole) Engine (part) example
- Composition → subclass
  - **Each individual class** should be focused on performing **one task** (simple and straight forward)
  - Each subclass can be **self-contained**, which makes them **reusable**.
  - The **parent class** can focus only on **coordinating the data flow** between the subclasses.





Composition and subclasses

- **Subclass** or **direct implementation**?
  - One class one task
  - Task can be
    - storage and manipulation
    - coordination



Composition - recap

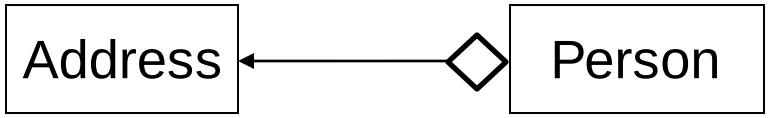
- Relationship between objects
  - Association
  - Object composition (**Composition** and **Aggregation**)
- **Object composition** is the process of **creating complex objects** from **simpler one**.
- Composition (models **part-of** relationship)
  - Whole is responsible for **existence** of part

Part 3
Aggregation

Aggregation

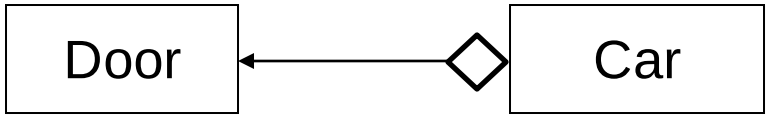
- An **aggregation** is also a **part-whole** relationship
- It models **has-a** relationship
- Similar to composition
  - The **parts** are **contained** within the **whole**
  - It is also a **unidirectional** relationship
- Unlike composition
  - Parts **can belong to more than one** object at a time
  - Whole **is not responsible for the existence** and lifespan of the parts

Aggregation



Singular part

- Every person has an address.
- One address can belong to more than one person at a time
- Address existed before the person starting living at the address
- Whole knows of existence (person knows)
- Part doesn't know about the whole



Multiplicative parts

- A car door is part of the car.
- Door belongs to the car,
- It can belong to other things as well, like the body of the car.
- The car is not responsible for the creation or destruction of the door.
- Whole knows about existence
- Part doesn't know about the whole

Aggregation tests

- The part (member) **is part of** the object (class)
- The part (member) **can belong to more than one object** (class) at a time
- The part (member) **does not** have its **existence** managed by the object (class)
- The part (member) **does not know** about the existence of the object (class)

Implementing aggregation VS composition

- Aggregation
  - **Parts** are **added** as **references** or **pointers**
  - **Whole** is **not responsible** for creation and deletion
  - Whole takes the objects it is going to point to as: 1) **constructor parameters**; 2) **parts are added later via access functions**
  - Parts exists **outside the scope** of whole
- Composition
  - **Parts** are **added** as **normal variables** (or pointers)
  - **Whole** is **responsible** for **creation** and **deletion**

Examples

Composition

```
class Part{
    //class implementation
};

class Whole {
    private:
        Part* p; //can be normal variable
    public:
        Whole() {
            this->p = new Part();
        }
        ~Whole(){
            delete p;
        }
};

int main()
{
    Whole w;
}
```

Aggregation

```
class Part{
    //class implementation
};

class Whole {
    private:
        Part* p;
    public:
        Whole(Part *p) {
            this->p = p;
        }
};

int main()
{
    Part* p = new Part();
    Whole w(p);
}
```

Person has an Address - Example

```
class Address
{
    private:
        int h_No; //house no
        int st_No;  //street no
        string sector; //sector
        string city; //store city
    public:
        //parameterized constructor
        Address(int h, int s, const string& sec, const string& c)
        { }

};
```

Person has an Address - Example

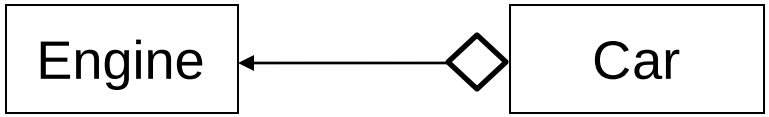
```
class Person
{
    private:
        string p_name; //person name

        //it will get reference to address object (part)
        const Address& p_address; // A person can live at only one address (here)

    public:
        //parameterized constructor
        Person(const string& s, const Address& address) : p_name{s}, p_address{ address }
        { }

        //display person details
        void disp_Person() const{
            cout << "Name: " << p_name << "; ";
            p_address.disp_Address();
        }
};
```

Person has an Address - Example

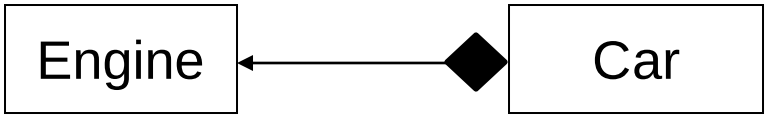
```
int main()
{
    //part object created
    Address part_Object( 12, 3, "G-20", "Islamabad" );

    //whole object created
    Person whole_Object("Random person", part_Object );

    whole_Object.disp_Person();


    return 0;
}
```

Aggregation or Composition

- When to do what?



Repair shop software



Car performance software

Implement the simplest relationship that meets your needs!!!

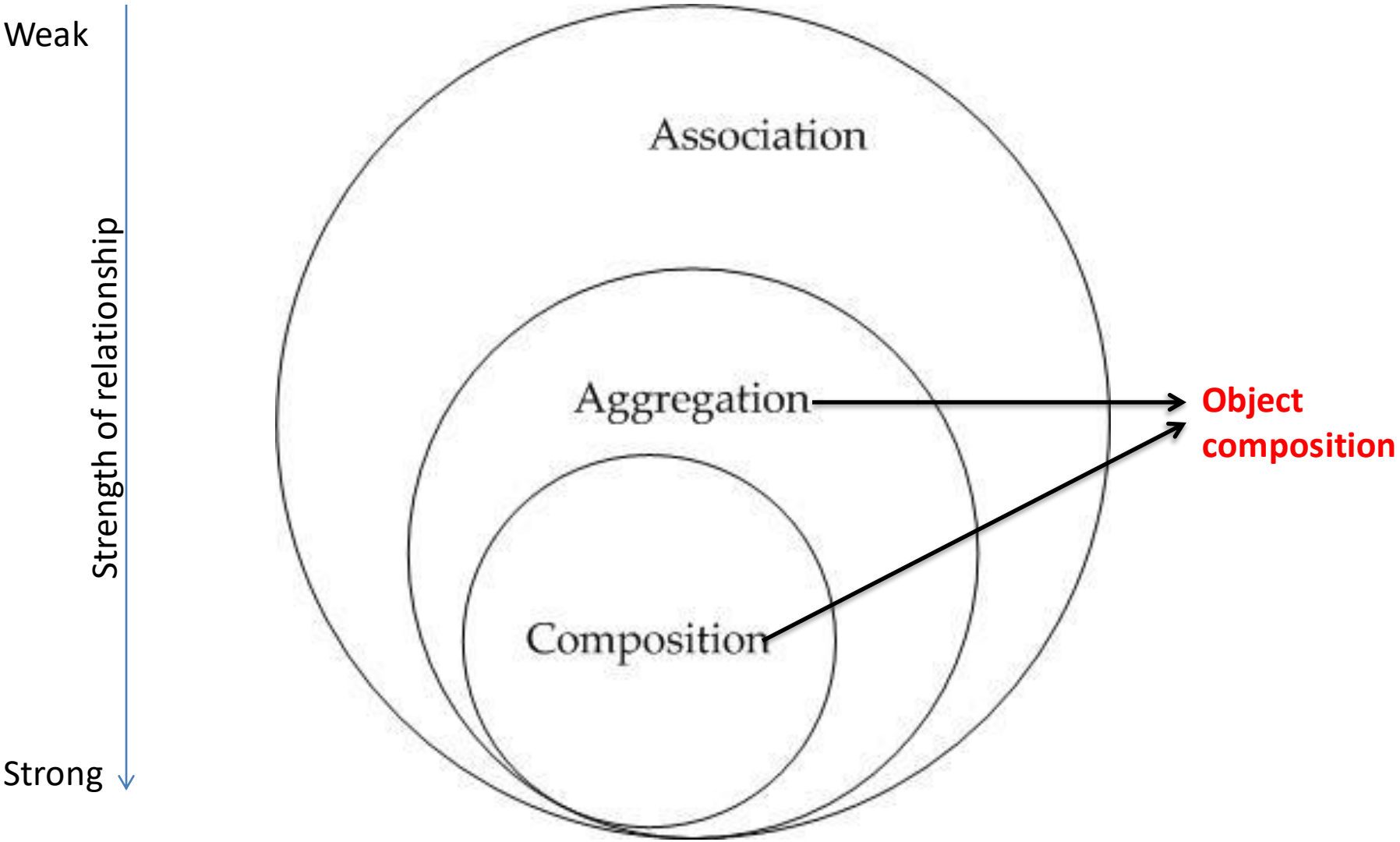
Not the one that seems like it would fit best in a real-life context.

Aggregation/Composition - recap

- Object composition
  - Composition
  - Aggregation
- Used to model relationships where a whole is built from one or more parts

Part 4
Association

Relationships between Objects

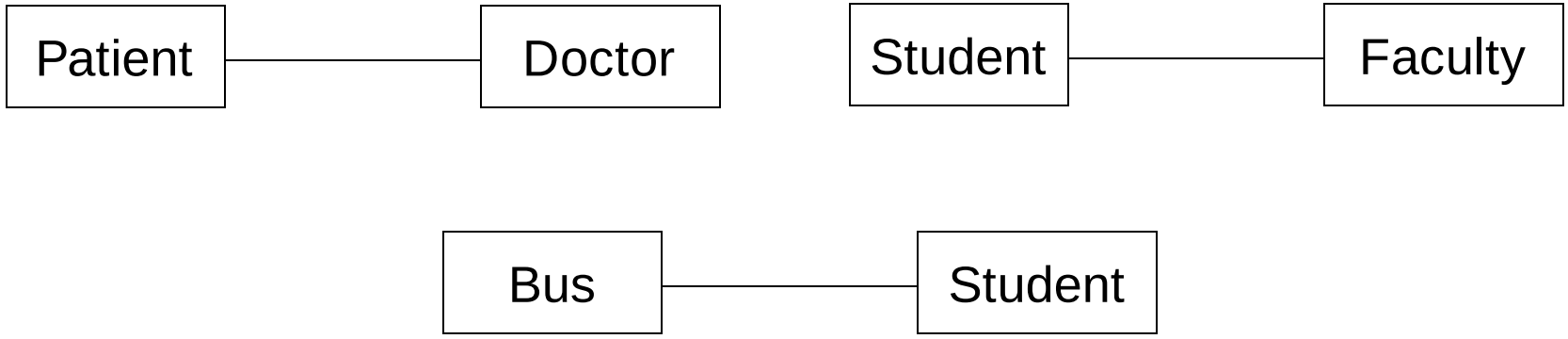


Association

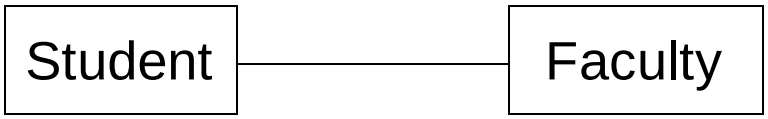
- A **weaker** type of relationship
- Two otherwise **unrelated objects**
- There is **no** implied **whole/part relationship**
- Models a **uses-a** relationship

Association

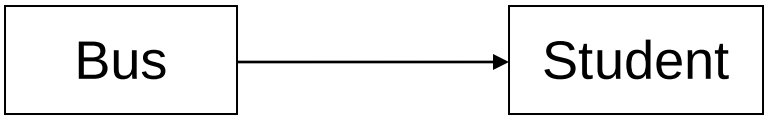
Composition	Aggregation	Association
Whole/Part relationship	Whole/Part relationship	**Associated object is unrelated**
Associated object can belong to only **one object**	Associated object can belong to multiple objects	Associated object can belong to multiple objects
Unidirectional	Unidirectional	**Bidirectional**



Association



- The teacher clearly has a relationship with his students and *vice versa*
- It's not a part/whole (object composition) relationship
- A teacher can see many students
- A student can see many teachers
- Neither of the object's lifespans are tied to the other.
- Bidirectional



- A student has a relationship with the route bus
- Its not a part/whole relationship
- Multiple students can be on a certain route
- Neither of the object's lifespans are tied to the other
- Unidirectional

Association tests

- The associated object (member) is otherwise **unrelated** to the object (class)
- The associated object (member) can belong to **more than one object** (class) at a time
- The associated object (member) **does not** have its **existence** managed by the object (class)
- The associated object (member) **may or may not know about the existence** of the object (class)

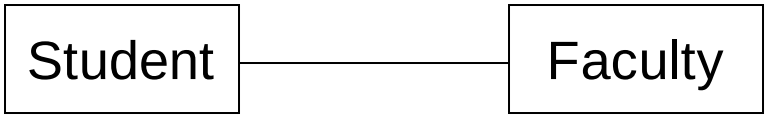
Implementing Association

- Associations are a **broad type** of relationship
- They can be implemented in many different ways
  - Associations are implemented **using pointers**

```
class A{//associated object
    private:
        //private members
    public:
        A(){
        }
};

class B{
    private:
        A* a;
    public:
        //constructors and member functions
};
```

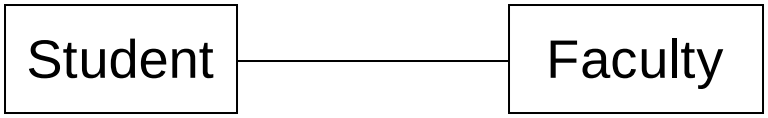
```
class A{//associated object
    private:
        B* b;
        //private members
    public:
        A(){
        }
};

class B{
    private:
        A* a;
    public:
        //constructors and member functions
};
```

Student-Faculty association - example



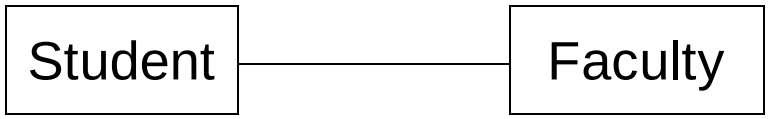

```
class Student
{
    private:
        string s_name;
        int n_faculty;
        Faculty* faculty[5]; //student can register with five faculty members only

        //this is kept private so student cannot add faculty instead faculty add student
        //addStudent function in Faculty class is public
        void addFaculty( Faculty& faculty);
    public:
        Student(const std::string& name): n_faculty{0}, s_name{ name }
        {}

        int getFacultys();

        void printFaculty();

        const std::string& getName() const { return s_name; }

        //because it need to access add faculty
        friend void Faculty::addStudent(Student& student);
};
```

Student-Faculty association - example




```
class Faculty
{
    private:
        string f_name;
        int n_students;//total number of students a faculty can have
        Student* student[10];//faculty can have no more than 10 students

    public:
        Faculty(const std::string& name) : n_students{0}, f_name{name}
        {}

        int getStudents(){
            return n_students;
        }

        const string& getName() const {
            return f_name;
        }

        void printStudents();
        void addStudent(Student& student);

};
```

Student-Faculty association - example



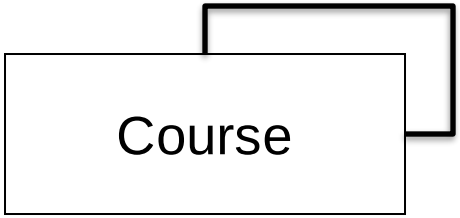

```
int main()
{
    Student s1("Good");
    Student s2("Better");
    Student s3("Best");

    Faculty fac_1("Bilal Khalid Dar");
    Faculty fac_1("Maheen Arshad");

    fac_1.addStudent(s1);
    fac_2.addStudent(s2);
    fac_2.addStudent(s1);

    s1.printFaculty();
    s3.printFaculty();
    fac_2.printStudent();

}
```

It was a bi-directional association

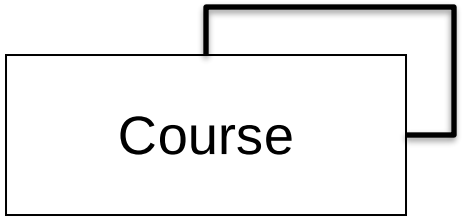
Remember to avoid bidirectional associations!!!

Reflexive association

- When **objects** have a **relationship** with **other objects** of the **same type**
  - Consider a course class

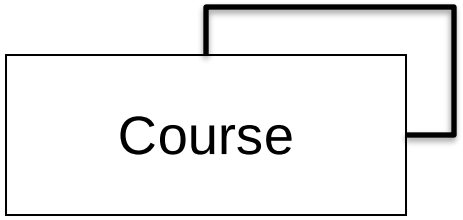


Course - Example




```
class Course
{
    public:
        string name;
        const Course *prereq;//reflexive association

    public:
        //constructor to initialize a course
        Course(const string &name, const Course *prereq = NULL)
        {
            this->name = name;
            this->prereq = prereq;
        }

        friend ostream& operator<< (ostream&, Course&);
};
```

Course - Example

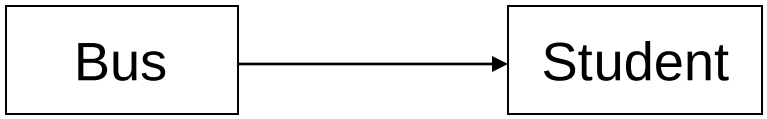



```
int main(){
    Course PF("Programming Fundamentals"); //course without a prereq

    Course OOP("Object Oriented Programming", &PF); //course with a prereq

    cout << PF;
    cout << OOP;

    return 0;
}
```

Beware! It can lead to a chain of associations!

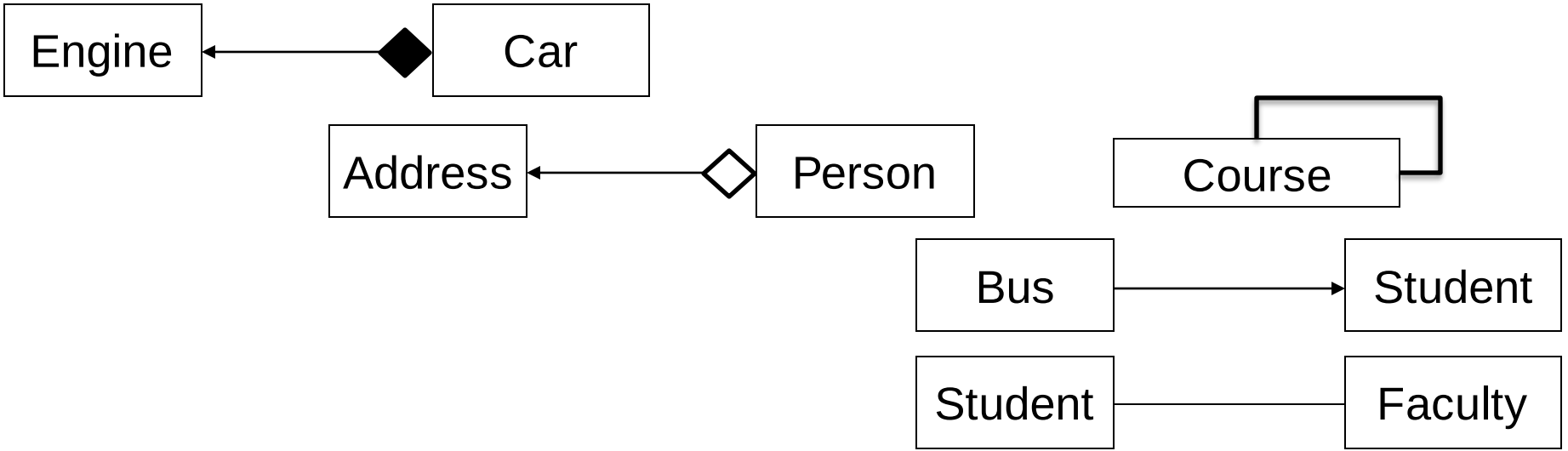
Indirect association

- In an **association** using **pointers/reference** is **not strictly required**.
  - **Any kind of data** that allows you to **link two objects** together suffices.



Composition vs Aggregation vs Association

Property	Composition	Aggregation	Association
Relationship type	Whole/part	Whole/part	Otherwise unrelated
Members can belong to multiple classes	No	Yes	Yes
Members existence managed by class	Yes	No	No
Directionality	Unidirectional	Unidirectional	Unidirectional or bidirectional
Relationship verb	Part-of	Has-a	Uses-a



Implement the following class diagram