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THE KNOWLEDGE UNIVERSITY

Sri Lanka Institute of Information Technology

Faculty of Computing

SE1020 - Object-Oriented Programming

Year 01 and Semester 02

Lecture 04

Relationships and Class Diagram

Recall. . .

- The SDLC in an Object-Oriented context
- More about Object-Oriented analysis
- Noun and verb analysis
- CRC cards
- Analysis classes

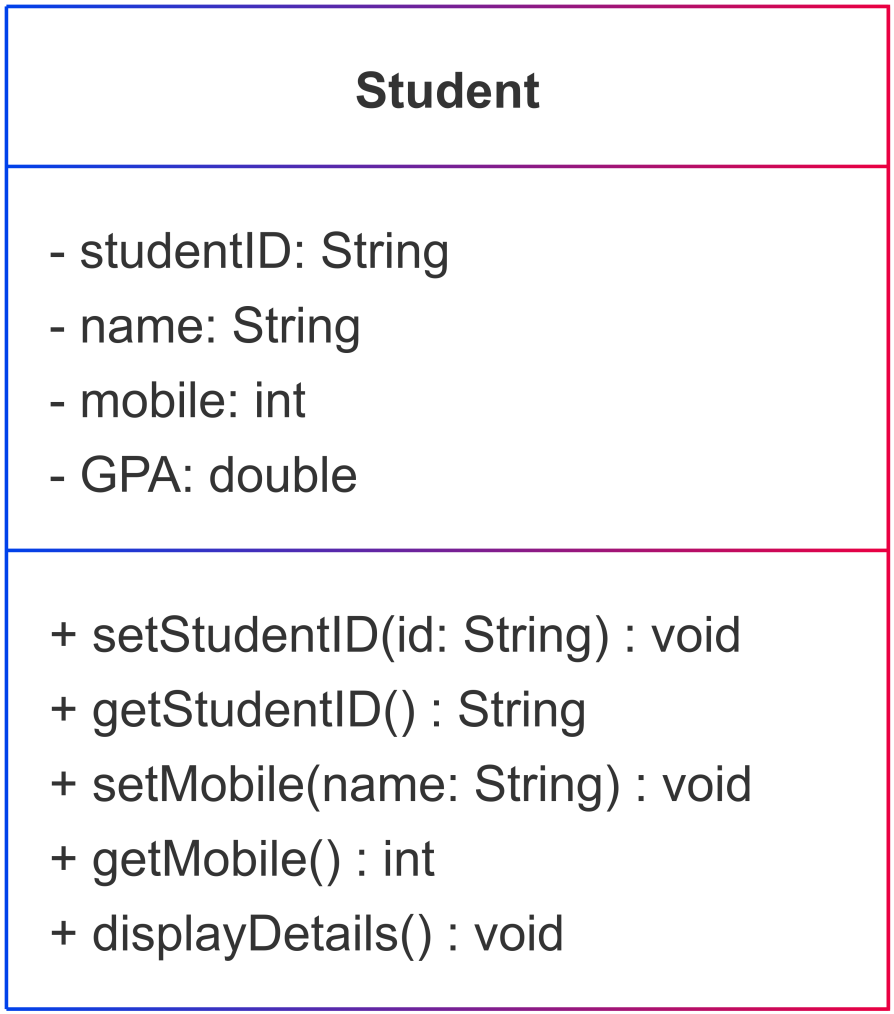
Lecture 04 - Part 01

Inheritance and Composition

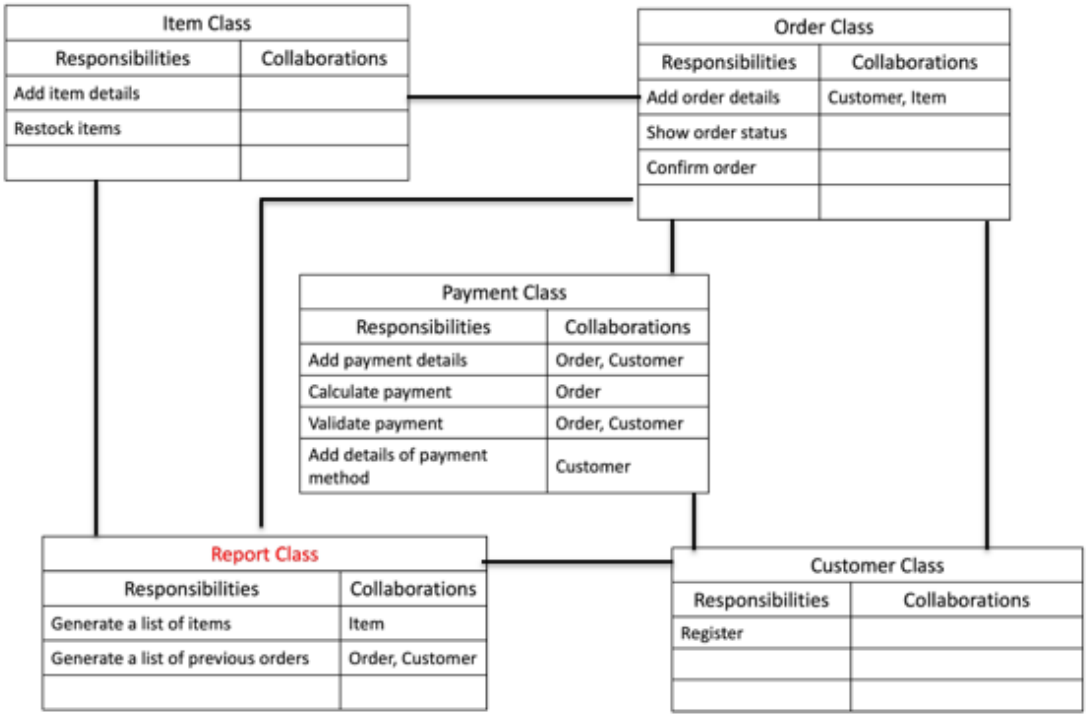
Learning Objectives

- Understand the different types of relationships between classes.
- Implement inheritance relationship in Java.
- Understand and apply Polymorphism in real-world examples
- Identify and implement composition relationship.

UML notation - Class

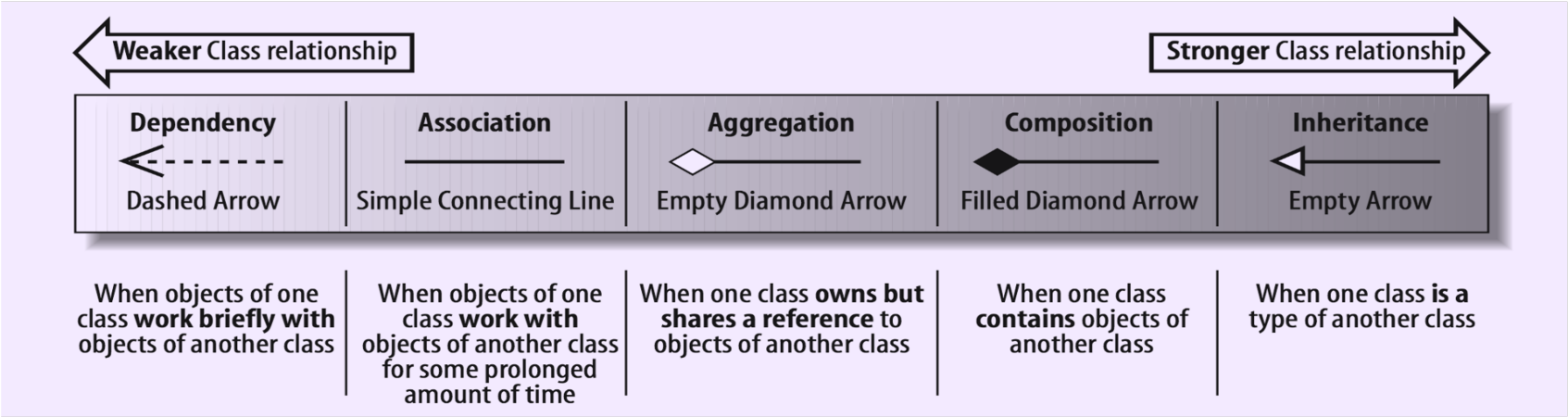


Relationships between classes



- We can see that there are relationships between classes when we draw CRC cards. We can divide all relationships into five different categories

Relationships between classes



uses | has a | ------Whole part relationships--------- | | is a

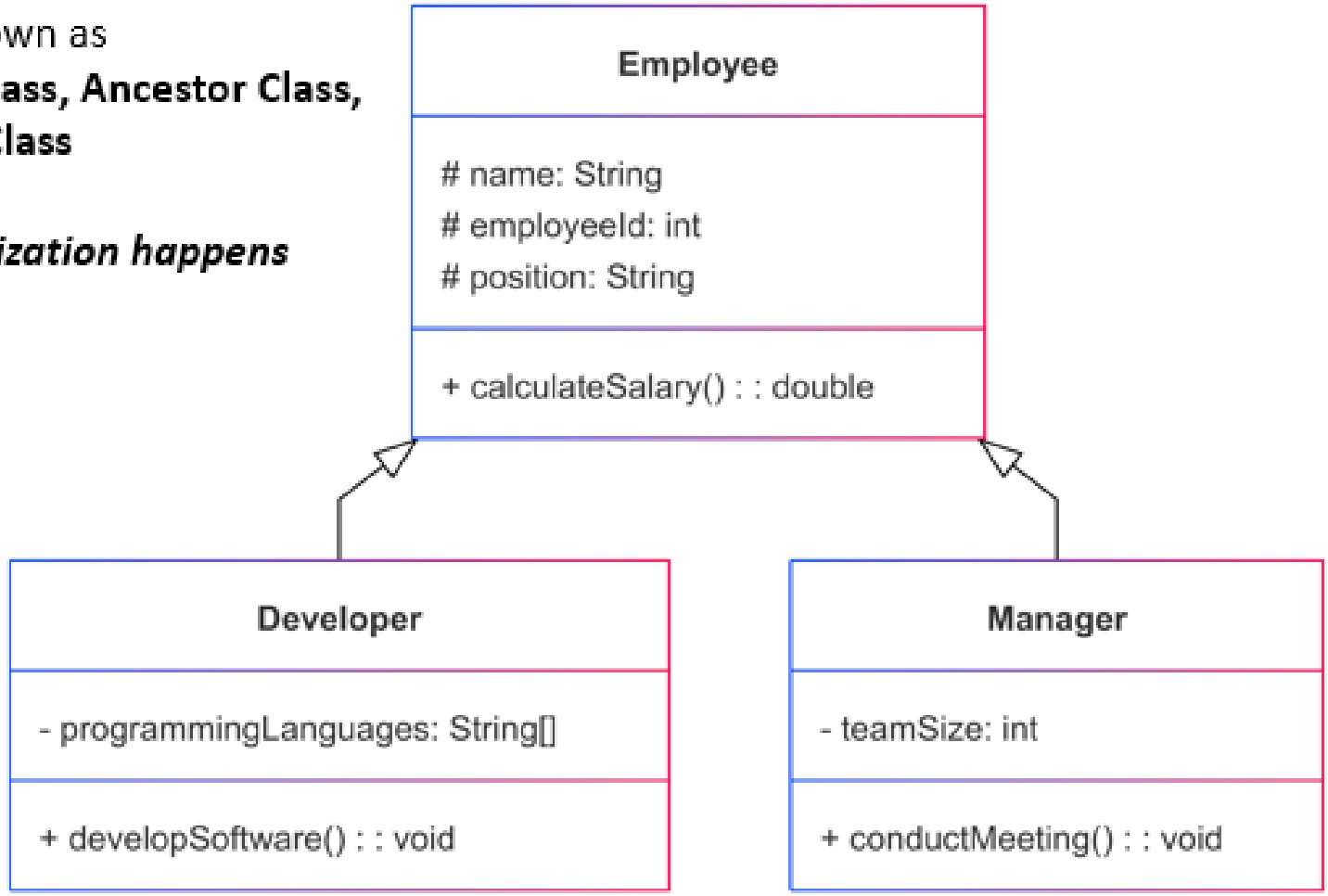
When objects of one class **works briefly** with with objects of another class	When objects of one class **works** with with objects of another class	When the parts **can** exist without The whole	When the parts **cannot** exist without the whole	When one **class is a type of** another class

Relationship Type 01: **Inheritance**

- Also Known as **Generalization**
- Inheritance represents an "**is-a-kind-of**" relationship in Java.
- It defines a relationship between a **general class (superclass/parent)** and a **more specific class (subclass/child)**.
- The subclass **inherits the properties and behaviors** (attributes and methods) of the superclass.
- In Java, inheritance is implemented using the **"extends"** keyword.
- Graphically, it is often represented with an empty arrow pointing **from the subclass to the superclass** in UML diagrams.

Also known as
Super Class, Ancestor Class, Parent Class

Generalization happens here



Also known as, **Sub Class, Descendant Class, Derived Class**

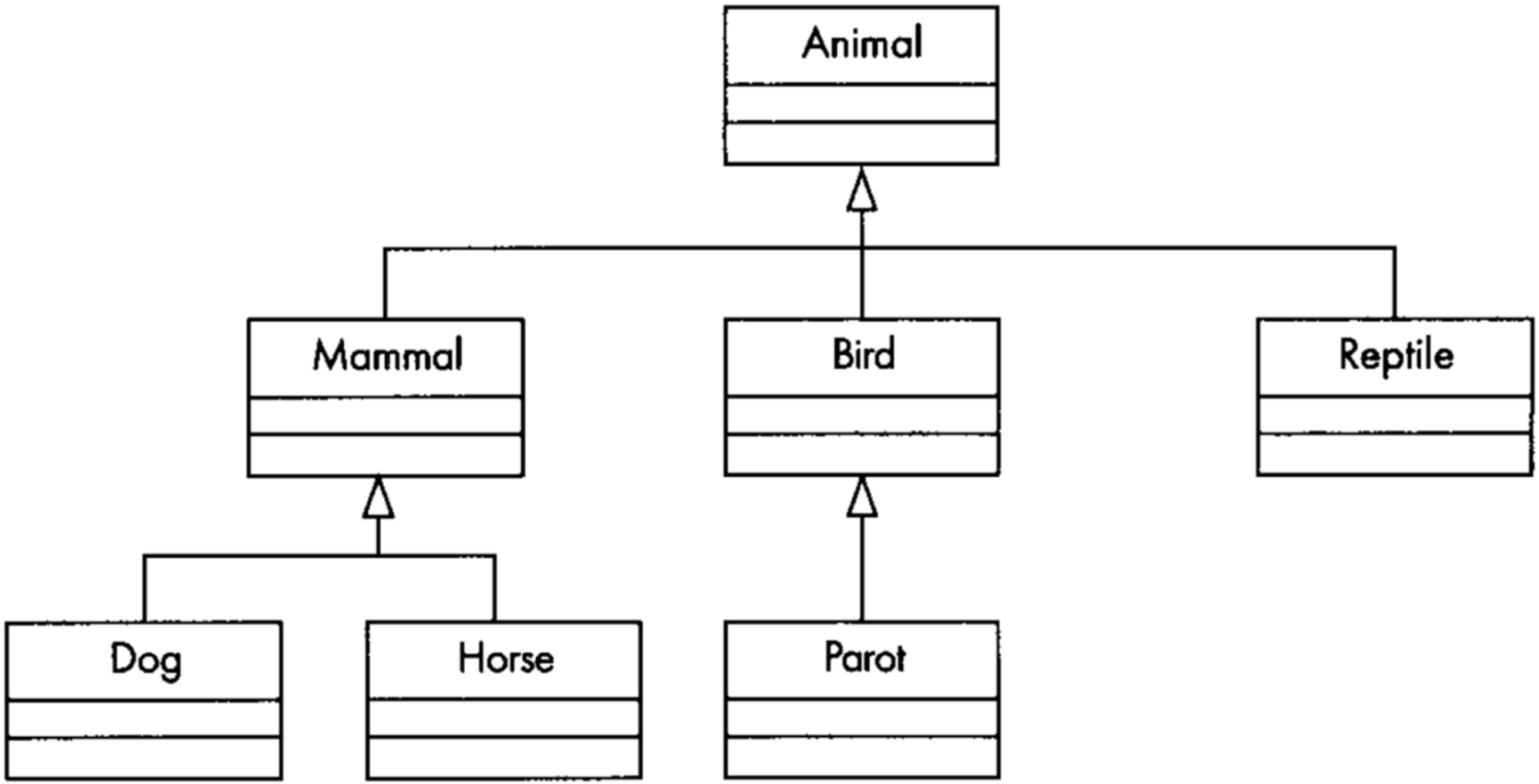
Specialization happens here

Inheritance

- **Super Class / Parent : Employee**
- **Sub Classes / Children : Manager, Developer**

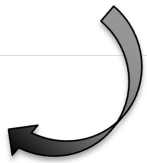
- Children (Manager and Developer) inherit the properties and methods of its parent class (Employee)
- The super-class (Employee class) is a generalization of the sub-class (Manager class).
- The sub-class (Manager class) is a specialization of the super-class (Employee class) .

Real World Example: Inheritance



Implementing Inheritance

- Step 01: Implement the Parent class
  - Make the attributes **"protected"** so the child class can access/inherit.



```java
class Employee {
    protected String name;
    protected int employeeId;
    protected String position;

    //Default Constructor
    public Employee() {
        System.out.println("Employee Constructor called!!!");
    }

    // Parameterized Constructor
    public Employee(String pName, int pEmpId, String pPosition) {
        this.name = pName;
        this.employeeId = pEmpId;
        this.position = pPosition;
    }

    // Method to calculate salary
    public double calculateSalary() {
        System.out.println("Calculating salary for Employee...");
        return 0.0;
    }

    // Display employee details
    public void displayInfo() {
        System.out.println("Name: " + name);
        System.out.println("Employee ID: " + employeeId);
        System.out.println("Position: " + position);
    }
}
```

Implementing Inheritance

- Step 02: Implement the Child classes
  - Use the **extends** keyword to implement the inheritance relationship.
  - Declare attributes as **private** so they can only be accessed within the **Manager** or **Developer** class.
  - Define only the attributes specific to the subclass, as the parent class's attributes and methods are automatically inherited.
  - Use the **super()** keyword to pass values for the parent class's attributes to its constructor.
  - Override methods where necessary to customize their behavior in the subclass.

```java
class Manager extends Employee {

    private int teamSize;

    //Default Constructor
    public Manager() {
        System.out.println("Manager Constructor called!!!");
    }

    // Parameterized Constructor
    public Manager(String pName, int pEmpId, String pPosition, int pTeamSize) {

        super(pName, pEmpId, pPosition);

        this.teamSize = pTeamSize;
    }

    // Manager-specific method
    public void conductMeeting() {
        System.out.println(name + " is leading a team of " + teamSize + " members.");
    }

    //Calculate the salary for a Manager
    public double calculateSalary() {
        System.out.println("Calculating salary for Manager...");
        return 90000.0;
    }
}
```

```java
class Developer extends Employee {
    private String[] programmingLanguages;

    //Default Constructor
    public Developer() {
        System.out.println("Developer Constructor called!!!");
    }

    // Constructor
    public Developer(String pName, int pEempId, String pPosition, String[] PLanguages) {
        super(pName, pEempId, pPosition);
        this.programmingLanguages = PLanguages;
    }

    // Developer-specific method
    public void developSoftware() {
        System.out.println(name + " is developing software using: ");
        for(int i = 0; i < programmingLanguages.length; i++) {
            System.out.println("- " + programmingLanguages[i]);
        }
    }

    //Calculate the salary for a Developer
    public double calculateSalary() {
        System.out.println("Calculating salary for Developer...");
        return 70000.0;
    }
}
```

```java
public class CompanyHierarchy {
    public static void main(String[] args) {
        // Creating a Developer object
        String[] devLanguages = {"Java", "Python", "C++"};
        Developer dev = new Developer("Alice", 101, "Software Developer", devLanguages);

        // Creating a Manager object
        Manager mgr = new Manager("Bob", 102, "Project Manager", 5);

        // Display Developer details and actions
        System.out.println("Developer Details:");
        dev.displayInfo();
        dev.developSoftware();
        System.out.println("Salary: $" + dev.calculateSalary());

        System.out.println("\n----------------------\n");

        // Display Manager details and actions
        System.out.println("Manager Details:");
        mgr.displayInfo();
        mgr.conductMeeting();
        System.out.println("Salary: $" + mgr.calculateSalary());
    }
}
```

Output:

```
Developer Details:
Name: Alice
Employee ID: 101
Position: Software Developer
Alice is developing software using:
- Java
- Python
- C++
Calculating salary for Developer...
Salary: $70000.0

----------------------

Manager Details:
Name: Bob
Employee ID: 102
Position: Project Manager
Bob is leading a team of 5 members.
Calculating salary for Manager...
Salary: $90000.0
```

Constructor Chaining

Constructor chaining happens when a constructor of a **subclass** automatically calls the constructor of its **superclass** before executing its own body.

```java
class Employee{
    private int Id;

    public Employee(){
        System.out.println("Employee Constructor called!");
    }
}

class Manager extends Employee{
    private int teamSize;

    public Manager(){
        System.out.println("Manager Constructor called!");
    }
}

public class Company {
    public static void main(String[] args) {
        Manager m = new Manager();
    }
}
```

Output:

```
Employee Constructor called!
Manager Constructor called!
```

Step 1: Execution starts in main()

```
Manager m = new Manager();
```

This line creates an object of the Manager class. The constructor of **Manager** gets called.

Step 2: Calling the Manager Constructor

```
public Manager() {
    System.out.println("Manager Constructor called!");
}
```

Since Manager extends Employee, before executing Manager constructor, Java first calls the constructor of the immediate parent class (Employee). Even though we don't explicitly call super();, Java automatically inserts super(); as the first line in the constructor.

Step 3: Calling the Employee Constructor

```
public Employee() {
  System.out.println("Employee Constructor called!");
}
```

This constructor gets executed before the Manager constructor because of constructor chaining.
It prints:

Employee Constructor called!

Step 4: Returning to the Manager Constructor

After finishing the Employee constructor, execution returns to the Manager constructor, where the next line is executed:

```
System.out.println("Manager Constructor called!");
```

It prints:

Manager Constructor called!

Final Output :

```
Employee Constructor called!
Manager Constructor called!
```

Activity 01:Guess the output of the code?

```
class Employee{
    private int Id;

    public Employee(){
        System.out.println("Employee Constructor called!");
    }
}

class Manager extends Employee{
    private int teamSize;

    public Manager(){
        System.out.println("Manager Constructor called!");
    }
}

class AreaManager extends Manager{
    private String allocated_area;

    public AreaManager(){
        System.out.println("AreaManager Constructor called!");
    }
}

public class Company {
    public static void main(String[] args) {
        AreaManager m = new AreaManager();
    }
}
```

Method Overriding

- Method overriding occurs when a subclass provides a new version of a method that is already defined in its superclass.
- The overridden method in the subclass must have:
  - The same name
  - The same return type
  - The same parameters

    as the method in the superclass.

```java
class Employee{
    private int Id;

    // Method to calculate salary
    public double calculateSalary() {
        System.out.println("Calculating salary for Employee...");
        return 0.0;
    }
}

class Manager extends Employee {
    private int teamSize;

    //Calculate the salary for a Manager
    public double calculateSalary() {
        System.out.println("Calculating salary for Manager...");
        return 90000.0;
    }
}
```

Since **Manager** class inherits from **Employee** class, it also gets the ***calculateSalary()*** method, but we can change the implementation according to the child class (**Manager**) behaviour .

```java
class Developer extends Employee {
    private int teamSize;

    //Calculate the salary for a Developer
    public double calculateSalary() {
        System.out.println("Calculating salary for Developer...");
        return 70000.0;
    }
}
```

The ***calculateSalary()*** method is called on the **Manager** object (m).Because **Manager** overrides ***calculateSalary(),*** the overridden method in **Manager** class executes instead of the one in **Employee** class.

```java
public class Company {
    public static void main(String[] args) {
        System.out.println();
        Manager m = new Manager();
        double salary1 = m.calculateSalary();
        System.out.println("Salary of Manager is : " + salary1);
        System.out.println();

        Developer dev = new Developer();
        double salary2 = dev.calculateSalary();
        System.out.println("Salary of Developer is : " + salary2);
    }
}
```

Output:

```
Calculating salary for Manager...
Salary of Manager is : 90000.0

Calculating salary for Developer...
Salary of Developer is : 70000.0
```

The **calculateSalary()** method is called on the **Developer** object (dev).Because **Developer** overrides **calculateSalary(),** the overridden method in **Developer** class executes instead of the one in **Employee** class.

- In Java, the method that runs is decided while the program is running, based on the actual type of the object.
- Since m is a Manager object, Java calls the calculateSalary() method from the Manager class, even though the Employee class has the same method.
- This behavior is called **runtime polymorphism**

Polymorphism

- Polymorphism means **"many forms"** – the ability of a method or object to take different forms.
- In Java, polymorphism allows a single method name to work with different types of objects.
- It helps in code reusability, flexibility, and maintainability.

Example: The **calculateSalary()** method in the Employee class was overridden in the Manager and Developer classes. When the **calculateSalary()** method is called, it executes the version that belongs to the specific object on which it was called.

A real world example

Consider the request (analogues to a method) *"please cut this in half"*. *According to the context the steps of the procedure may be different.*

Types of Polymorphism

1. **Compile-time Polymorphism (Method Overloading)**
   - Multiple methods with the same name but different parameters.
   - The method that will be executed is decided during compile time.

```
class MathOperations {
    int add(int a, int b) {
            return a + b;
    }

    double add(double a, double b) {
            return a + b;
    }
}
```

Types of Polymorphism

2. **Runtime Polymorphism (Method Overriding)**
   - A subclass provides a new version of a method from the parent class.
   - The program decides which method to execute while it is running.

```
class Employee {
    void work() {
        System.out.println("Employee is working.");
    }
}

class Developer extends Employee {
    void work() {
        System.out.println("Developer is coding.");
    }
}
```

Activity 02:Guess the output of the code?

```
class Animal {
    void makeSound() {
        System.out.println("Animal makes a sound.");
    }
}

class Dog extends Animal {
    void makeSound() {
        System.out.println("Dog barks.");
    }
}

public class Test {
    public static void main(String[] args) {
        Animal myAnimal = new Dog();
        myAnimal.makeSound();
    }
}
```

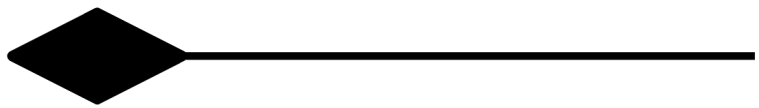
Let's try the Question 03 from the Tutorial 03

Lecture 04 - Part 02

Composition and Aggregation

Relationship Type 02: **Composition**

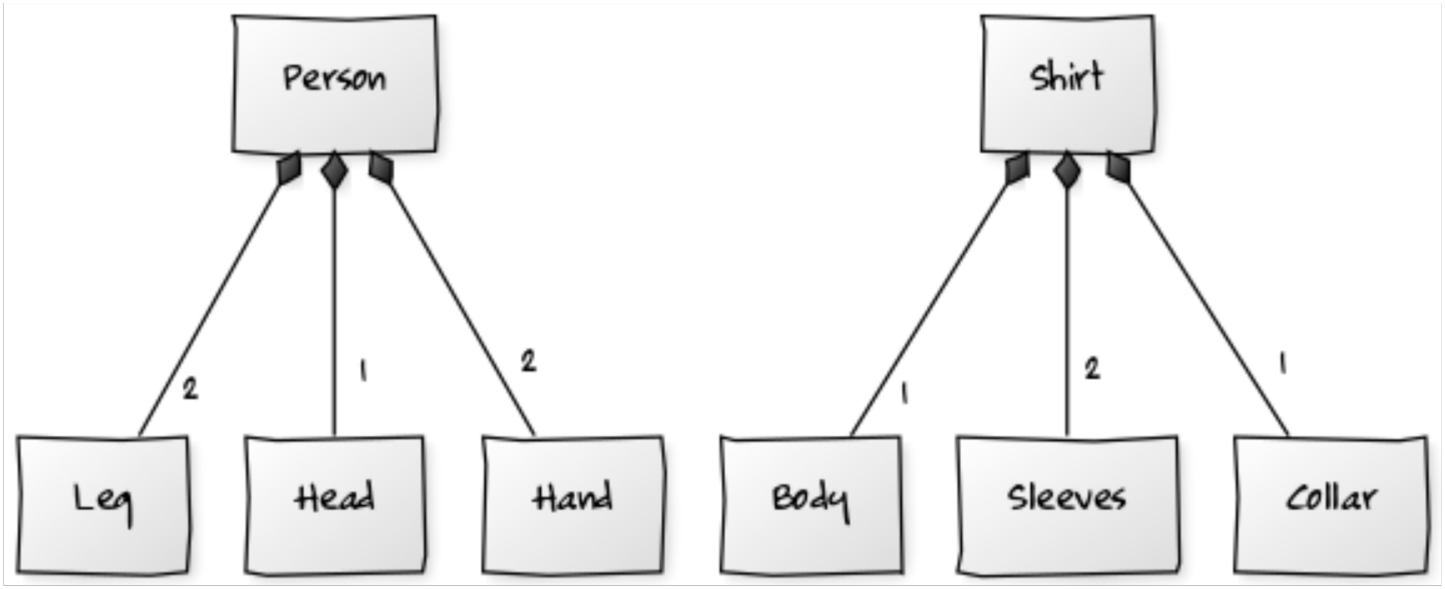
- Composition means one class is made up of one or more objects of other classes (whole-part relationship).
- It is a strong form of relationship, where one class contains an object of another class as a part of its attributes.
- **If the containing (whole) object is destroyed, the contained (part) object is also destroyed.**
- In Java, composition is implemented using instance variables that reference other objects.
- In diagrams, composition is shown using a filled diamond connected by a line. The diamond is placed next to the whole (containing) class, indicating a strong relationship between the whole and its parts.



Example 01

- Whole : Book
- Part : Page
- A Book consists of pages,
- A Page **cannot exist** without the Book.
- Implies that the "Part cannot exist without Whole"

Example 02



Head, Hand and Leg are parts of the Person and these ***parts cannot exist*** without a Person

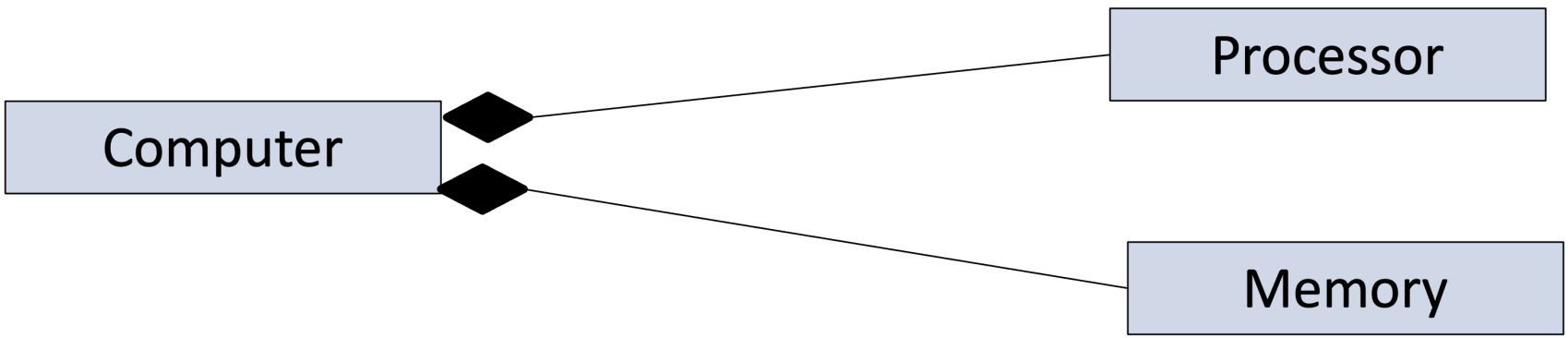
Body, Sleeve, Collar are parts of the Shirt and these ***parts cannot exist*** without a Shirt

Example 03

- Whole : Car
- Part : Engine
- A Car consists of an engine,
- An Engine cannot exist without the Car.
- Implies that the "Part cannot exist without Whole"

Composition Implementation

Consider a Computer that is made up of a Processor and a Memory. A Computer cannot function without its Processor and Memory. If the Computer is destroyed, its Processor and Memory are also destroyed with it. This is a Composition relationship.



Step 01: Implement the "Part" classes.

Create the Processor and Memory Classes.

```java
public class Processor {
    private String model;

    public Processor(String model) {
        this.model = model;
    }

    public void displayProcessor() {
        System.out.println("Processor Model: " + model);
    }
}
```

```java
public class Memory {
    private int sizeGB;

    public Memory(int sizeGB) {
        this.sizeGB = sizeGB;
    }

    public void displayMemory() {
        System.out.println("Memory Size: " + sizeGB + "GB");
    }
}
```

Step 02: Implement the "Whole" class.

The Computer class is composed of a Processor and a Memory. So these objects are created inside the Computer class and belong only to it.

```
public class Computer {
    private Processor processor;
    private Memory memory;
    private String brand;

    public Computer(String pbrand, String pProcessorModel, int pmemorySize) {
        this.brand = pbrand;
        processor = new Processor(pProcessorModel);
        memory = new Memory(pmemorySize);
    }

    public void displayComputerDetails() {
        System.out.println("Computer Brand: " + brand);
        processor.displayProcessor();
        memory.displayMemory();
    }
}
```

Step 03: Create the Main Class to Run the Program

Implement the Computer object and display its details..

```
public class CompositionExample {
    public static void main(String[] args) {
        // Create a Computer object
        Computer myComputer = new Computer("Dell", "Intel i7", 16);

        // Display computer details
        myComputer.displayComputerDetails();
    }
}
```

Output:

```
Computer Brand: Dell
Processor Model: Intel i7
Memory Size: 16GB
```

Let's try the Question 01 from the Tutorial 04

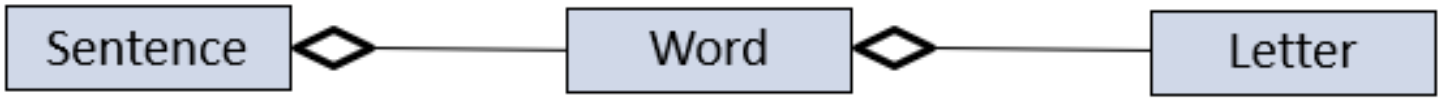
Relationship Type 03: **Aggregation**

- Aggregation represents a "whole-part" relationship where one class contains a reference to another class, but both can exist independently.
- It is a weaker relationship compared to composition.
- **If the whole (containing) object is destroyed, the part object continues to exist outside of it.**
- In Java, aggregation is implemented using instance variables that store references to other objects, but those objects are created outside the main class and passed as parameters.
- In UML diagrams, aggregation is represented by an unfilled diamond connected by a line. The diamond is placed next to the whole (containing) class, indicating a weak relationship between the whole and its parts.

Example 01

- Whole : Batch
- Part : Student
- A Batch consists of Students
- A Student **can exist** without the Batch.
- Implies that the "Part can exist without Whole"

Example 02



Words are parts of the Sentence and words ***can exist*** without a Sentence

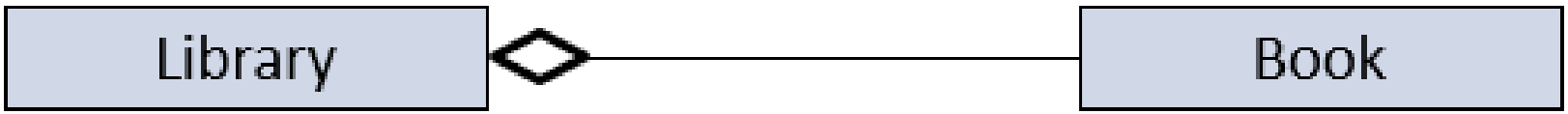
Letters are parts of the Word and letters ***can exist*** without a Word

Example 03

- Whole : Department
- Part : Professor
- A Department consists of Professors.
- A Professor **can exist** without being part of a Department.
- Implies that the "Part can exist without Whole"

Aggregation Implementation

A Library contains multiple Books, but each Book can exist independently outside the Library. If the Library closes, the Books do not get destroyed; instead, they can be transferred to another Library or remain in circulation. This represents Aggregation.



Step 01: Implement the "Part" class.

Create the Book Class.

```
class Book {
    private String title;
    private String author;

    public Book(String pTitle, String pAuthor) {
        this.title = pTitle;
        this.author = pAuthor;
    }

    public void displayBookDetails() {
        System.out.println("Book Title: " + title + ", Author: " + author);
    }
}
```

Step 02: Implement the "Whole" class.

The Library class contains references to two Book objects. The books are created outside and passed into the Library.

```
class Library {
    private String libraryName;
    private Book book1;
    private Book book2;

    public Library(String pLibraryName, Book book1, Book book2) {
        this.libraryName = pLibraryName;
        this.book1 = book1;
        this.book2 = book2;
    }

    public void displayLibraryDetails() {
        System.out.println("Library: " + libraryName);
        System.out.println("Books in the Library:");
        book1.displayBookDetails();
        book2.displayBookDetails();
    }
}
```

Step 03: Create the Main Class to Run the Program

```java
public class LibraryApp {
    public static void main(String[] args) {
        // Creating independent Book objects
        Book book1 = new Book("The Great Gatsby", "F. Scott Fitzgerald");
        Book book2 = new Book("To Kill a Mockingbird", "Harper Lee");

        // Creating a Library object with existing Books
        Library library = new Library("City Library", book1, book2);

        // Display Library and Book details
        library.displayLibraryDetails();
    }
}
```

Output:

```
Library: City Library
Books in the Library:
Book Title: The Great Gatsby, Author: F. Scott Fitzgerald
Book Title: To Kill a Mockingbird, Author: Harper Lee
```

Key Differences Between Aggregation and Composition

Feature	Composition (Strong)	Aggregation (Weak)
Relationship Type	Strong Part of relationship	Weak Part of relationship
Lifecycle Dependency	Part cannot exist without the whole	Part can exist without the whole
Object Creation	Created inside the whole class	Created outside the whole class and passed
UML Representation	Filled diamond	Empty diamond
Example	Engine is a part of the Car, and an Engine cannot exist without a Car	Department is a part of university, and a Department can exist without an University

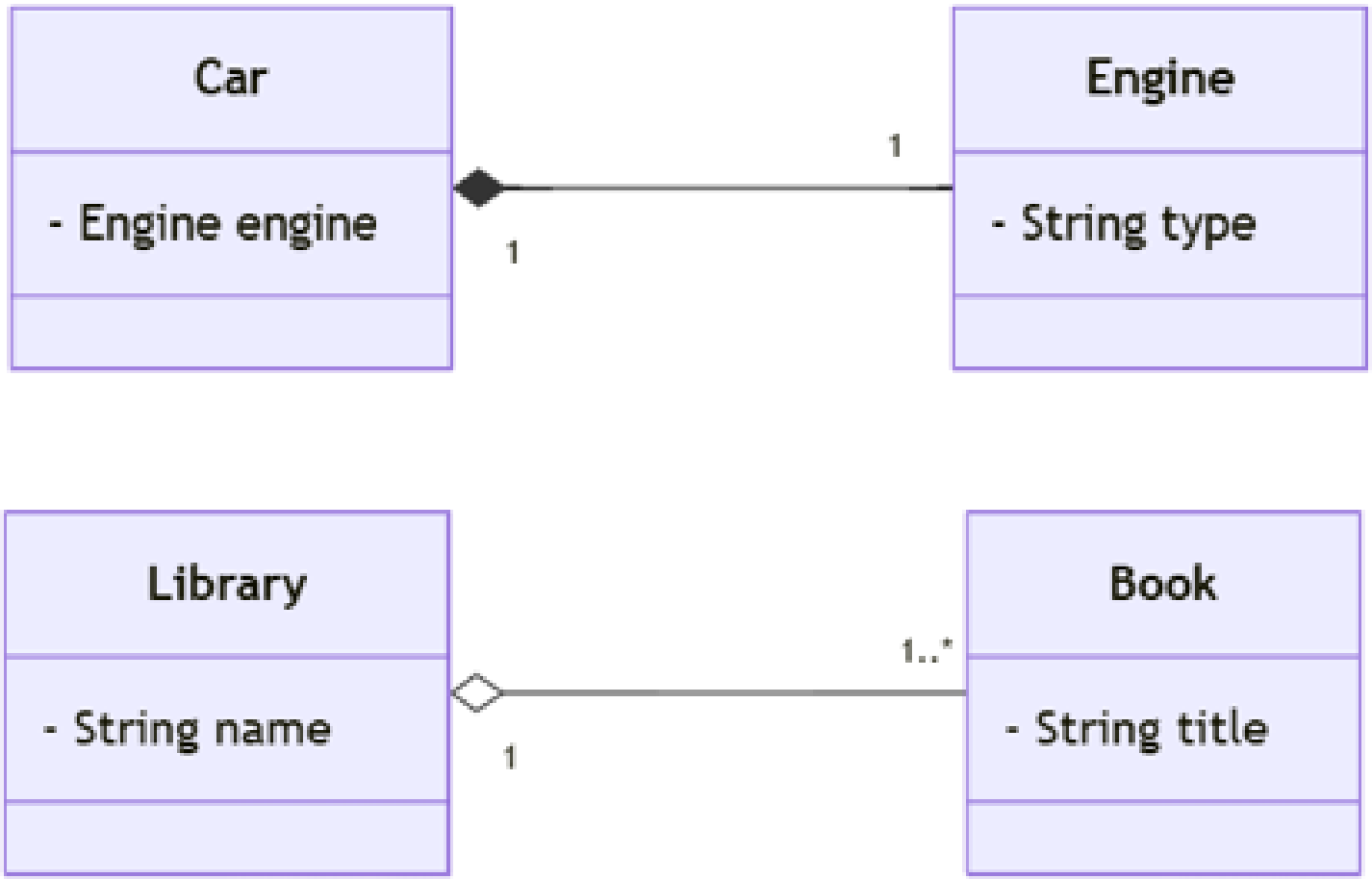
Let's try the Question 03 from the Tutorial 04

Multiplicity in UML

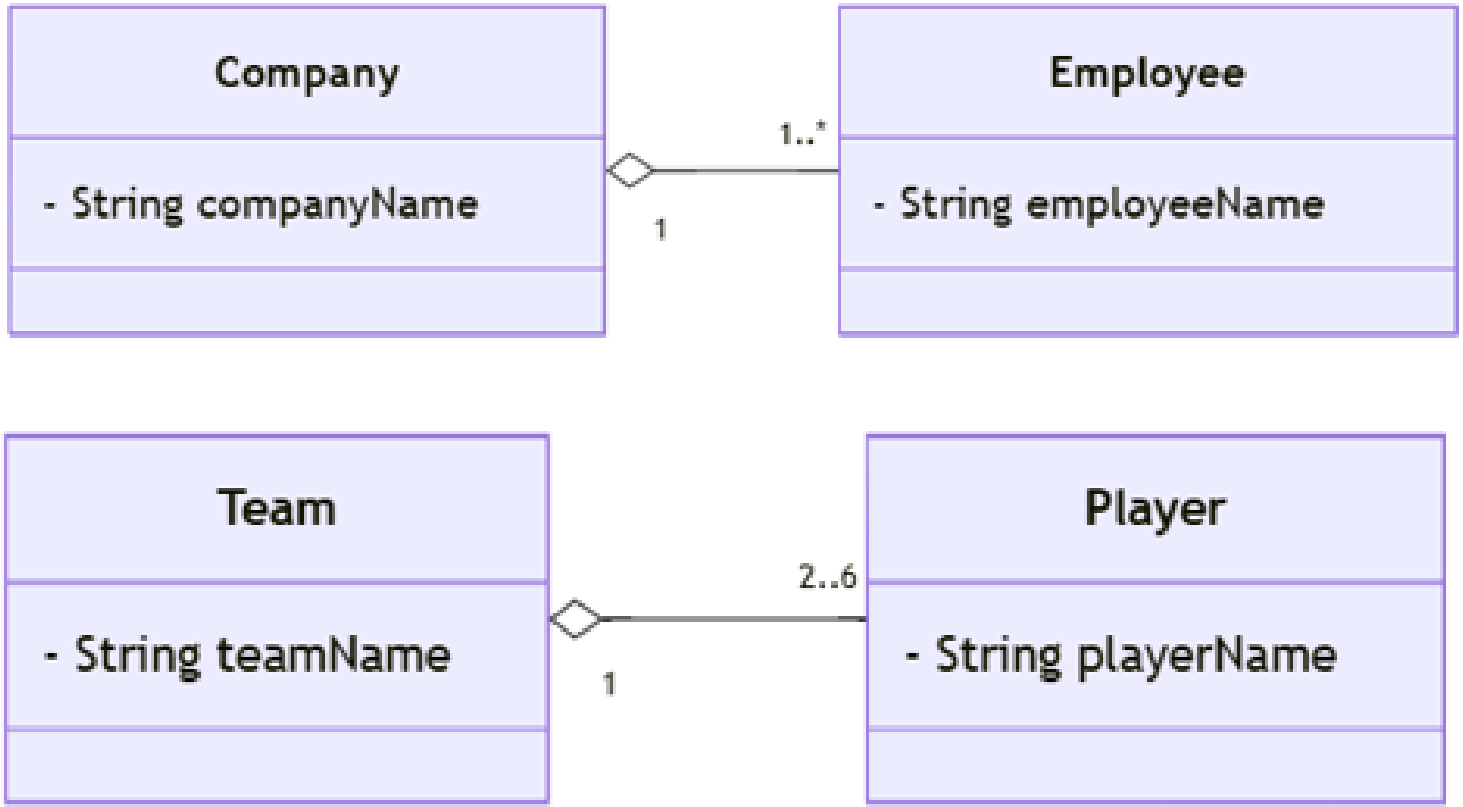
Multiplicity defines how many instances of one class can be associated with instances of another class in a relationship. It is commonly used in association, aggregation, and composition relationships.

Multiplicity	Notation	Meaning	Example
One-to-One (1..1)	1..1	Exactly one instance of a class is related to exactly one instance of another class	A Car has exactly one Engine.
One-to-Many (1..*)	1..*	One instance of a class can be associated with one or more instances of another class.	A Library has multiple Books.
Zero or One (0..1	0..1	The relationship is optional—an instance may have zero or one associated object.	A Person may have one Passport or none.
Zero-to-Many (0..*)	0..*	An instance may have zero or many associated objects.	A Company may have multiple Employees or none.
Fixed Range (n..m)	n..m	The relationship allows a specific number of instances within the given range.	A Team must have between 2 to 5 Players (2..5).
Exactly n (n..n)	n..n	A class must be associated with exactly n instances of another class.	A Bike must have exactly 2 Wheels (2..2).

Multiplicity in UML



Multiplicity in UML



Summary

- Different types of relationships define how classes interact, including inheritance, composition, and aggregation.
- Inheritance allows one class to reuse the properties and methods of another, while polymorphism enables method overriding and flexibility in behavior.
- Composition represents a strong "part of" relationship where parts cannot exist independently, while Aggregation represents a weaker "part of" relationship where parts can exist independently.
- Multiplicity specifies how many instances of one class can be linked to another, helping define one-to-one, one-to-many, or many-to-many relationships in class diagrams.

Thank You!