

CSE201: Monsoon 2020, CSE Section  
Advanced Programming

# **Lecture 03: Class Relationships**

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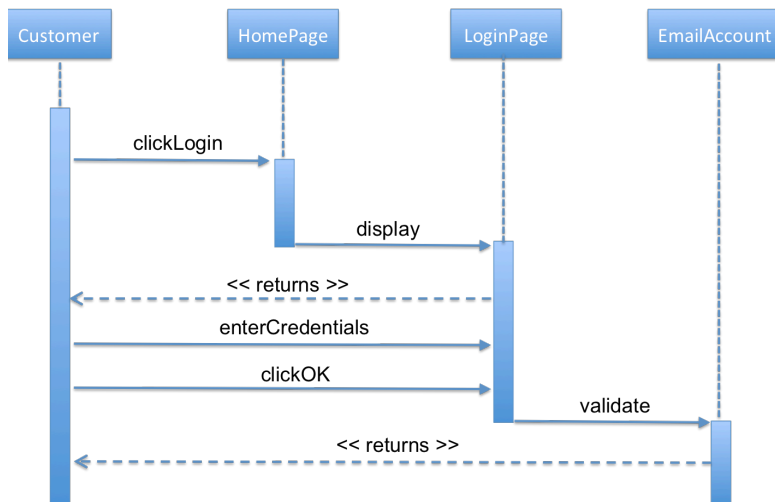
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# Last Lecture

- Program development
- Identifying classes and objects
- Sequence diagrams
- Working with objects
  - Objects as parameters
  - Variable reassignment
  - Instance variables

For accessing an online email **account**, the **customer** will first **click** the login button on the **home page** of the email account. This will **display** the **login page** of email account. Once the customer gets directed to the login page, he will **enter** his user id and password, and then **click OK** button. The email account will first **validate** the customer credentials and then grant access to his email account.



```

public class PetShop {

    public PetShop() {
        this.testGroomer();
    }

    public void testGroomer() {
        Dog django = new Dog();
        DogGroomer groomer = new DogGroomer();
        groomer.groom(django);
    }
}
    
```

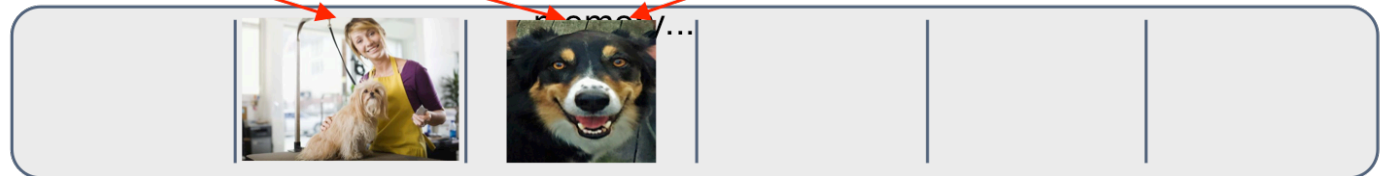
```

public class DogGroomer {

    public DogGroomer() {
        // this is the constructor!
    }

    public void groom(Dog shaggyDog) {
        // code that grooms shaggyDog goes here!
    }
}
    
```

Somewhere in



```

public class PetShop {

    /* This is the constructor! */
    public PetShop() {
        this.testGroomer();
    }

    public void testGroomer() {
        Dog django = new Dog();
        DogGroomer groomer = new DogGroomer();
        groomer.groom(django);
        django = new Dog(); //old ref garbage collected
        groomer.groom(django);
    }
}
    
```

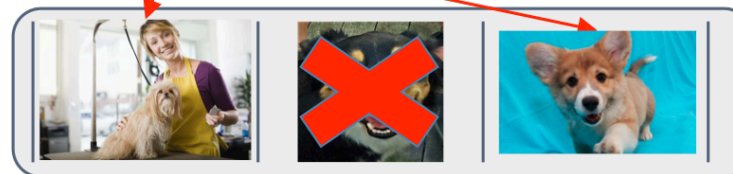
```

public class PetShop { declaration

    private DogGroomer _groomer;

    /* This is the constructor! */
    public PetShop() {
        _groomer = new DogGroomer(); assignment
        this.testGroomer();
    }

    public void testGroomer() {
        Dog django = new Dog(); //local var
        _groomer.groom(django);
    }
}
    
```



# This Lecture

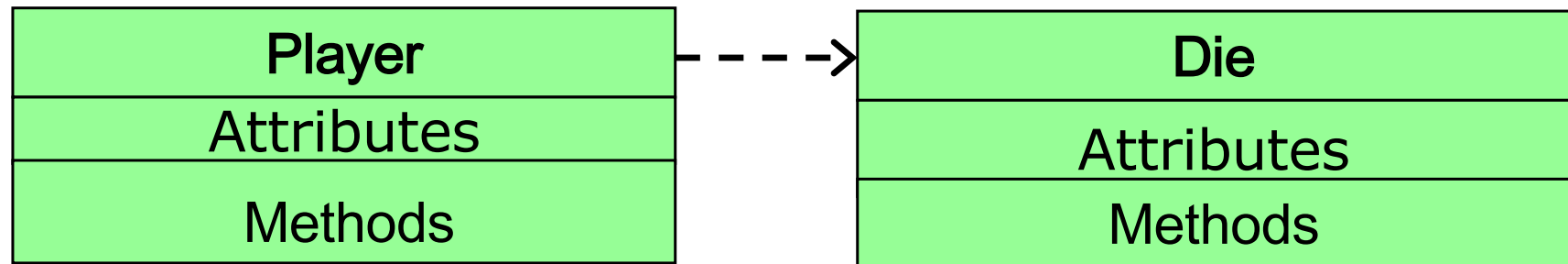
- Class relationships

Slide acknowledgements: Internet resources + CS15, Brown University

# UML: Quick Introduction

- UML stands for the *Unified Modeling Language*
  - We will cover this in depth in later lectures
- Much detailed than sequence diagrams
- *UML diagrams* show relationships among classes and objects
  - Lines connecting the classes
- A UML *class diagram* consists of one or more classes, each with sections for the class name, attributes (data), and operations (methods)

# A Sample UML Class Diagram



# Class Relationships

- The whole point of OOP is that your code replicates real world objects, thus making your code readable and maintainable
- When we say real world, the real world has relationships
- When writing a program, need to keep in mind “big picture”—how are different classes related to each other?

# Most Common Class Relationships

- **Composition**
  - A “contains” B
- **Association**
  - A “knows-about” B
- **Dependency**
  - A “depends on” B
- **Inheritance**
  - HarleyDavidson “is-a” Bike

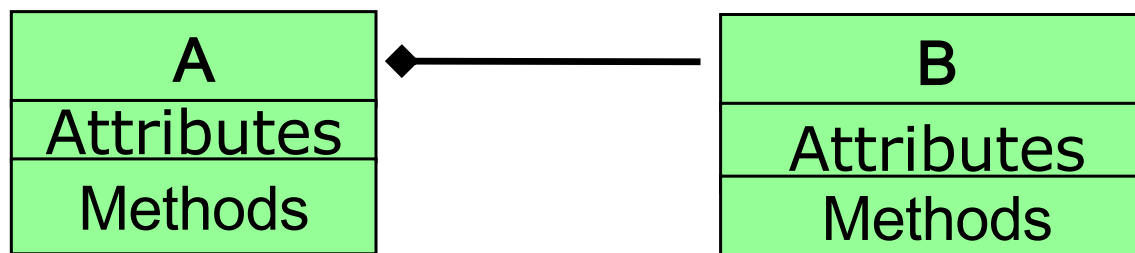
# Composition Relationship

- Class A **contains** object of class B
  - A **instantiate** B
- Thus A knows about B and can call methods on it
- But this is **not symmetrical!** B can't automatically call methods on A
- Lifetime?
  - **The death relationship**
  - Garbage collection of A means B also gets garbage collected



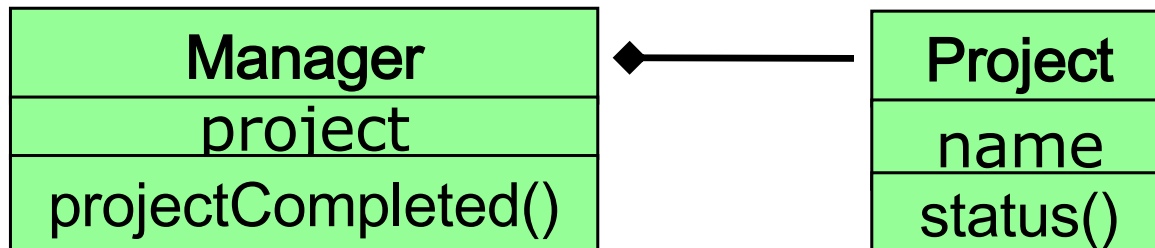
# Composition in UML

- Represented by a solid arrow with diamond head
- In below UML diagram, A is composed of B



# Composition Example (1/2)

- Manager is fixed for a project and is responsible for the timely completion of the project. If manager leaves, project is ruined



```
class Project {
    private String name;
    public boolean status() { ... }
    .....
}
// A manager is fixed for a project
class Manager {
    private Project project;
    public Manager() {
        this.project = new Project("ABC");
    }
    public boolean projectCompleted() {
        return project.status();
    }
}
```

# Composition Example (2/2)

- **PetShop** contains a **DogGroomer**
- Composition relationship because **PetShop** itself instantiates a **DogGroomer** with  
    “new DogGroomer();”
- Since **PetShop** created a **DogGroomer** and stored it in an instance variable, all **PetShop**'s methods “know” about the **\_groomer** and can access it

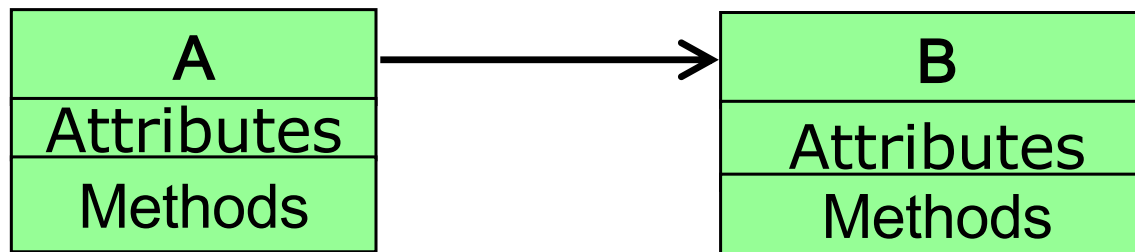
```
public class PetShop {  
  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer();  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();//local var  
        _groomer.groom(django);  
    }  
}
```

# Association Relationship

- Association is a relationship between two objects
- Class A and class B are **associated** if A “knows about” B, but B is not a component of A
- But this is **not symmetrical!** B “doesn’t know about” A
- **Class A holds a class level reference to class B**
- Lifetime?
  - Objects of class A and B have their own lifetime, i.e., they can exist without each other

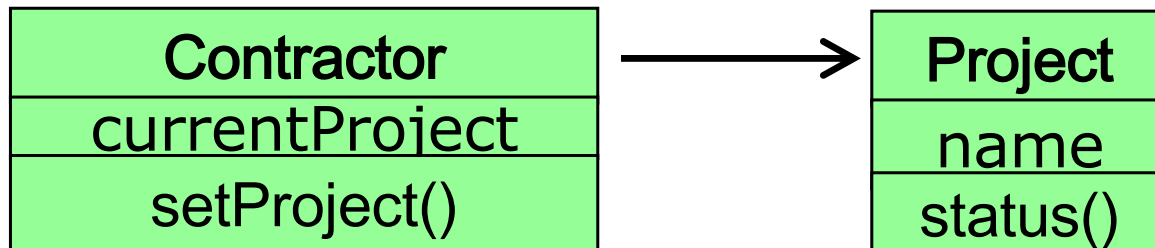
# Association in UML

- Represented by a solid arrow
- In below UML diagram, A holds a reference of B



# Association Example (1/4)

- A contractor's project keep's changing as per company's policy and contractor's performance



```
class Project {
    private String name;
    public boolean status() { ... }
    .....
}
// Contractor's project keep changing
class Contractor {
    private Project currentProject;
    public Contractor(Project proj) {
        this.currentProject = proj;
    }
    public void setProject(Project proj){
        this.currentProject = proj;
    }
}
```

# Associations Example (2/4)

- **Association** means that one object knows about another object that is not one of its components

```
public class DogGroomer {
```

```
    public DogGroomer() {  
        // this is the constructor!  
    }
```

```
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```

# Associations Example (2/4)

- As noted, **PetShop** contains a **DogGroomer**, so it can send messages to the **DogGroomer**
- But what if the **DogGroomer** needs to send messages to the **PetShop** she works in?
  - the **DogGroomer** probably needs to know several things about her **PetShop**: for example, operating hours, grooming supplies in stock, customers currently in the shop...

```
public class DogGroomer {
```

```
    public DogGroomer() {  
        // this is the constructor!  
    }  
}
```

```
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```



# Associations Example (2/4)

- The **PetShop** keeps track of such information in its properties
- Can set up an **association** so that **DogGroomer** can send her **PetShop** messages to retrieve information she needs

```
public class DogGroomer {  
  
    public DogGroomer() {  
        // this is the constructor!  
    }  
  
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```

# Associations Example (2/4)

- This is what the full association looks like
- Let's break it down line by line
- **But note we're not yet making use of the association in this fragment**

```
public class DogGroomer {  
  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop; // store the assoc.  
    }  
  
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```

# Associations Example (2/4)

- We declare an instance variable named `_petShop`
- We want this variable to record the instance of `PetShop` that the `DogGroomer` belongs to

```
public class DogGroomer {  
  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop; // store the assoc.  
    }  
  
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```

# Associations Example (2/4)

- Modified **DogGroomer**'s constructor to take in a parameter of type **PetShop**
- Constructor will refer to it by the name **myPetShop**
- Whenever we instantiate a **DogGroomer**, we'll need to pass it an instance of **PetShop** as an argument. Which? The **PetShop** instance that created the **DogGroomer**, hence use **this**

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop; // store the assoc.  
    }  
    //groom method elided  
}
```

---

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    //testGroomer() elided  
}
```

# Associations Example (2/4)

- Now store `myPetShop` in instance variable `_petShop`
- `_petShop` now points to same `PetShop` instance passed to its constructor
- After constructor has been executed and can no longer reference `myPetShop`, any `DogGroomer` method can still access same `PetShop` instance by the name `_petShop`

```
public class DogGroomer {  
  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop; // store the assoc.  
    }  
  
    public void groom(Dog shaggyDog) {  
        shaggyDog.setHairLength(1);  
    }  
}
```

# Associations Example (2/4)

- Let's say we've written an accessor method and a mutator method in the `PetShop` class:  
`getClosingTime()` and  
`setNumCustomers(int customers)`
- If the `DogGroomer` ever needs to know the closing time, or needs to update the number of customers, she can do so by calling
  - `getClosingTime()`
  - `setNumCustomers(int customers)`

```
public class DogGroomer {  
  
    private PetShop _petShop;  
    private Time _closingTime;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop; // store assoc.  
        _closingTime = myPetShop.getClosingTime();  
        _petShop.setNumCustomers(10);  
    }  
}
```

# Association: Under the Hood (1/5)

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();  
        _groomer.groom(django);  
    }  
}
```

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop;  
    }  
  
    /* groom and other methods elided for this  
    example */  
}
```

Somewhere in memory...



# Association: Under the Hood (2/5)

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();  
        _groomer.groom(django);  
    }  
}
```

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop;  
    }  
  
    /* groom and other methods elided for this  
    example */  
}
```

Somewhere in memory...



Somewhere else in our code, someone calls `new PetShop()`. An instance of `PetShop` is created somewhere in memory and `PetShop`'s constructor initializes all its instance variables (just a `DogGroomer` here)



# Association: Under the Hood (3/5)

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();  
        _groomer.groom(django);  
    }  
}
```

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop;  
    }  
  
    /* groom and other methods elided for this  
    example */  
}
```

Somewhere in memory...



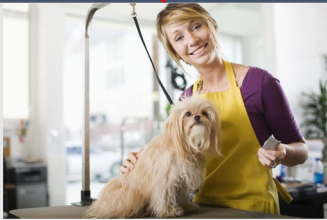
The PetShop instantiates a new DogGroomer, passing itself in as an argument to the DogGroomer's constructor (remember the `this` keyword?)

# Association: Under the Hood (4/5)

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();  
        _groomer.groom(django);  
    }  
}
```

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop;  
    }  
  
    /* groom and other methods elided for this  
    example */  
}
```

Somewhere in memory...



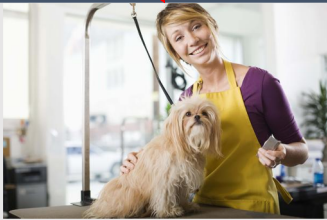
When the DogGroomer's constructor is called, its parameter, myPetShop, points to the same PetShop that was passed in as an argument.

# Association: Under the Hood (5/5)

```
public class PetShop {  
    private DogGroomer _groomer;  
  
    public PetShop() {  
        _groomer = new DogGroomer(this);  
        this.testGroomer();  
    }  
  
    public void testGroomer() {  
        Dog django = new Dog();  
        _groomer.groom(django);  
    }  
}
```

```
public class DogGroomer {  
    private PetShop _petShop;  
  
    public DogGroomer(PetShop myPetShop) {  
        _petShop = myPetShop;  
    }  
  
    /* groom and other methods elided for this  
    example */  
}
```

Somewhere in memory...



The DogGroomer sets its `_petShop` instance variable to point to the same PetShop it received as an argument. Now it “knows about” the petShop that instantiated it! And therefore so do all its methods...

# Associations Example (3/4)

- Here we have the class **Professor**
- We want **Professor** to know about his TAs—he didn't create them or vice versa, hence no containment – they are peer objects
- Let's set up associations!

```
public class Professor {  
  
    // declare instance variables here  
    // and here...  
    // and here...  
    // and here!  
  
    public Professor(/* parameters */) {  
  
        // initialize instance variables!  
        // ...  
        // ...  
        // ...  
    }  
  
    /* additional methods elided */  
}
```

# Associations Example (3/4)

- The **Professor** needs to know about 4 TAs, all of whom will be instances of the class **TA**
- Once he knows about them, he can call methods of the class **TA** on them: **remindTA**, **runRefresherModule**, etc.
- Take a minute and try to fill in this class

```
public class Professor {  
  
    // declare instance variables here  
    // and here...  
    // and here...  
    // and here!  
  
    public Professor(/* parameters */) {  
  
        // initialize instance variables!  
        // ...  
        // ...  
        // ...  
    }  
  
    /* additional methods elided */  
}
```

# Associations Example (3/4)

- Here's our solution!
- Remember, you can choose your own names for the instance variables and parameters
- The Professor can now send a message to one of his TAs like this:

`_ta1._runRefresherModule();`

```
public class Professor {  
  
    private TA _ta1;  
    private TA _ta2;  
    private TA _ta3;  
    private TA _ta4;  
  
    public Professor(TA firstTA,  
                    TA secondTA, TA thirdTA,  
                    TA fourthTA) {  
  
        _ta1 = firstTA;  
        _ta2 = secondTA;  
        _ta3 = thirdTA;  
        _ta4 = fourthTA;  
    }  
  
    /* additional methods elided */  
}
```

# Associations Example (3/4)

- We've got the **Professor** class down
- Now let's create a professor and TAs from a class that contains all of them: **Course**
- Try and fill in this class!
  - You can assume that the **TA** class takes no parameters in its constructor.

```
public class Course {  
  
    // declare Professor instance var.  
    // declare four TA instance vars.  
    // ...  
    // ...  
    // ...  
  
    public Course() {  
        // instantiate the four TAs  
        // ...  
        // ...  
        // instantiate the professor!  
    }  
}
```

# Associations Example (3/4)

- We declare `_vivek`, `_akanksha`, `_akash`, `_alind` and `_abhiprayah` as instance variables
- In the constructor, we instantiate them
- Since the constructor of `Professor` takes in 4 `TAs`, we pass in `_akanksha`, `_akash`, `_alind` and `_abhiprayah`

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                               _akash , _alind , _abhiprayah);  
    }  
}
```



# Associations Example (3/4)

```
public class Professor {  
  
    private TA _ta1;  
    private TA _ta2;  
    private TA _ta3;  
    private TA _ta4;  
  
    public Professor(TA firstTA,  
                    TA secondTA, TA thirdTA  
                    TA fourthTA){  
  
        _ta1 = firstTA;  
        _ta2 = secondTA;  
        _ta3 = thirdTA;  
        _ta4 = fourthTA;  
        _ta1.runRefresherModule();  
    }  
    /* additional methods elided */  
}
```

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                               _akash , _alind , _abhiprayah);  
    }  
}
```

# Associations Example (4/4)

- What if we want the TAs to know about **Professor** too?
- Need to set up another association
- Can we just do the same thing?

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                               _akash , _alind , _abhiprayah);  
    }  
}
```

# Associations Example (4/4)

- This doesn't work: when we instantiate `_akanksha`, `_akash`, `_alind` and `_abhiprayah`, we would like to pass them an argument, `_vivek`
- But `_vivek` hasn't been instantiated yet! And can't initialize `_vivek` first because the TAs haven't been created yet...
- What can we try instead?

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                                _akash , _alind , _abhiprayah);  
    }  
}
```

# Associations Example (4/4)

- Need a way to pass `_vivek` to `_akanksha`, `_akash`, `_alind` and `_abhiprayah` **after** we instantiate `_vivek`
- Use a new method, `setProf`, and pass each TA `_vivek`

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                                _akash , _alind , _abhiprayah);  
    }  
}
```

# Associations Example (4/4)

```
public class TA {  
    private Professor _professor;  
  
    public TA() {  
        //Other code elided  
    }  
  
    public void setProf(Professor prof) {  
        _professor = prof;  
    }  
}
```

- Now each TA will know about \_vivek!

```
public class Course {  
  
    private Professor _vivek;  
    private TA _akanksha;  
    private TA _akash;  
    private TA _alind;  
    private TA _abhiprayah;  
  
    public Course() {  
        _akanksha = new TA();  
        _akash = new TA();  
        _alind = new TA();  
        _abhiprayah = new TA();  
        _vivek = new Professor(_akanksha,  
                                _akash , _alind , _abhiprayah);  
  
        _akanksha.setProf(_vivek);  
        _akash.setProf(_vivek);  
        _alind.setProf(_vivek);  
        _abhiprayah.setProf(_vivek);  
    }  
}
```

# Question

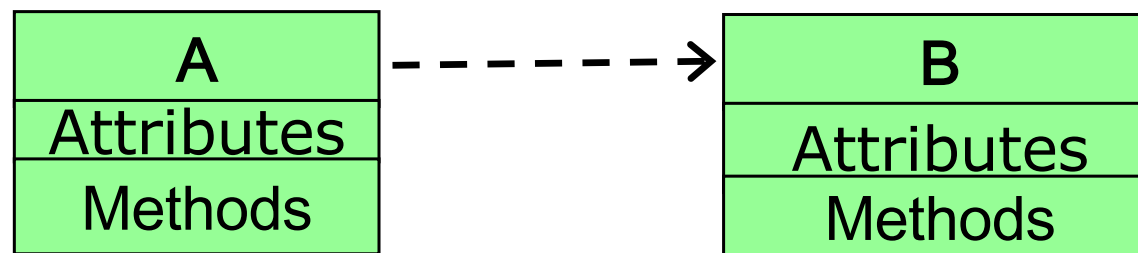
- What happens if `setProf` is never called?
- Will the TAs be able to call methods on the `Professor`?

# Dependency

- Class A **depends** on class B if A cannot carry out its work without B, but B is neither a component of A nor it has association with A
- **A is requesting service from an object of class B**
  - A or B “**doesn’t know**” about each other (no association)
  - A or B “**doesn’t contain**” each other (no composition)
- But this is **not symmetrical!** B doesn’t depends on A

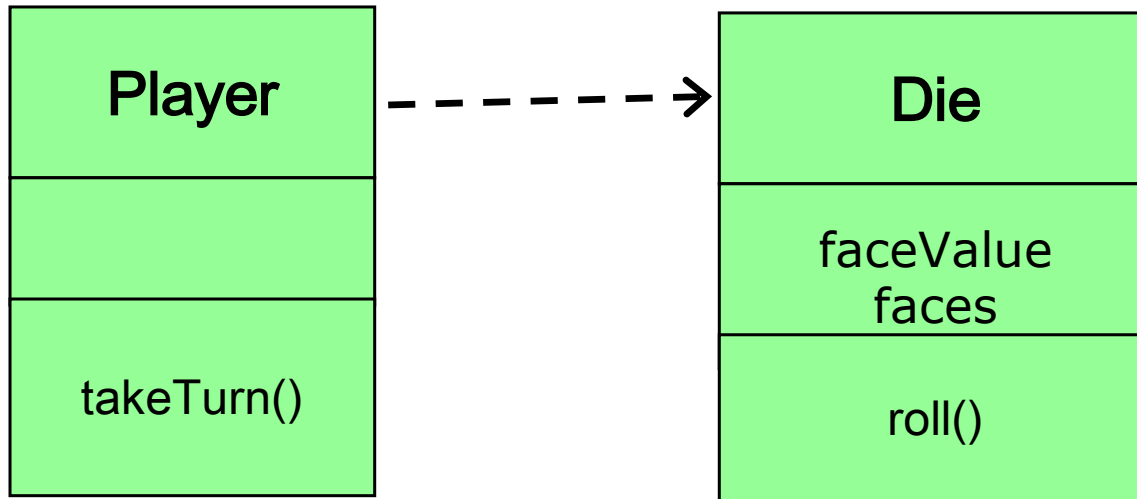
# Dependency in UML

- Represented by a dashed arrow starting from the dependent class to its dependency
  - A is dependent on B
  - A is requesting service from B





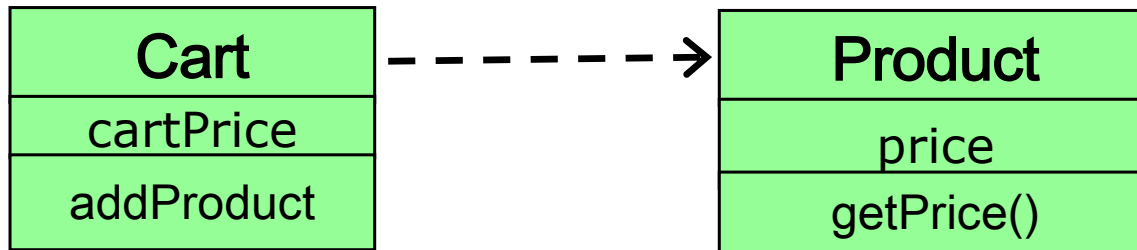
# Dependency Example (1/3)



```
class Die {
    private int faceValue, faces;
    .....
    public void roll() { ..... }
}

class Player {
    public void takeTurn(Die die) {
        die.roll();
    }
}
```

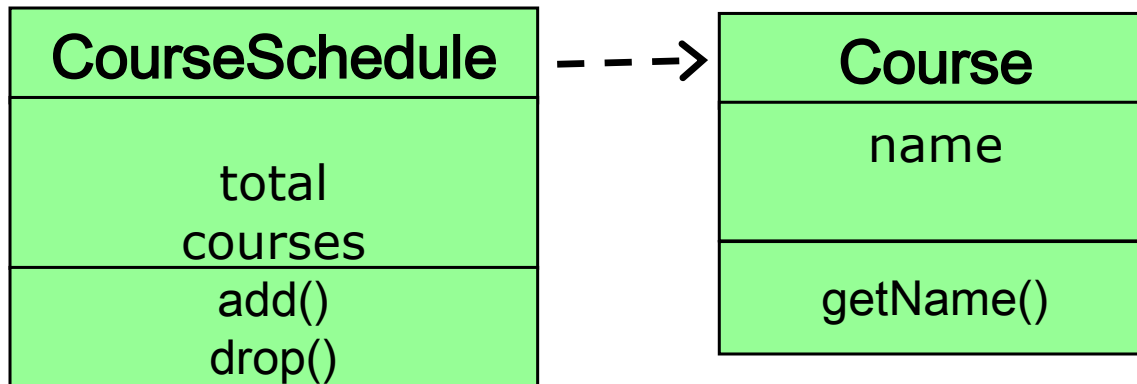
# Dependency Example (2/3)



```
class Product {
    private double price;
    .....
    public double getPrice() { ..... }
}

class Cart {
    private double cartPrice;
    public void addProduct(Product p) {
        cartPrice += p.getPrice();
    }
}
```

# Dependency Example (3/3)



```
class Course {
    private String name;
    .....
    public String getName() { ..... }
}

class CourseSchedule {
    private int total;
    private String courses[];
    public void addCourse(Course c) {
        courses[total++] = c.getName();
    }
    .....
}
```

# Next Lecture

- Interfaces in Java
- Assignment-1 to be announced next week