
MAHARISHI UNIVERSITY of MANAGEMENT
Engaging the Managing Intelligence of Nature
Computer Science Department
CS401 Modern Programming Practices (MPP)
Professor Paul Corazza

Lecture 4: Interaction Diagrams

Appreciating Dynamism in Silence

Wholeness Statement

In an OO program, objects collaborate with other objects to achieve the objectives of the program. *Sequence diagrams* document the sequence of calls among objects for a particular operation. *Object diagrams* show relationships among objects and the associations between them; they clarify the role of multiple instances of the same class. The principle of *delegation* clarifies responsibilities of each class and its instances: Requests that arrive at a particular object but cannot properly be handled by the object are *delegated* to other objects. Finally, *polymorphism* makes it possible to add new functionality without modifying existing code (as per the *Open-Closed Principle*). In these ways, we use UML diagrams to capture the dynamic features of the system; representing dynamism in the form of a static map illustrates the principle that dynamism has its basis in, and arises within, silence.

Interaction Diagrams

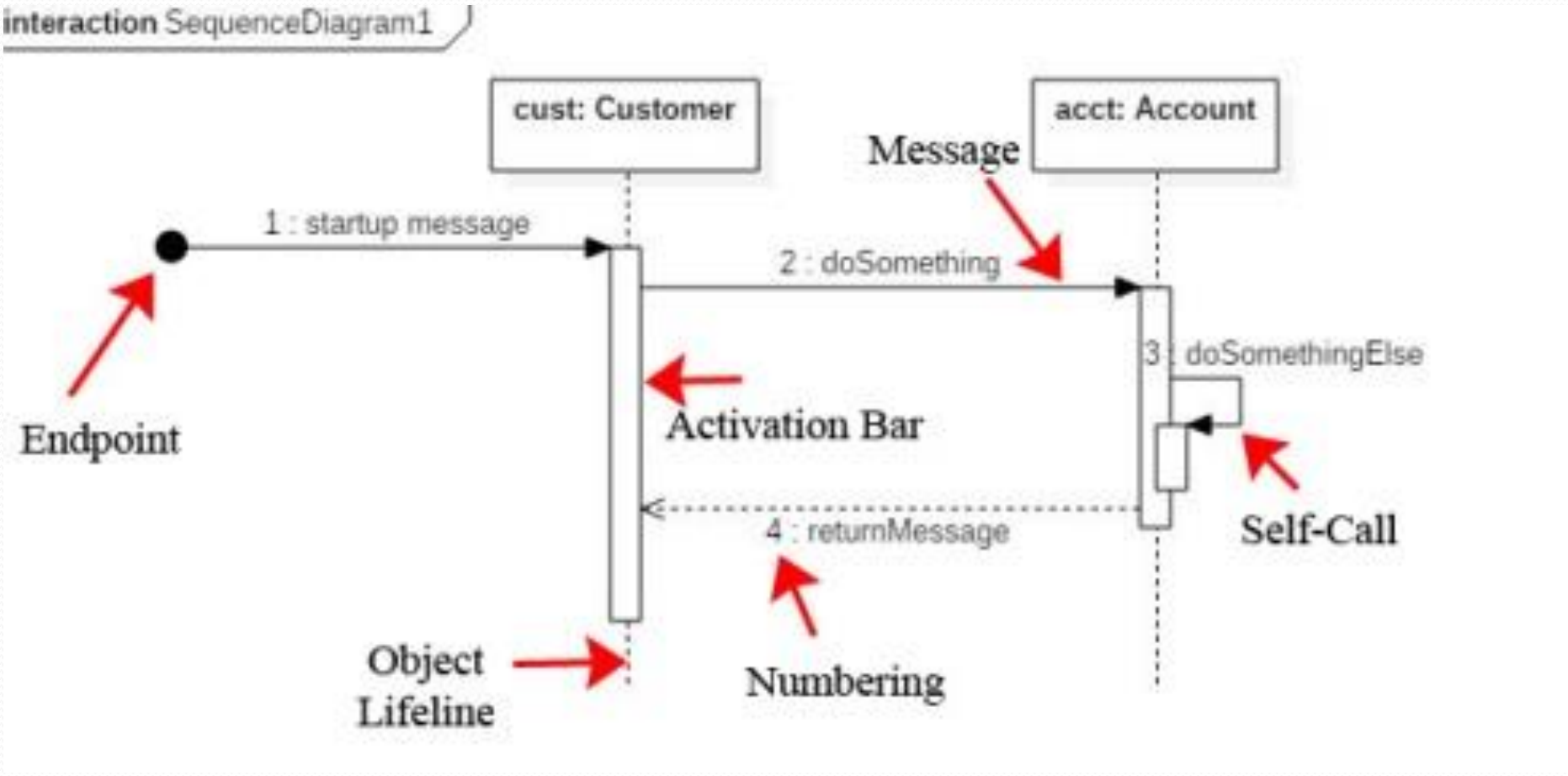
Interaction diagrams describe how groups of objects collaborate in some behavior.

- The UML defines several forms of interaction diagram, of which the most common is the sequence diagram.
- Typically, a sequence diagram captures the behavior of a single flow of a use case (like “deposit money”, “open account”, “calculate total price of an order”).
- The diagram displays the objects and messages between them that are involved in completing a given flow for a use case.

Lesson 4: Overview

- **Sequence Diagrams**
- Delegation
- Polymorphism

Anatomy of a Sequence Diagram

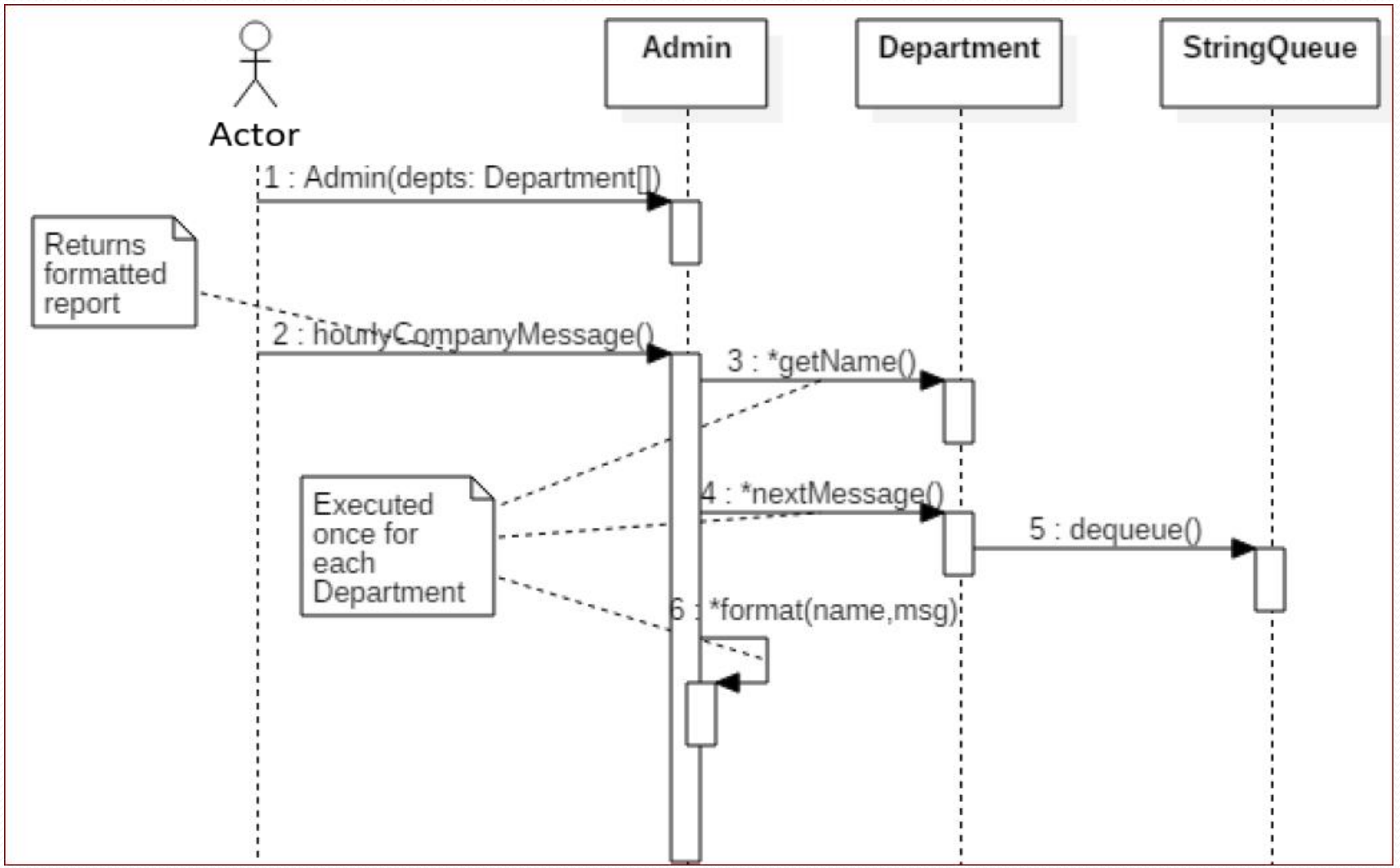


Sequence Diagrams

A sequence diagram shows interaction between objects

- Horizontal arrows (= messages) indicate calls
- Every message has a number and a name
- Sometimes numbering is *hierarchical* (not used in this course but illustrated in an upcoming slide)
- Activation bars indicate method call duration
- Vertical dotted line shows lifetime of object
- Is a dynamic view of a flow through a Use Case
- Typically, a sequence diagram begins with an action by an Actor, but sometimes an action may be initiated by some other part of the system. In that case the starting point is called an *Endpoint*. Subsequent steps occur as one object after another is accessed to accomplish the actor's request

Example: Sequence Diagram

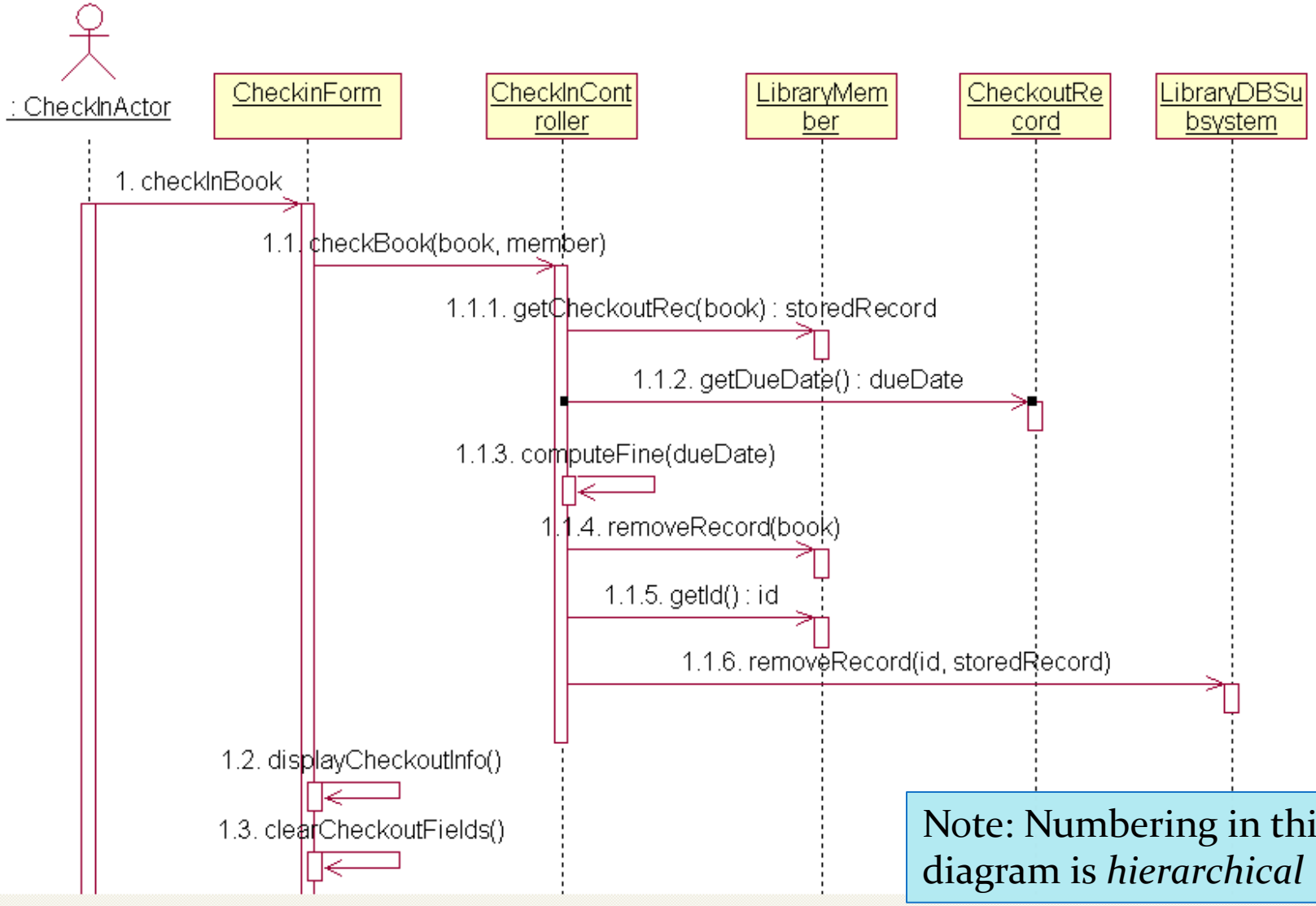


Exercise 4.1

Create a sequence diagram based on the flow that occurs when an actor invokes the `checkinBook` method on `CheckinForm`. You must use correct numbering and activation bars (in the correct way!). You must show all parameters.

```
//FROM CLASS CheckinForm
public void checkinBook() {
   theCheckinController.checkBook(m_book, m_member);
   displayCheckoutInfo();
   clearCheckoutFields();
}

//FROM CLASS CheckinController
public void checkBook(Book book, LibraryMember member) {
   CheckoutRecord storedRecord = member.getCheckoutRec(book);
   Date dueDate = storedRecord.getDueDate();
   double fine = computeFine(dueDate);
   member.removeRecord(book);
   libraryDBSubsys.removeRecord(member.getID(), storedRecord);
}
```

Solution

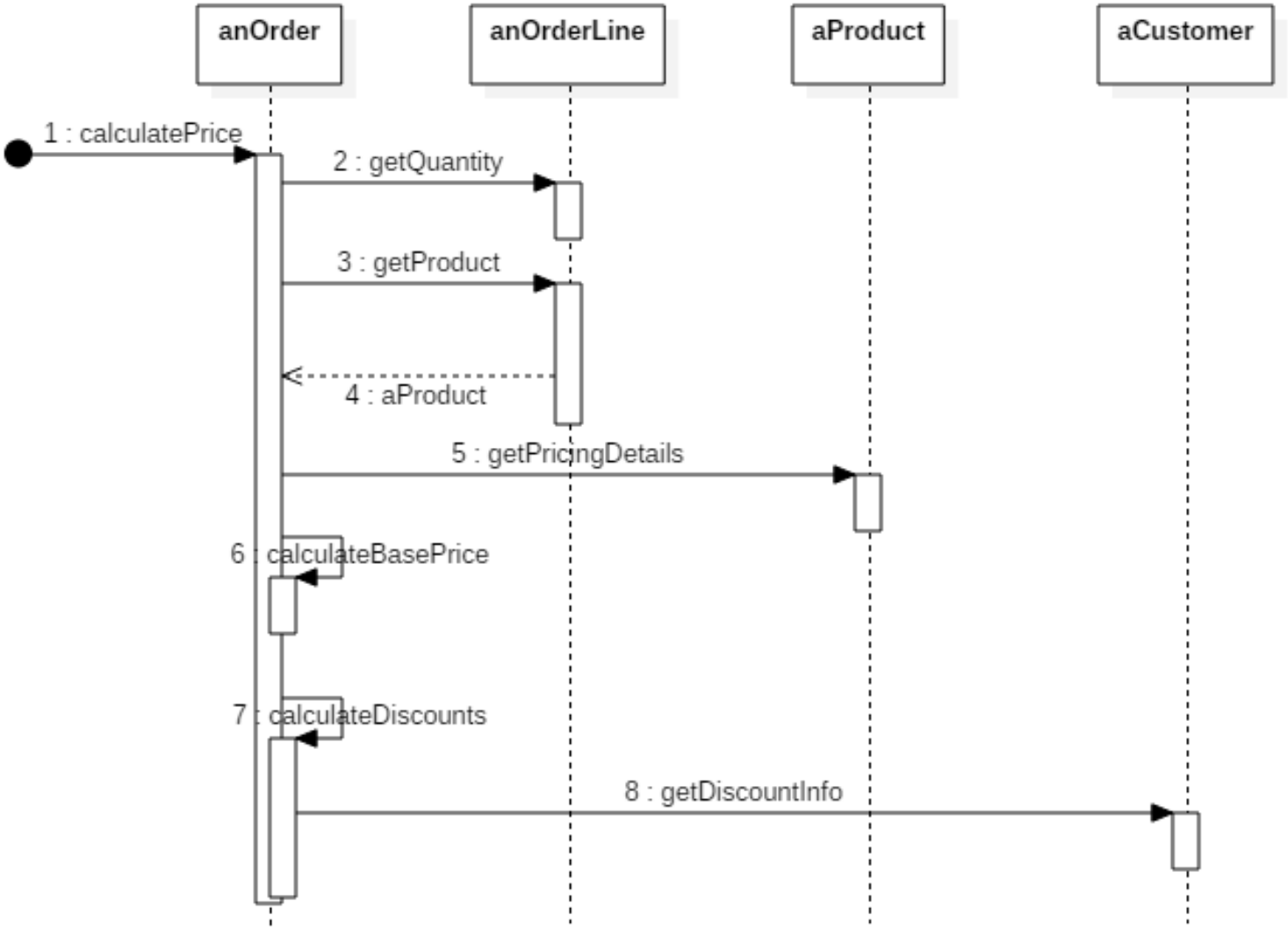


Note: Numbering in this diagram is *hierarchical*

Real-World Example

- We have an order and we are going to invoke a command on it to calculate its price.
- To do that, the order needs to look at all the line items on the order and determine their prices, which are based on the pricing rules of the order line's products.
- Having done that for all the line items, the order then needs to compute an overall discount, which is based on rules tied to the customer.

Centralized Control Solution

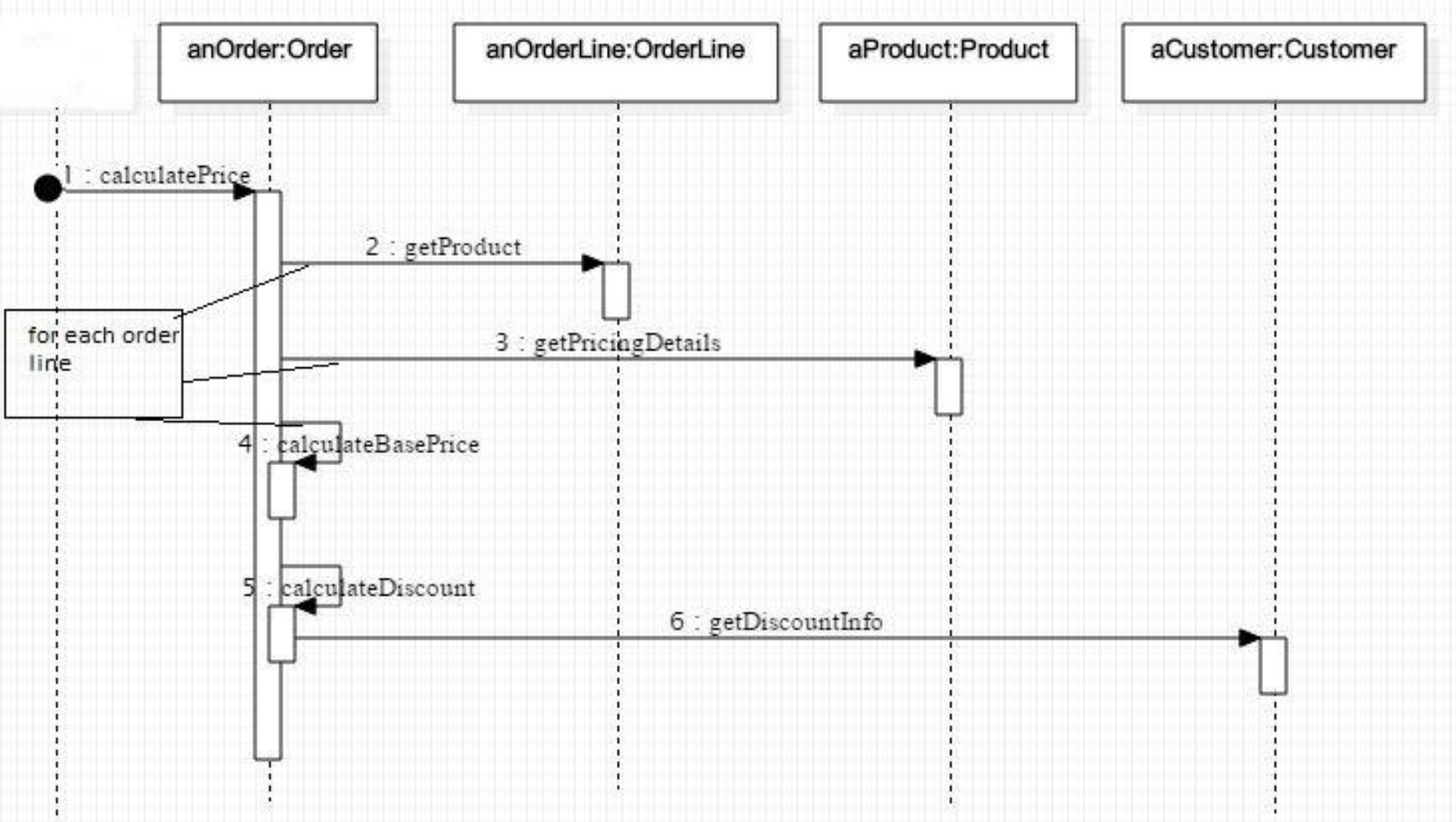


About the Diagram

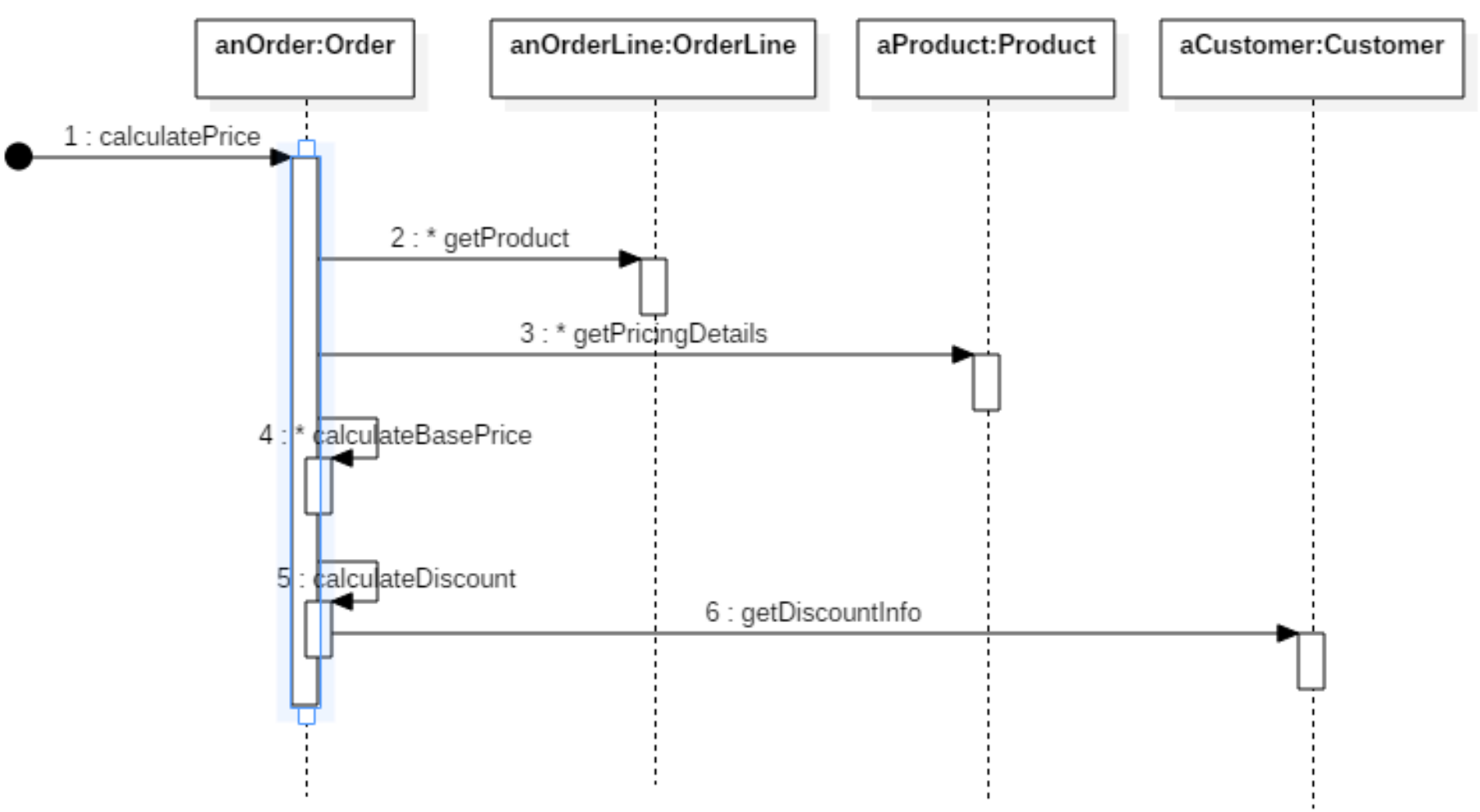
- Activation bars. These always mark the beginning and end of a "method call"
- Actor not shown. In modeling real systems, actions are typically initiated by an Actor, but to display the behavior of a portion of a system, an action may be initiated by an *Endpoint*, as shown here.
- Centralized Control. Solutions in which there is one primary controlling class are often used for understanding a problem domain, but during design, control is *distributed* so that different objects handle different parts of the flow according to their responsibilities

- Indicating Loops: The sequence of messages getQuantity, getProduct, getPricingDetails, and calculateBasePrice needs to be done for each order line on the order, while calculateDiscounts is invoked just once. Diagram does not show that these loops are occurring.
- How to show looping is occurring. There are several UML ways to do this:
  - *Use Notes*. To indicate an operation is repeated, a simple note can be used.
  - *Use an Iteration Marker*. Marking an operation with an asterisk (*) indicates that the operation repeats. This is an economical way, but gives no information other than a loop is occurring. [UML2 considers this approach to be deprecated – but it is still used sometimes anyway]
  - *Use an Interaction Frame*. Introduced in UML2.0. An interaction frame marks off a piece of a sequence diagram to indicate that a loop is occurring there. One objection to this approach is that it makes the diagram harder to read – in this course we do not use interaction frames.

Showing Looping with Notes



Showing Looping with Iteration Marker



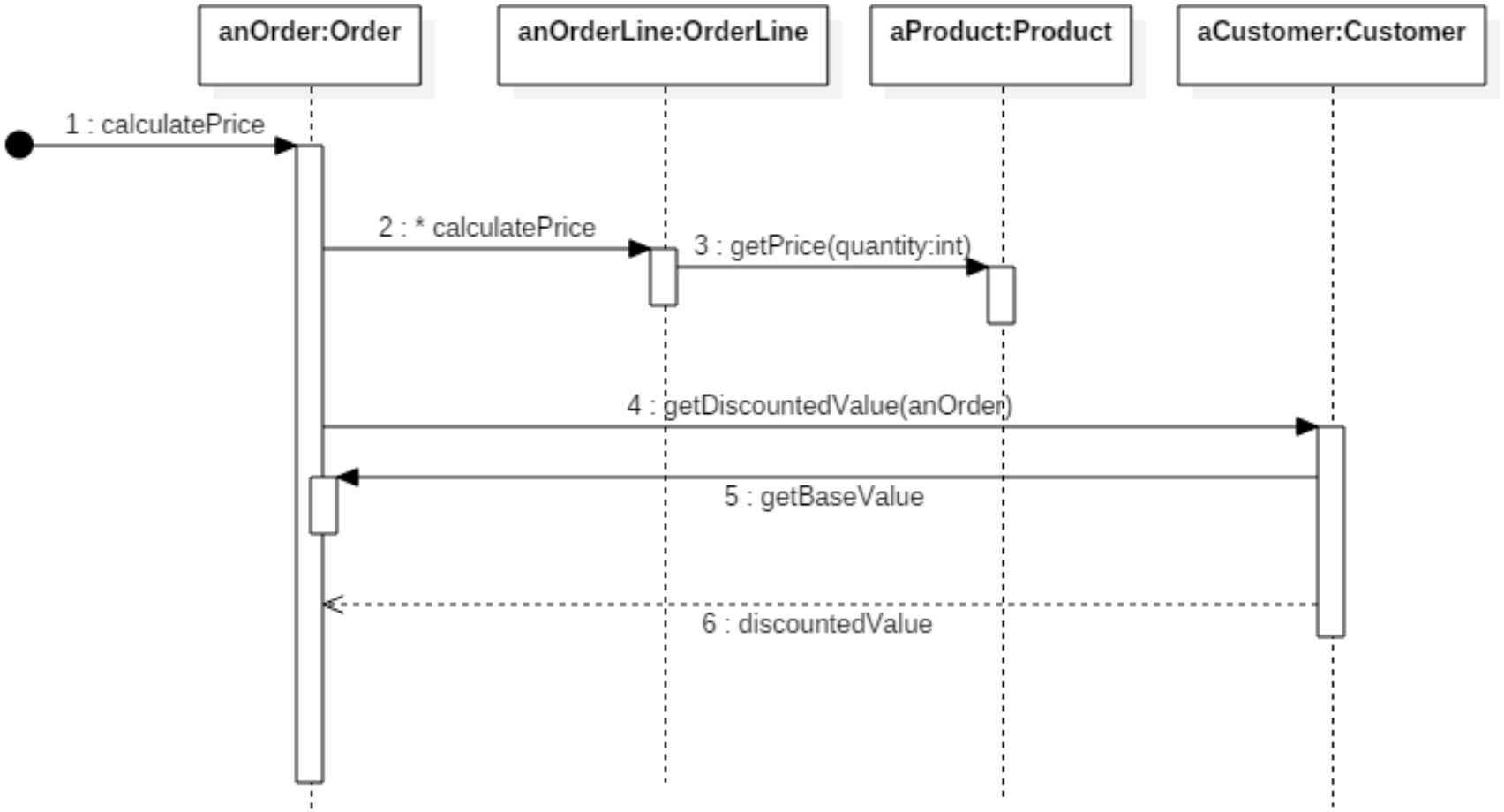
About These Diagrams

- *Loops.* The previous diagrams show two ways to indicate looping – in this course we will use iteration markers
- *Representing Objects in UML.* Diagrams also show proper UML syntax for indicating objects along the top. The syntax is:

  instanceName:className

  Both can be included, or one or the other can be dropped

Distributed Control Solution



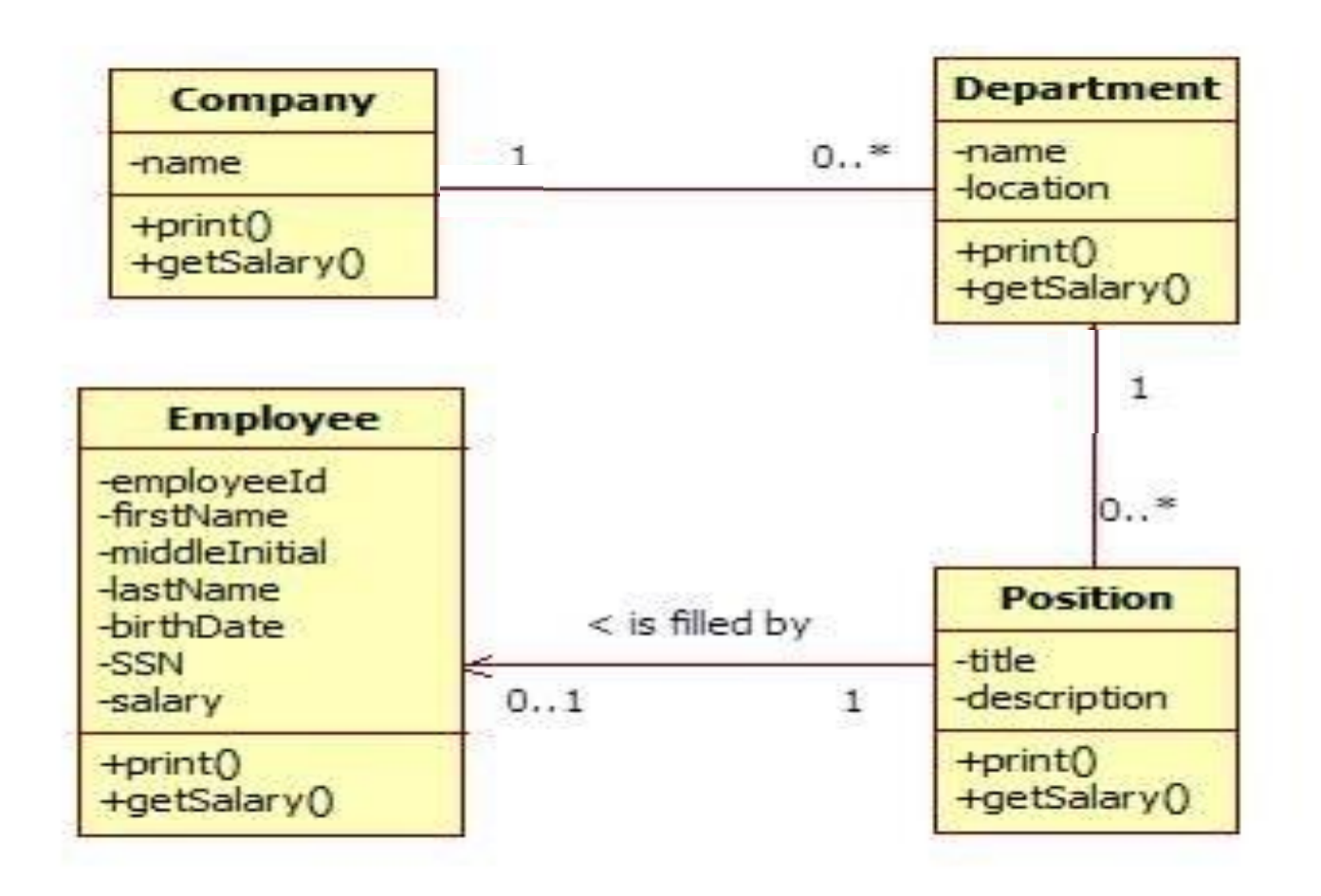
Exercise 4.2

A Company has a name and many Departments (zero or more). Each Department has a name, location, and many Positions. Each Position has a title and a description and is filled by a single Employee. An Employee has an employeeId, firstname, middleInitial, lastName, birthDate, SSN, and salary.

First Task: Sketch a class diagram to provide a model of the above description. Main goal is to identify the (four) classes and indicate some obvious attributes and associations. Write the Java code for your classes.

Second Task: Draw a sequence diagram illustrating *distributed control* for the following operation: Compute the sum of all salaries of all Employees in the Company

The Class Diagram



The Code – the Classes with Attributes

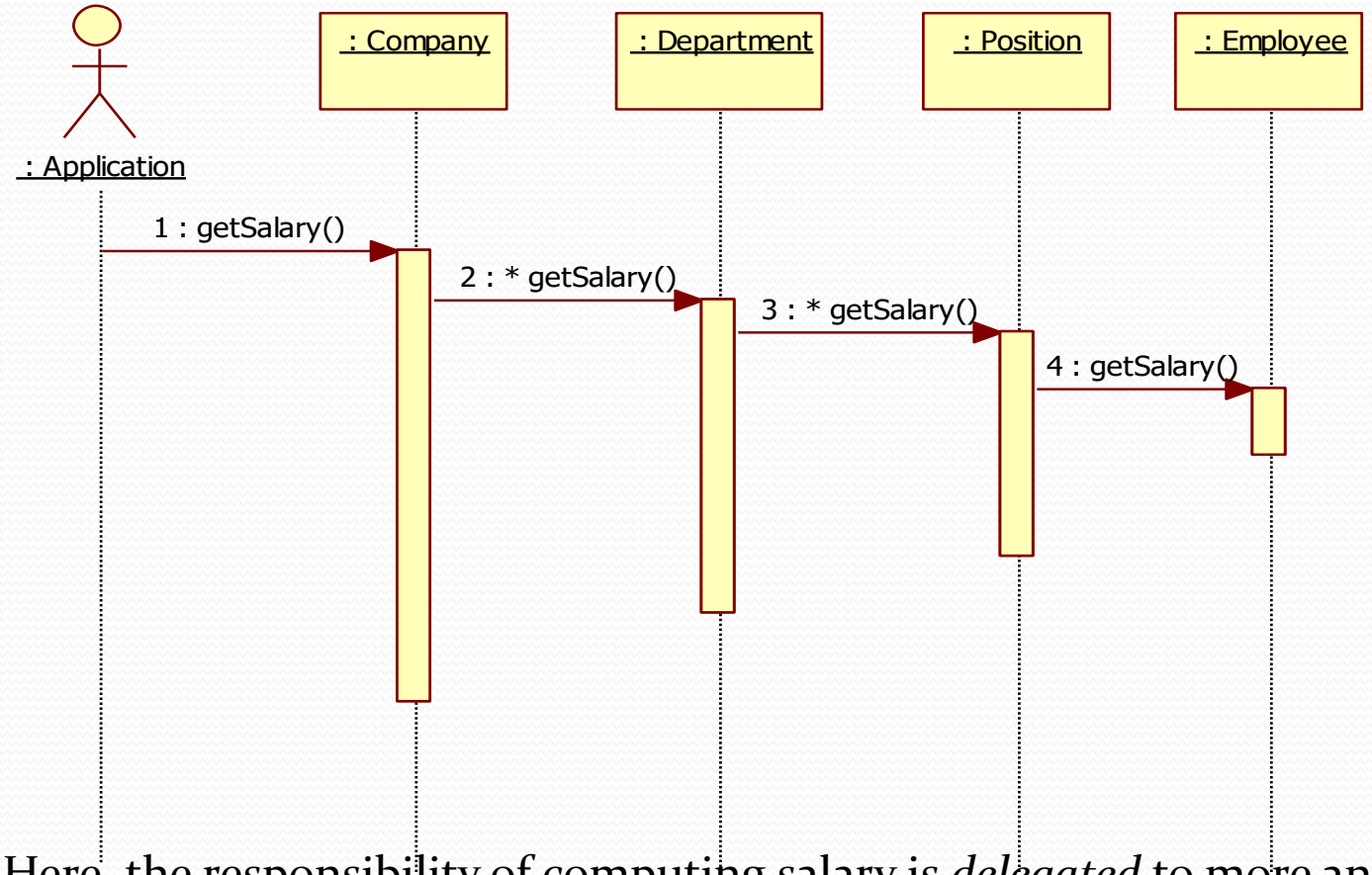
```
public class Company {
  private String name;
  private List<Department> departments;

}
```

```
public class Department {
  private String name;
  private String location;
  private List<Position> positions;
}
```

```
public class Employee {
  private String employeeId;
  private String firstName;
  private String middleInitial;
  private String lastName;
  private String SSN;
  private Date birthDate;
  private double salary;

}
```

```
public class Position {
  private String title;
  private String description;
  private Employee emp;

}
```

A Distributed Control Solution



Note: Here, the responsibility of computing salary is *delegated* to more and more fine-grained objects that carry out the task according to their own level of responsibility. Ultimately, the computation depends on each Employee salary. It is obvious and natural for control to be *distributed* in this case.

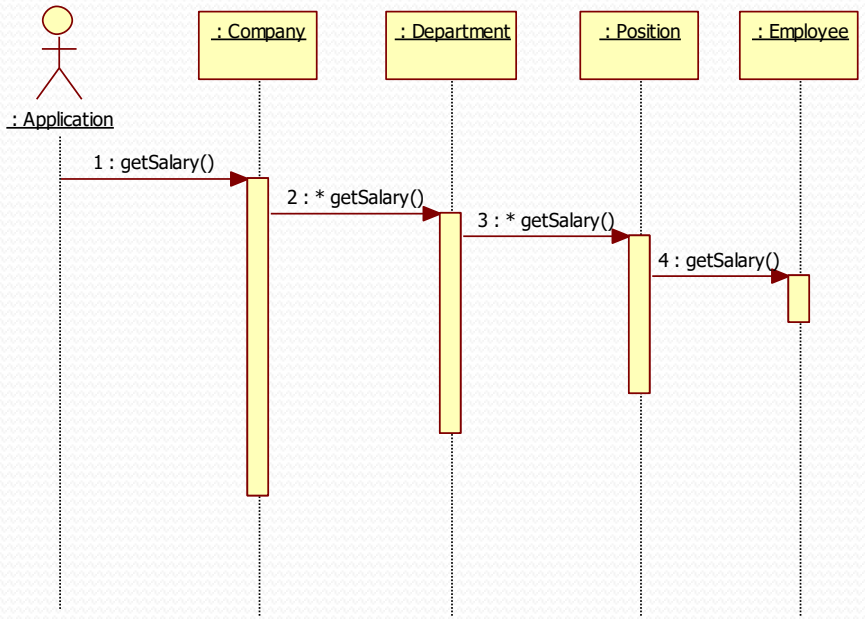
Turning It into Code

- Now we add the code showing the methods we will use to print out the salaries in our four classes.
- Here is the simple main class.

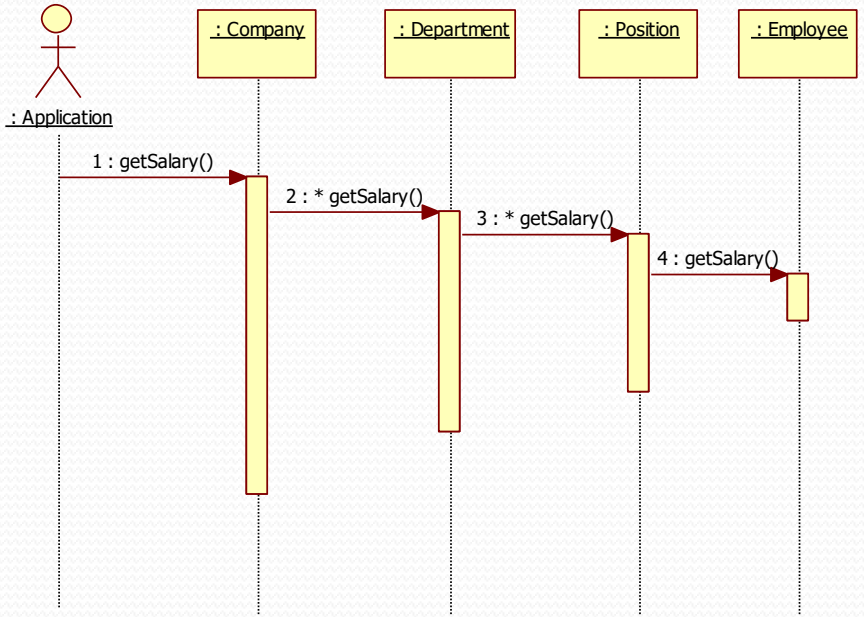
```
public class Application {
  public static void main(String[] args) {
    ...
    double totalSalary = company.getSalary();
  }
}
```

(continued)

```
public class Company {
  private String name;
  private List<Department> departments;

  public double getSalary() {
    double result = 0.0;
    for (Department dep : departments) {
      result += dep.getSalary();
    }
    return result;
  }
}
```



```java
public class Department {
  private String name;
  private String location;
  private List<Position> positions;

  public double getSalary() {
    double result = 0.0;
    for (Position p : positions) {
      result += p.getSalary();
    }
    return result;
  }
}
```



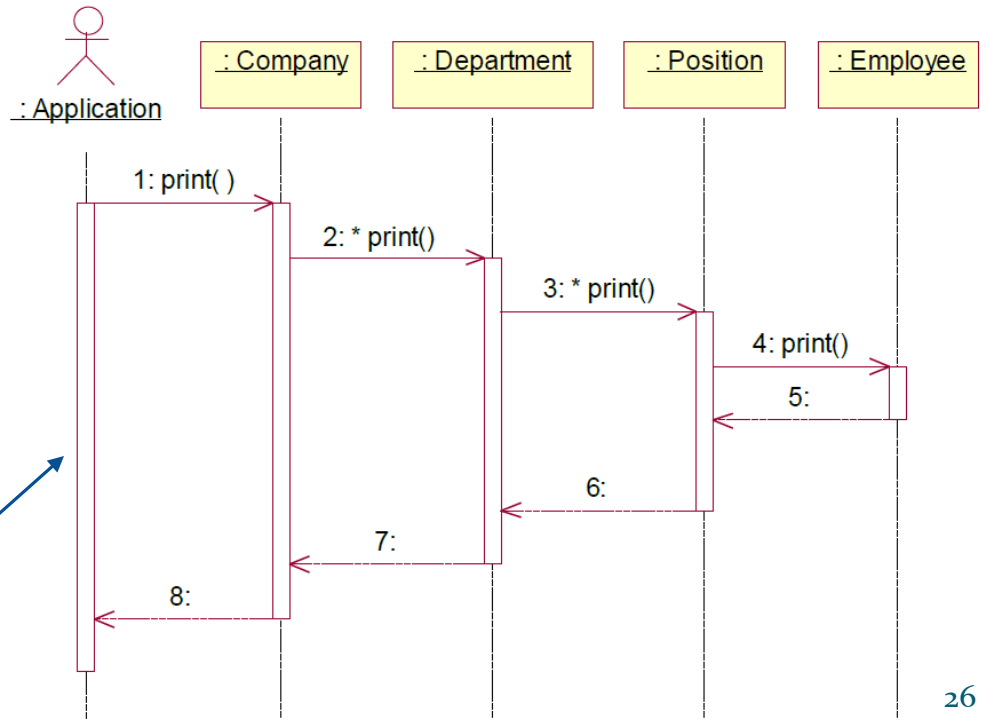

```java
public class Position {
  private String title;
  private String description;
  private Employee emp;

  public double getSalary() {
    return emp.getSalary();
  }
}
```

```java
public class Employee {
  private String firstname;
  private double salary;

  public double getSalary() {
    return salary;
  }
}
```

Return Arrows

- Return arrows may be shown, optionally. Instead, sometimes a Note is used to indicate a return value.
- When a return value makes the diagram more understandable, it is good to show it
- Showing all return arrows is bad practice because it clutters the diagram

The example here shows what a waste of space return arrows can be – and they do not add anything valuable



Bad use of returns

Main Point 1

Sequence Diagrams document the sequence of calls different objects (should) make to accomplish a specific task.

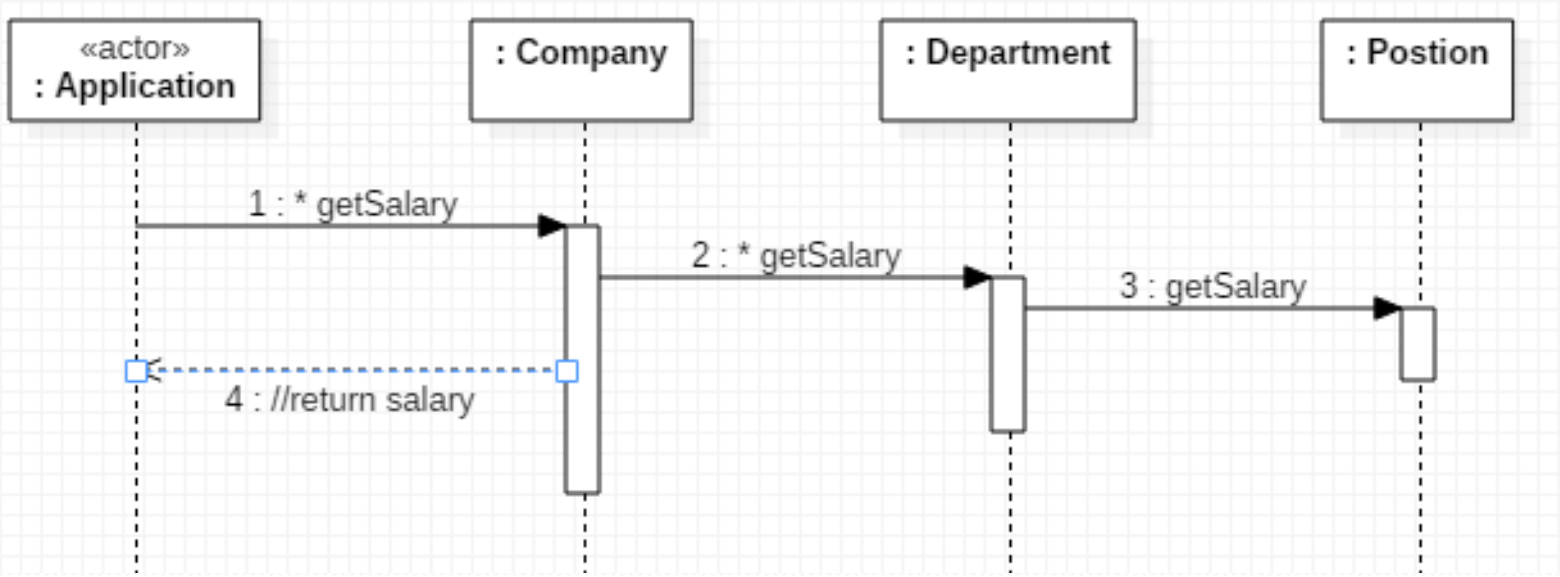
Likewise, harmony exists in diversity: Even though each object is specialized to only perform tasks related to itself, objects harmoniously collaborate to create functionality far beyond each object's individual scope.

Lesson 4: Overview

- Sequence Diagrams
- **Delegation**
- Polymorphism

Delegation

- A class can express functionality in its interface, but it may delegate some or all of the responsibility to an associated class to carry out the action



Main Point 2

OO Systems use delegation. An individual object only works with its own properties – acts only on what it knows – and then asks related objects to do what they know.

When individual actions are on the basis of self-referral dynamics, individual actions are automatically in harmony with each other because all arise from the dynamics of the a single unified field.

Lesson 4: Overview

- Sequence Diagrams
- Delegation and Propagation
- **Polymorphism**

Polymorphism

- Polymorphism = many forms
  - Objects of a particular type can take different forms
  - Achieved through dynamic binding (late binding)
  - Implies that a type has subtypes (extends, implements)

```
Account[] accts =
   {new CheckingAccount(),
    new SavingsAccount()};
double total = 0.0;
for(Account a: accts) {
  total += a.getBalance();
}
```

The runtime first checks the runtime type of the object to find a `getBalance()` method; if not found, it checks successive superclasses, rising finally to Object

Late Binding

- Binding is the connection of a method call to a method implementation.

- Late binding, or dynamic binding, occurs at run-time.
  - the JVM runtime finds the correct method body to associate with the method, and invokes it at run-time.
    - by traversing the inheritance chain, starting at the runtime type of the object
  - late binding is the implementation mechanism that makes polymorphism work (in Java)

Early Binding

Static, private, final methods are bound to the correct method body at compile time – this is called *early binding*.

Static methods. When a call is made to a static method, the method body may not be in the current class – it may be in a super class or some more distant ancestor. The compiler will climb the inheritance chain till it finds the first occurrence of an implemented version of the method and creates the binding – see demo lesson4.lecture.staticinherit.fifth and .second.

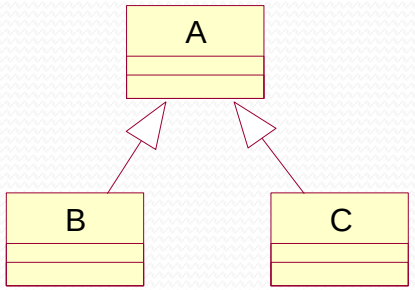
Private methods. When a private method is called on an object of type A, there is no possibility it was overridden in a subclass, and because of the visibility rules for overriding, it could not have been inherited from a superclass. The binding is uniquely determined in this case

Final methods. When a final method is called, it could not have been overridden in a subclass. The compiler climbs the inheritance chain till it finds the first place where this method has an implementation and performs the binding to that one. See demo lesson4.lecture.finalinherit

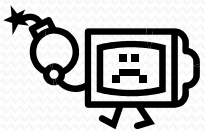
Static Typing

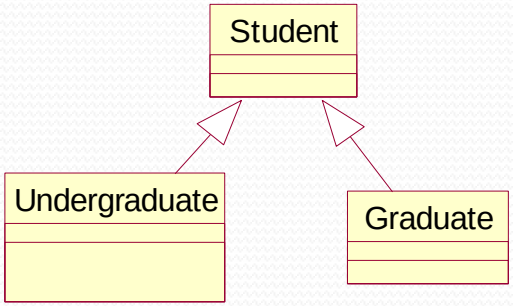
Objects of type B or C can be cast as type A

```
public class Student { ... }
public class Undergraduate extends Student { ... }
public class Graduate extends Student { ... }

Student st1, st2, st3;
Graduate st4;
st1 = new Student();
st2 = new Undergraduate();
st3 = new Graduate();
st4 = new Student();
```



Where is the Compiler Error?

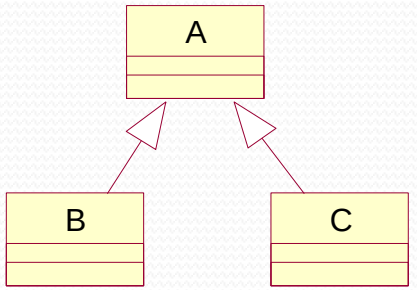


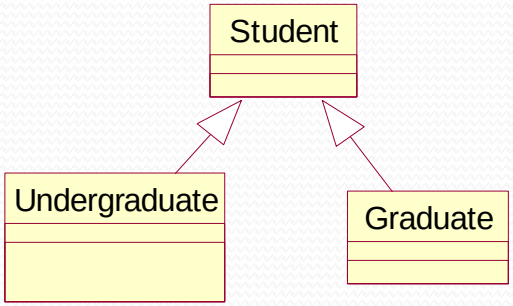


(continued)

Objects of type B or C can be cast as type A

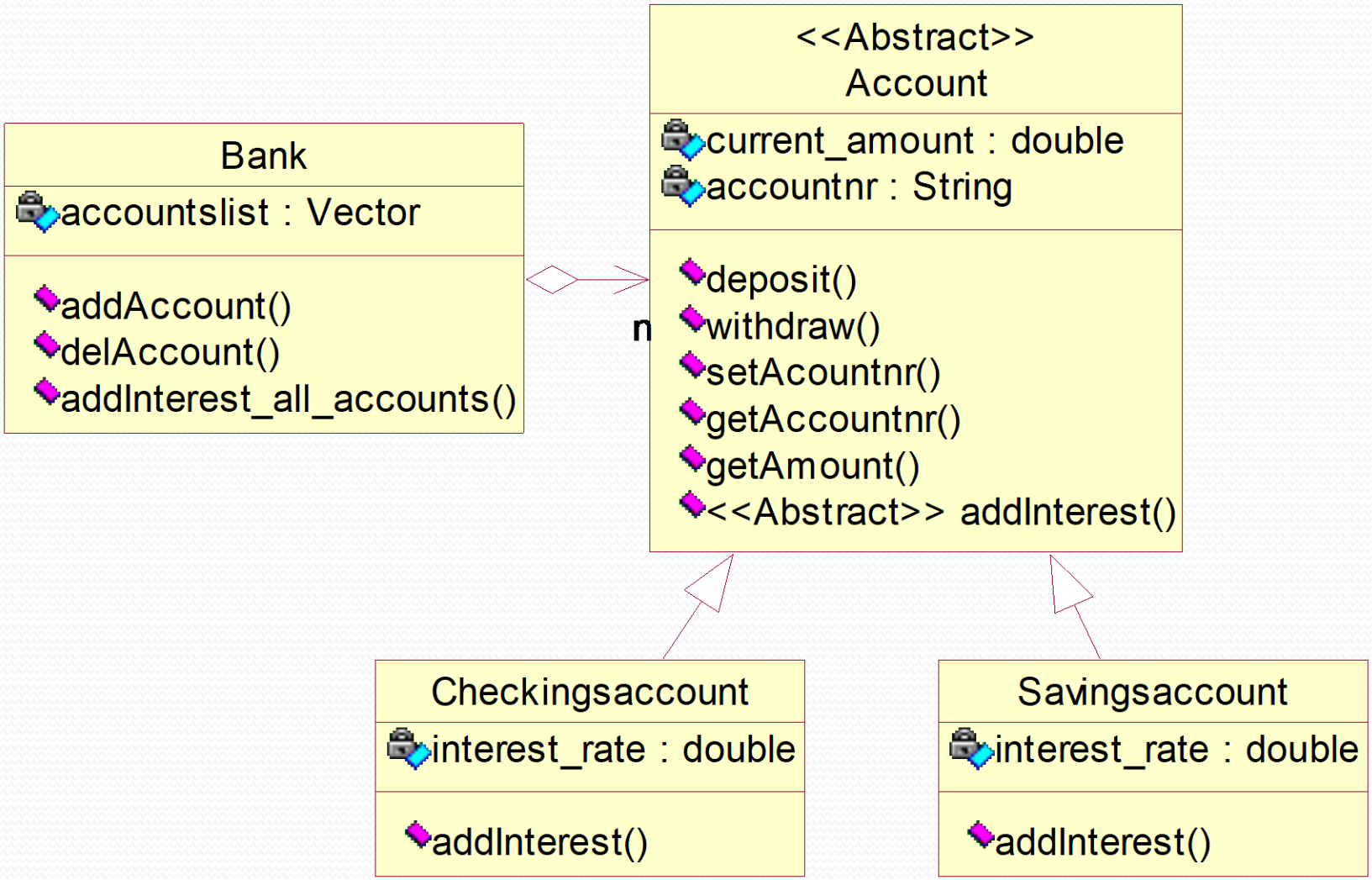
```
public class Student { ... }
public class Undergraduate extends Student { ... }
public class Graduate extends Student { ... }

Student st1, st2, st3;
Graduate st4;
st1 = new Student();
st2 = new Undergraduate();
st3 = new Graduate();
st4 = new Student(); //error
```





NOTE: In the first three cases, the Student class is the *static type* of the object created. The *runtime types* are, respectively, `Student`, `Undergraduate`, and `Graduate`.

Polymorphism Example



```java
public abstract class Account {
  private double current_amount;
  private String accountnr;

  public void deposit(double amount) {
    current_amount += amount;
  }
  public void withdraw(double amount) {
    current_amount -= amount;
  }

  public void setAccountnr(String anr) {
    accountnr = anr;
  }
  public String getAccountnr() {
    return accountnr;
  }

  public double getAmount() {
    return current_amount;
  }

  public abstract void addInterest();
}
```

```java
public class CheckingAccount extends Account {
  private double interest_rate = 0.01;

  @Override
  public void addInterest() {
    deposit(getAmount() * interest_rate / 2);
  }
}
```

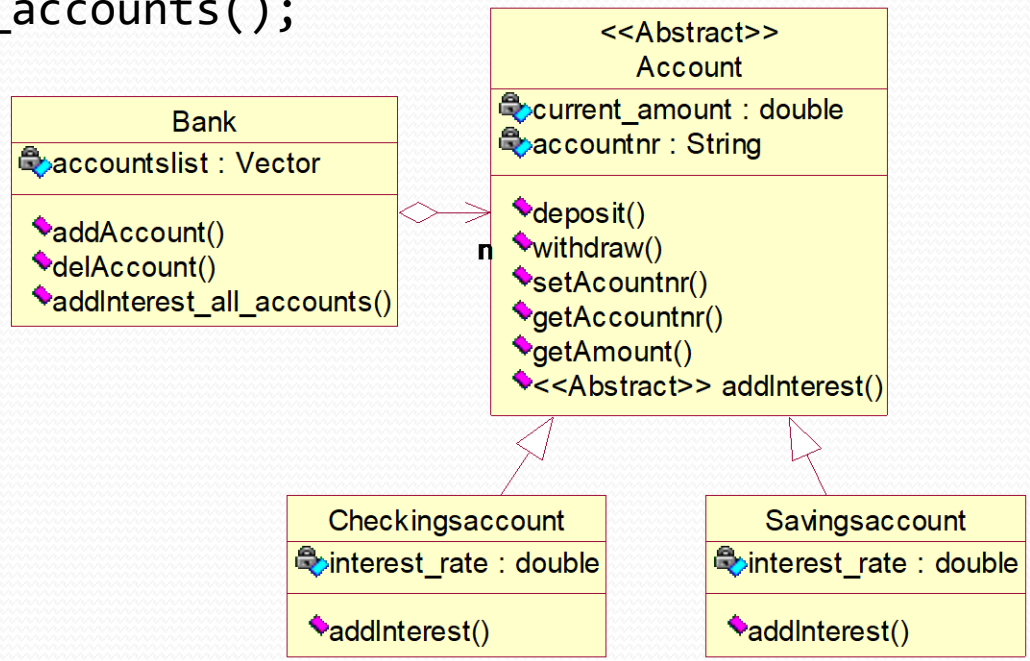
```java
public class SavingsAccount extends Account {
  private double interest_rate = 0.0425;

  @Override
  public void addInterest() {
    deposit(getAmount() * interest_rate);
  }
}
```

```
public class Bank {
  private Map<String, Account> accounts =
      new HashMap<String, Account>();

  public void addInterest_all_accounts() {
    for (Account a : accounts.values()) {
      a.addInterest();
    }
  }

  public void addAccount(String type, String accountnr) {
    Account account;
    if (type.equals("checking")) {
      account = new CheckingAccount();
    } else {
      account = new SavingsAccount();
    }
    account.setAccountnr(accountnr);
    accounts.put(accountnr, account);
  }

  public void delAccount(String accountnr){
    accounts.remove(accountnr);
  }
}
```

P2I

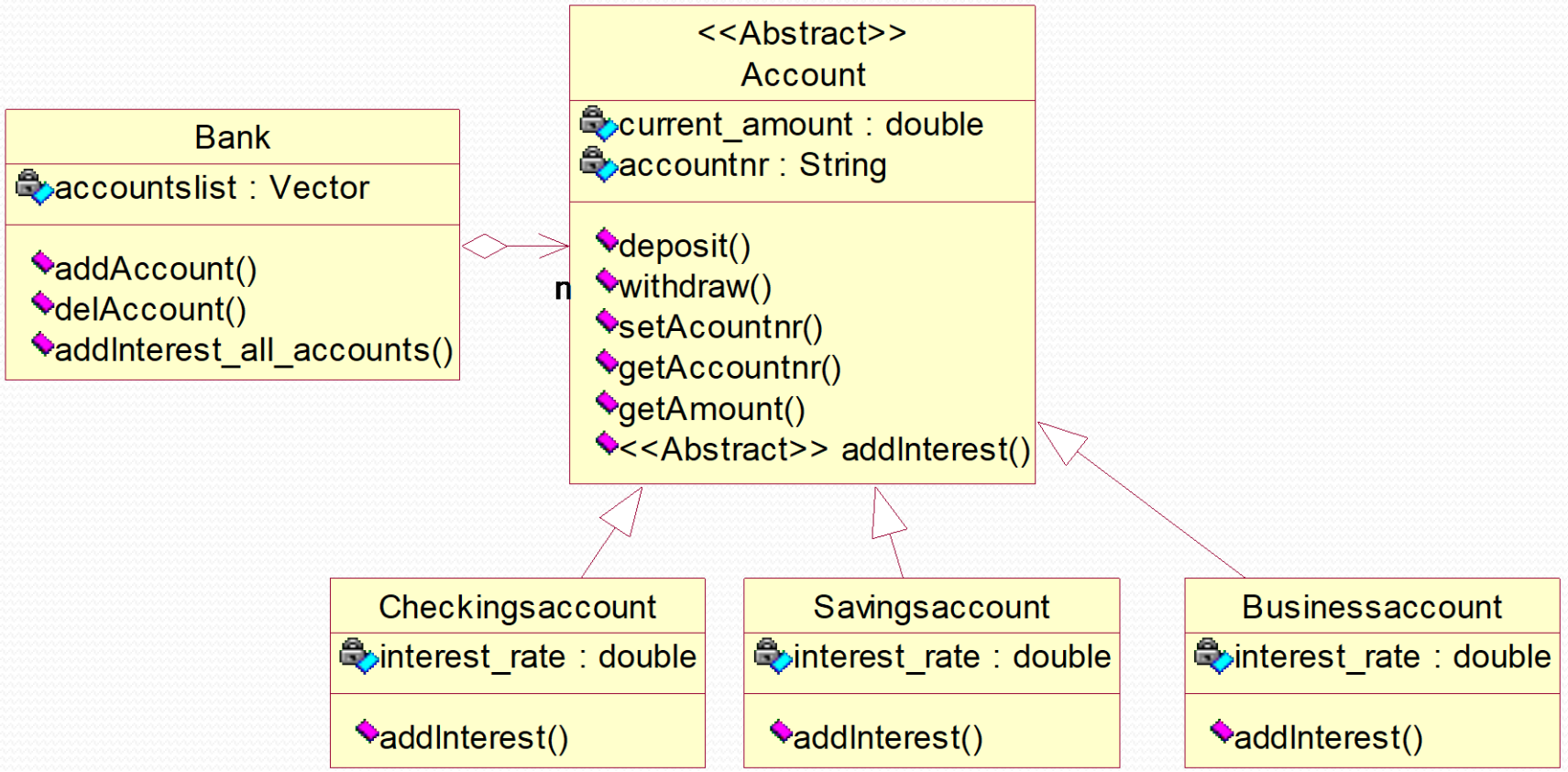
Polymorphism

```
public class BankApp {
    public static void main(String[] args) {
        Bank mybank = new Bank();
        mybank.addAccount("checking", "1");
        mybank.addAccount("checking", "2");
        mybank.addAccount("savings",  "3");

        mybank.addInterest_all_accounts();
    }
}
```



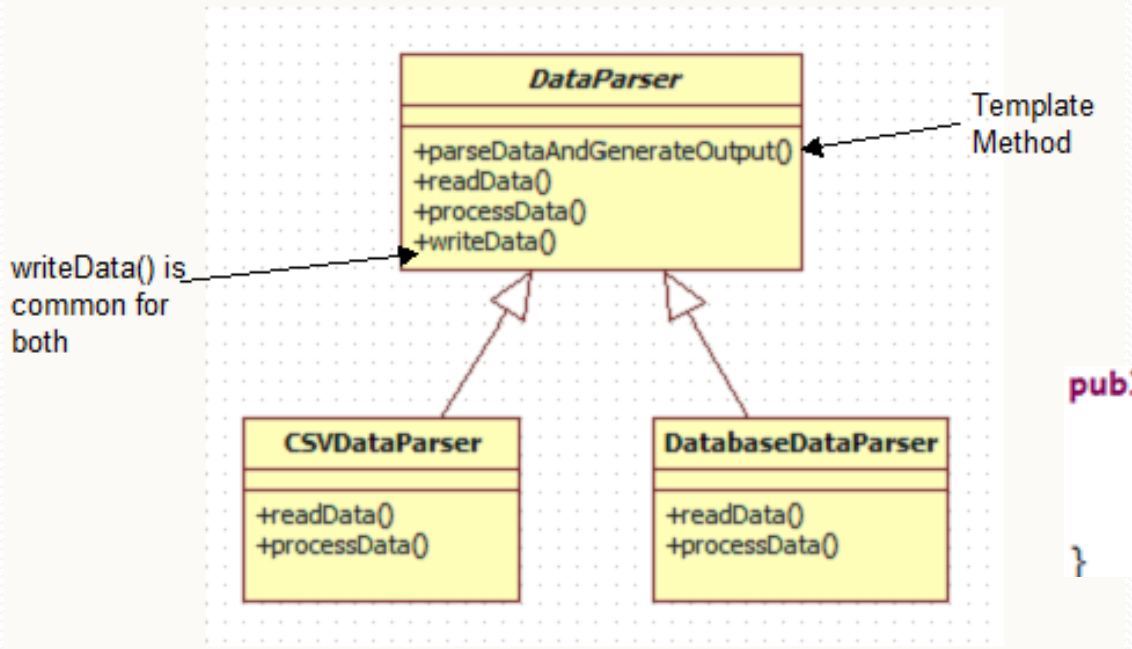
Why do we want polymorphism?

- It allows us to **extend** our program with new features without **changing** existing (already tested) code.



Polymorphism and the Template Method Pattern

Sometimes a class at the top of an inheritance hierarchy needs to carry out a sequence of tasks, some of which need to be implemented by subclasses. This situation is an example of the *Template Method Design Pattern* – see lesson4.lecture.template




```
public void parseDataAndGenerateOutput() {
    readData();
    processData();
    writeData();
}
```

Open-Closed Principle

- Software should be designed so that it is **open for extension**, but **closed for modification**.

- All systems change during their life cycle, but when a single change results in a cascade of changes, the program becomes fragile and unpredictable. When requirements change, you implement these changes by adding new code, not by changing old code that already works. Account example in earlier slides illustrates this principle

- Demo: lesson4.lecture.openclosed.closedcurve

- **Example**. If you work with a framework (like Spring), the *only way* to extend functionality is by adding new classes since you do not have the option to modify the framework code directly. This means that Spring's framework code adheres 100% to the Open-Closed Principle.

Main Point 5

Polymorphism supports use of the *Open-Closed Principle*: The part of our code that is established and tested is closed to modification (change), but at the same time the system remains open to changes, in the form of *extensions*.

In a similar way, progress in life is vitally important, and progress requires continual change and adaptation. But change stops being progressive if it undermines the integrity of life. Adaptability must be on the ground of stability.

Summary

This lesson has been about modeling Object Collaboration and the uses of Polymorphism.

- Sequence diagrams document the sequence of method calls between objects
- Object diagrams show the relationships between objects. It is important to know how a class diagram translates into an Object Diagram
- The OO tools of association, delegation, and polymorphism allow us to build software solutions that reflect accurately the system we are modeling and are efficient, flexible and extensible.

Connecting the Parts of Knowledge With the Wholeness of Knowledge

1. Sequence Diagrams and Object Diagrams both show how objects relate to each other.

2. To preserve encapsulation, objects should only act on their own properties, and to accomplish tasks that are the responsibility of other objects, they should send messages (delegation)

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3. **Transcendental Consciousness** by its very nature, has the fundamental association of self-referral – the Self being aware of the Self. This is its only responsibility

4. **Wholeness moving within itself**: In Unity Consciousness one experiences directly that the simple self-knowing of pure consciousness – maintenance of that one "responsibility" – automatically leads to accomplishment of all other responsibilities