Introduction to Operating Systems and SQL for Data Science

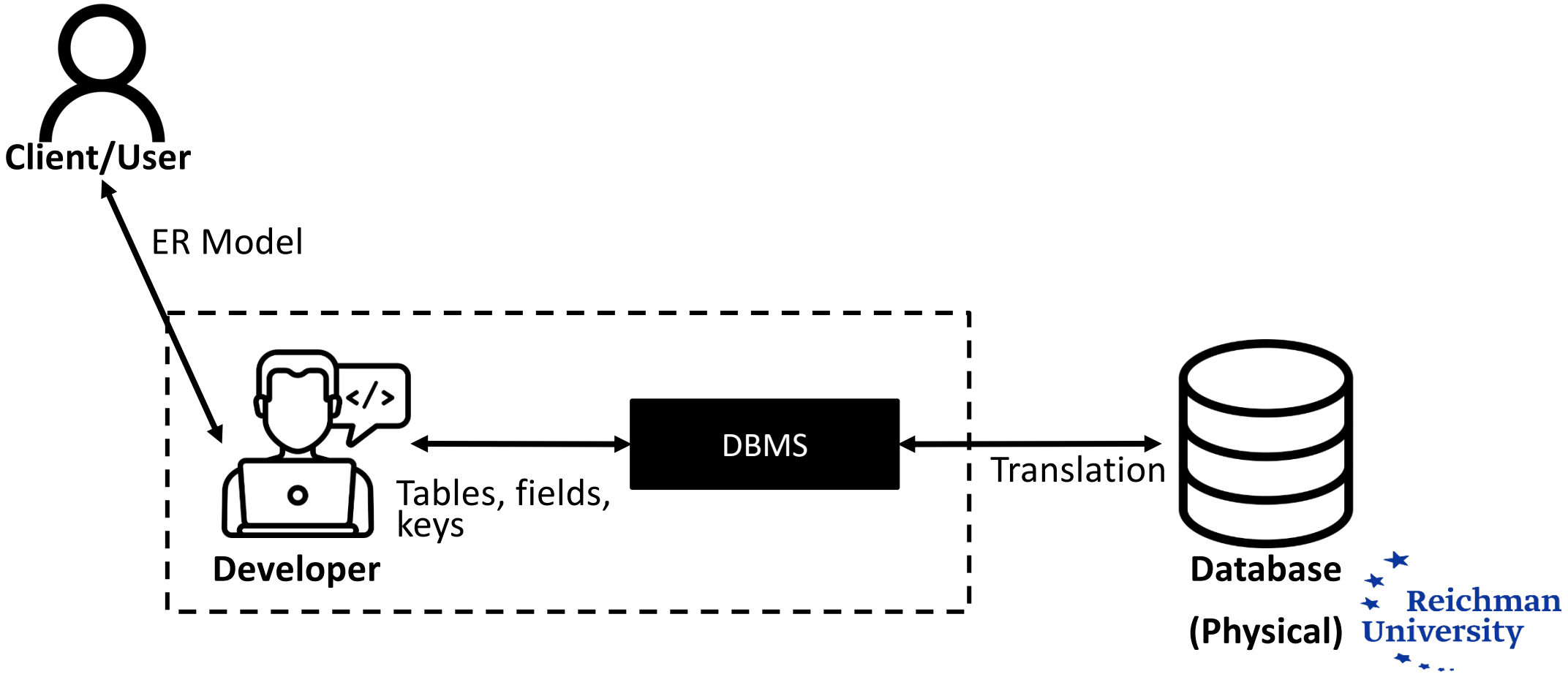
Lecture 11 – Conceptual model (ERD)

Previous lecture

- Normalization
- 1NF, 2NF, 3NF
- Functional dependencies
- Lossless-join decomposition
- BCNF

DBMS – the bridge between the logical to physical

How to build a data base to a real-world problem?



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Reminder: design stages of databases

- Conceptual design:
  - What data should be stored in the database and the relationships between them.
  - Does not include to the implementation of the system.
- Logical design:
  - How to represent the conceptual design in the structure of a particular DBMS.
  - For example, how to represent the data and the relationships between them in RDBMS.
- Physical design
  - Translation of the logical design into a physical structure.
  - Takes into account performance constraints, storage volumes, indexes, etc.

Conceptual design

How to perform a conceptual design

- What are the goals of conceptual design?
  - **Understanding the structure** of data in reality (in the organization).
  - **Representation of the data structure** using an abstract model (No "computer" terms)
  - **Communication tools** between clients/users and developers.

- What is the product of conceptual design?
  - Conceptual model: a description of the information we want to keep.

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Desirable features for a conceptual model

- Expressive: Allows expression of a variety of data, relationships and constraints.
- Simplicity: Easy to understand even for non-professionals (users).
- Minimalism: Includes a small number of basic terms that are simple and clear.
- Diagrammatic representation: Can be described by a simple diagram.
- Formality: Can be formally / accurately described.
- Accurate (algorithmic) mapping to a logical schema of the database.

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Entity Relation Diagram (ERD)

Entity Relation Diagram (ERD)

- A common conceptual model.
- Developed by Peter Chen in 1976.

Peter Chen

- It is a graphical model that represents the **information system as a collection of entities and of relationships between entities**.
- The model provides a tool for designing the database based on the information template in the organization

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Entity

An entity represents in the model a tangible or abstract object that has an existence and has a meaningful interest in a particular context.

- Examples:
  - Object (building, book, car, machine factory, item in stock).
  - Person[or any other living thing](factory worker, student, hospital patient, animal).
  - Abstract concept or idea (course, driving test, flight, employment).
  - Event (attendance report, bank account transaction, private entry into stock)
- An entity has attributes

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Attribute

- An attribute value is defined as the attribute content at a point in time.

- Examples
  - The value of the attribute height in the object "Avi Levy" is 1.80 meters.
  - The value of the checking account feature in account number X is 2,200 NIS.

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Types of attributes

- A simple attribute
  - Example: Student ID
- Composite attribute
  - Example: Address - including city, street, house number and zip code
- Multi-valued attribute
  - Example: Phones, grades
- Derived attribute
  - Example: The age attribute is derived from the year of birth attribute

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Key

- An entity group key is defined as a collection of **minimal** attributes that unambiguously identify an instance of a particular entity in the entity group

- Examples
  - In the "Students" entity group: ID is the key
  - In the "Soldiers" entity Group: ID **or** identity number (military) is the key
  - In the group of entities “Grades”: student ID + course number + semester + year is the key
  - In the "Courses" entity group: course number **or** department number + course name is the key

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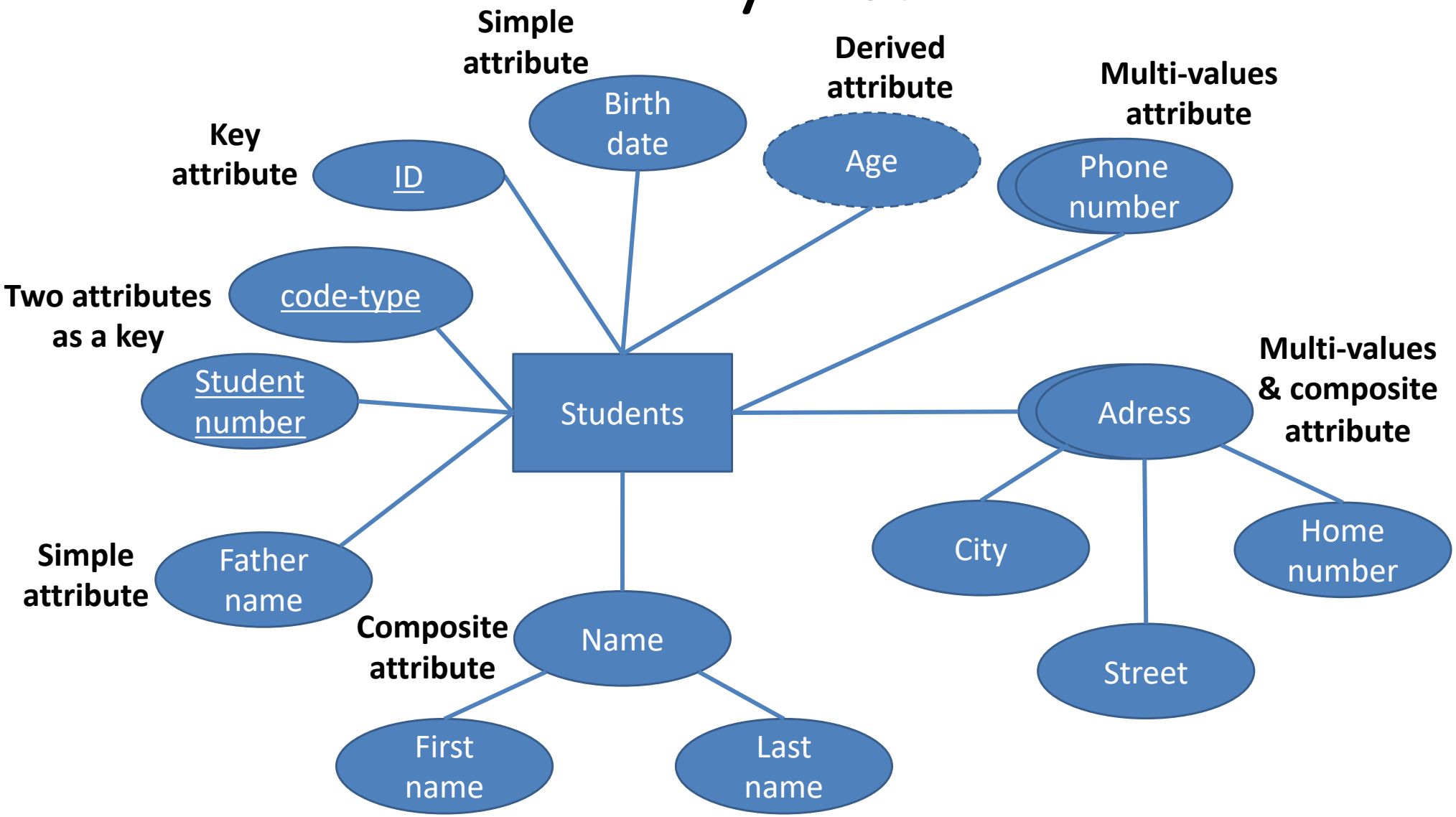
Is it a key?

- Is ID + student name is a key?
  - **No!** the key has to be minimal.

- Is the student name is a key?
  - **No!** because it does not unambiguously define each instance

My first ERD…



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Connection

Connection is a meaningful relationship between entities.

Examples:

- Students **study** in courses
- Actors **participate** in movies

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How relations looks in a diagram?

While an entity is modeled as a rectangle.

An attribute is modeled as an ellipse.

A relation is modeled as a rhombus.

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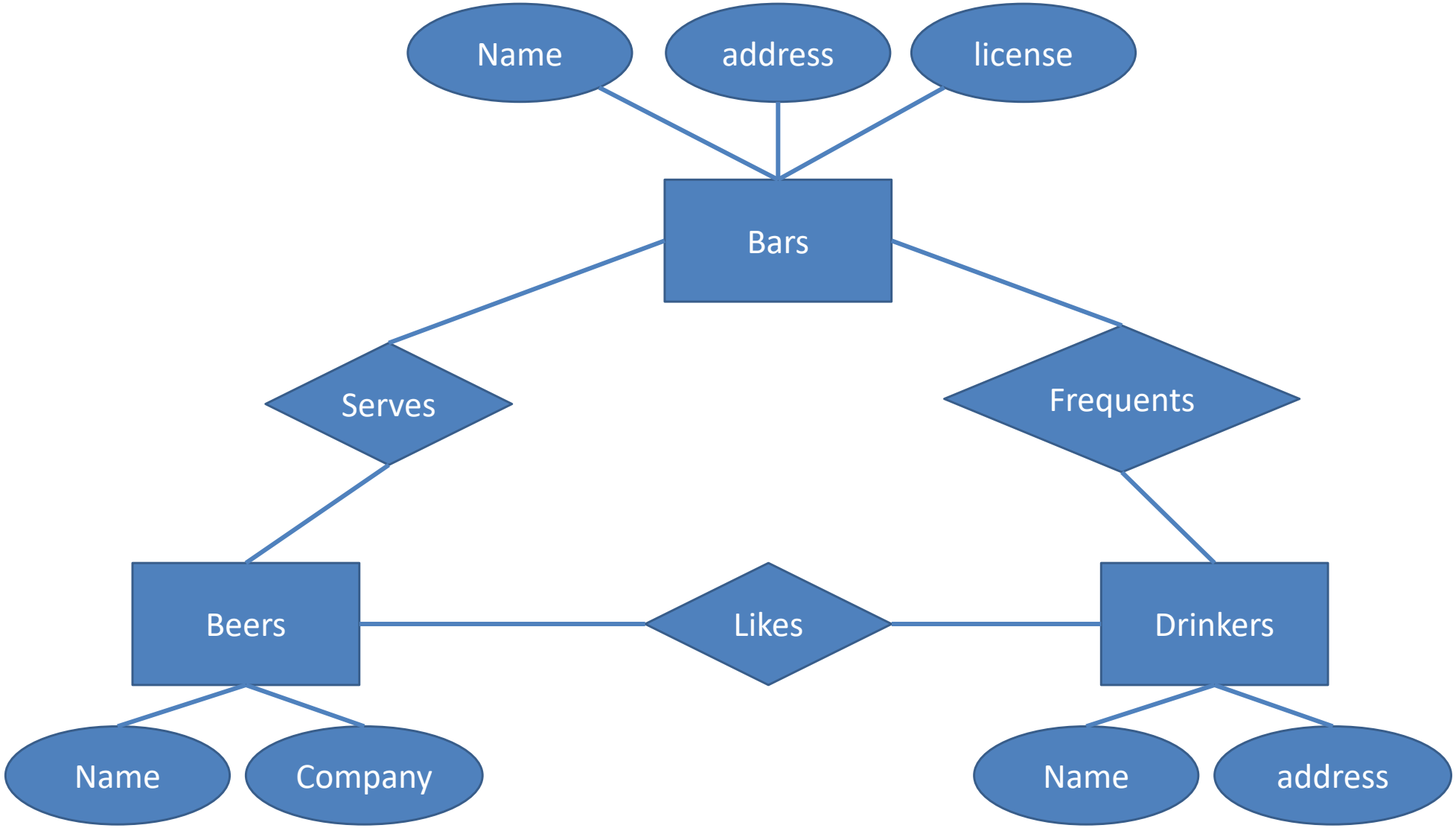
Example 2 - bars



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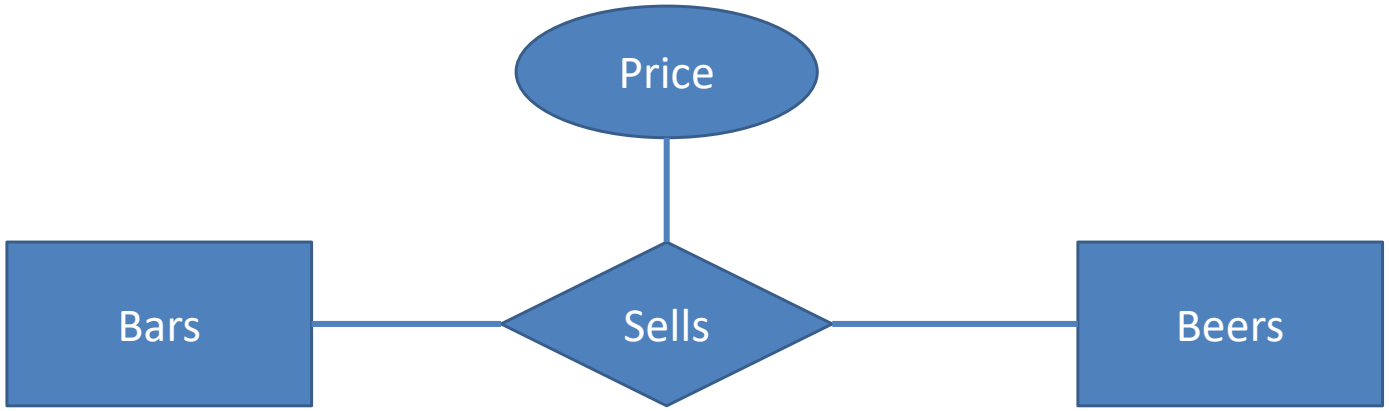
Informative connection

Sometimes we add features to the connection itself to add important information:



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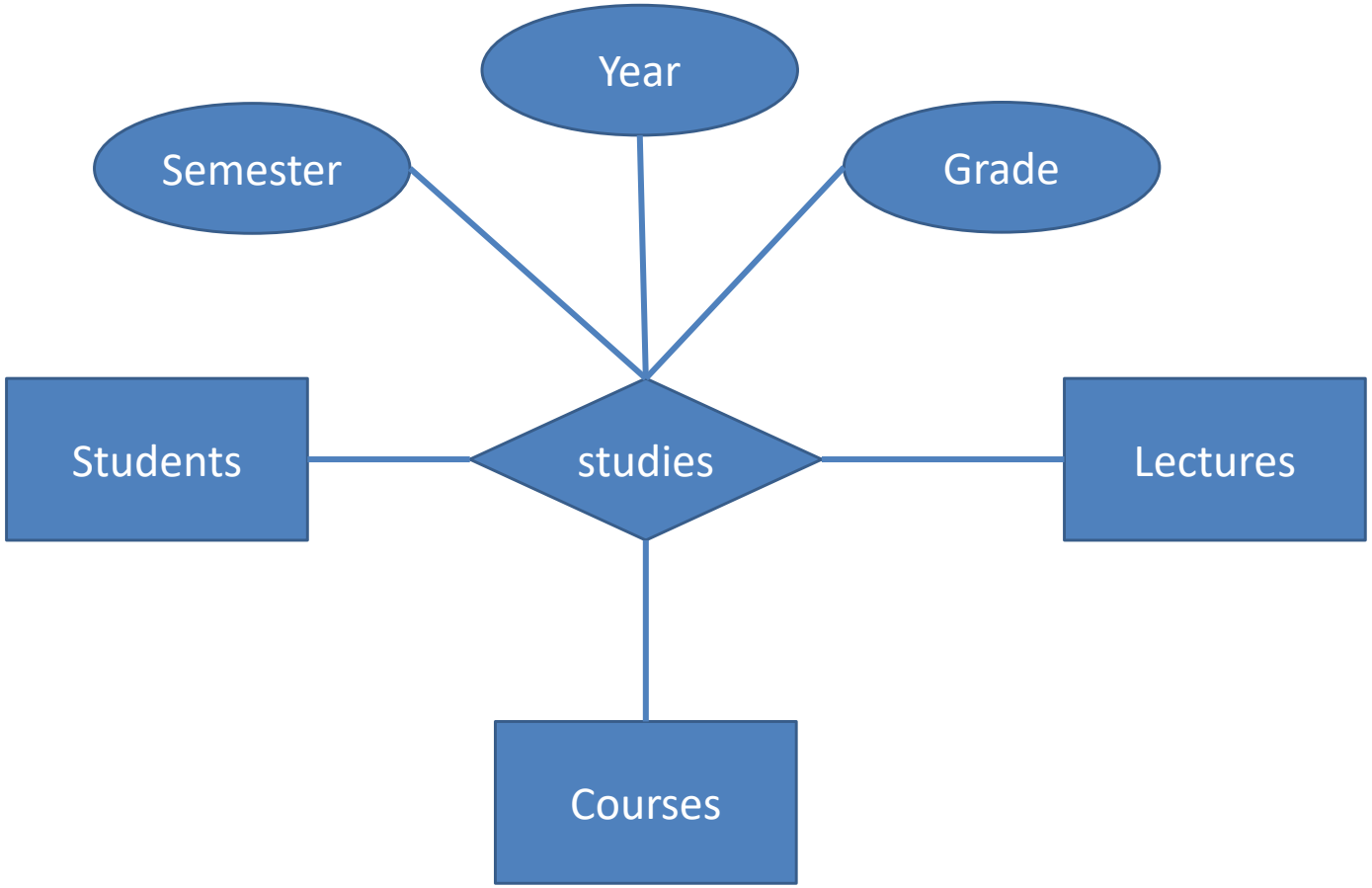
Example 2



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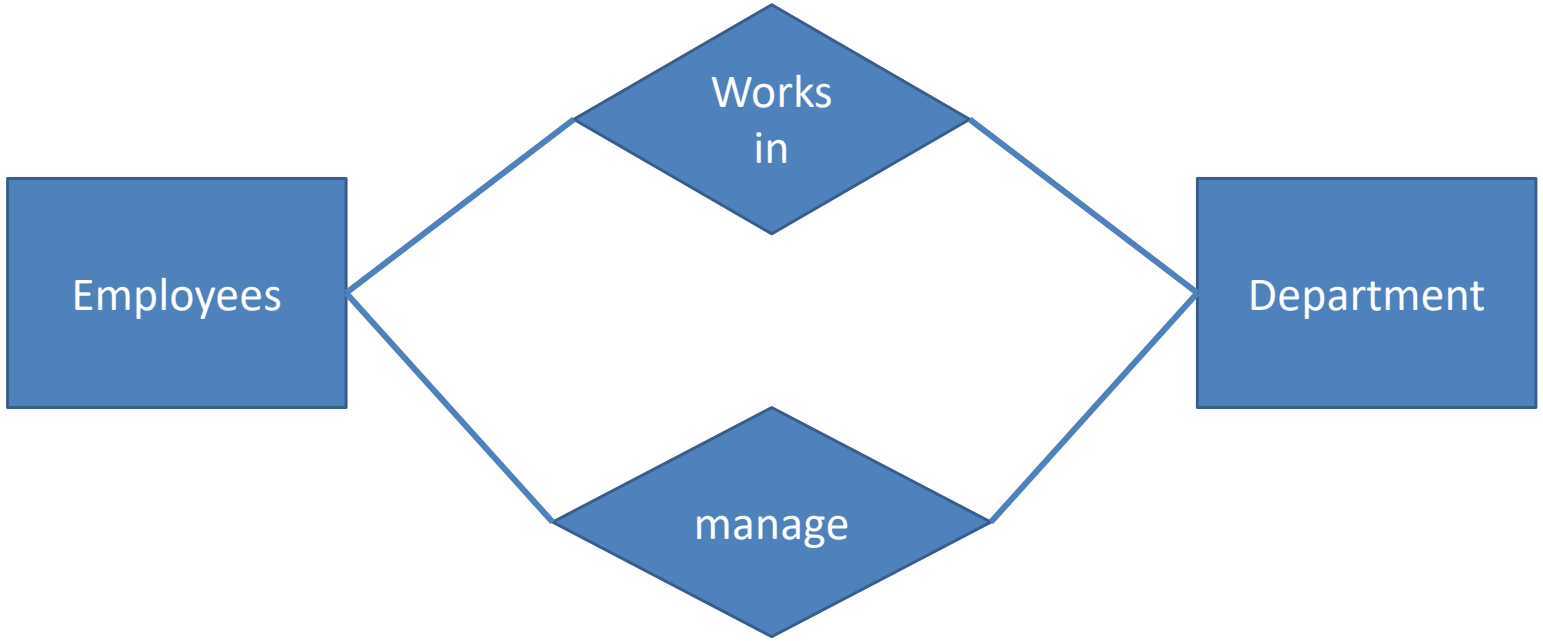
Several connections between the same entities



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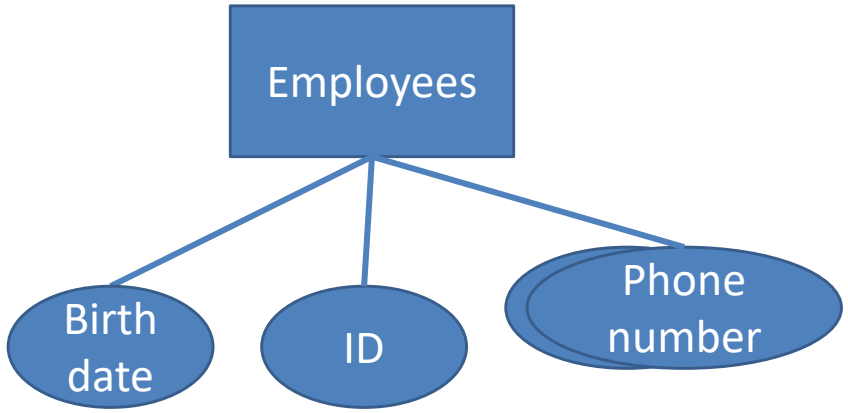
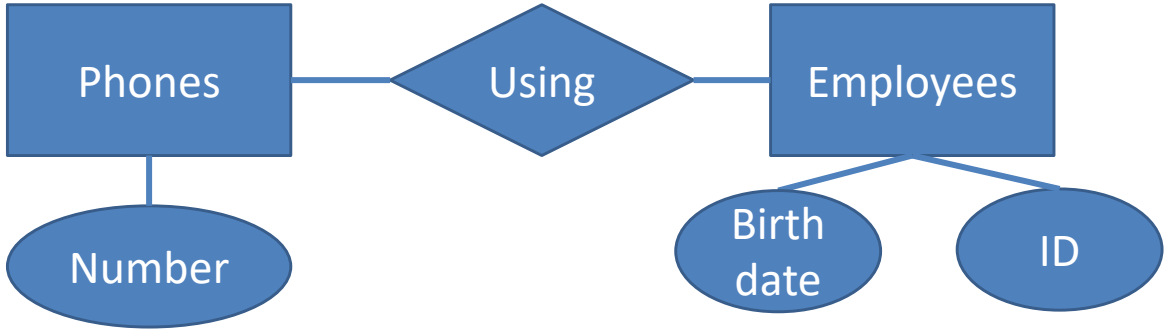
Connections vs. attributes

Example: for each employee there is one or more phone numbers.

How will the ERD look?





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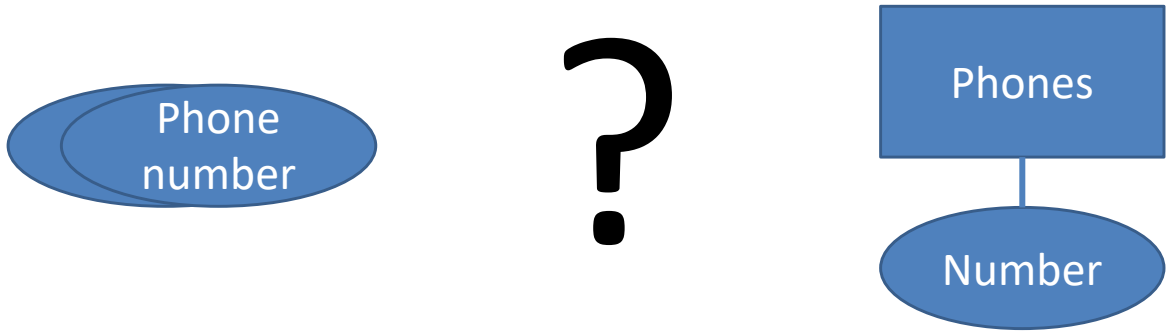
When an attribute and when an entity?



Rule of thumb:

If there are some attrbitures -> then it's an entity

Otherwise -> a feature of another entity

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Example

- In a system that deals with students in which all that is interesting to know about departments is their names.
- A department name will be defined as an attribute (of a student).
- If you are interested in more details about classes, then a class will be defined as an entity (that has at least two attributes).

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Characterization of connections

Characterization of connections

Relationships can be characterized by:

- **Connection type.**
- Connection cardinality.
- Connection degree.

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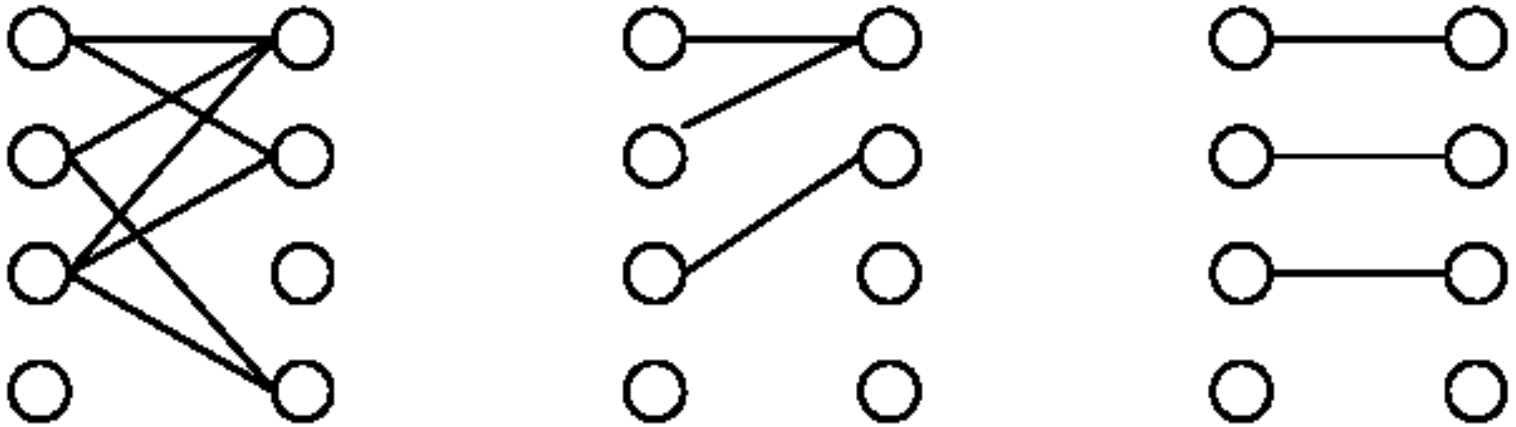
Connection type

Examples:

- Passenger in the plane and seat in the plane.
- Student and department.
- Student and course.



Many-many Many-one One-one

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Example to a 1-to-1 connection

A "one to one" connection exists between the "passengers" entity group and the "seat in flight" entity group.

why?

- Since each passenger has only one seat.
- Each seat has a maximum of one passenger.

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How we represent a 1-to-1 in the diagram?

<u>Note there are arrows on both sides!</u>

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Example to a one-to-many connection

The "One to Many" connection exists between the "Students" entity group and the "Departments" entity group.

Why? (Assuming a student can enroll in only one class)

- Because Each student belongs to only one department. (One)
- But each department has many(more than one) students. (Many)

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How we represent a 1-to-M in the diagram?

<u>Note there is an arrow on the side of the One!</u>

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Example to a many-to-many connection

The "Many to Many" connection exists between the "Students" entity group and the "Courses" entity group.

Why? Since-

- Each student can attend several courses.
- Each course has many(more than one) students.

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How we represent a M-to-M in the diagram?

<u>Note there are no arrows on either sides!</u>

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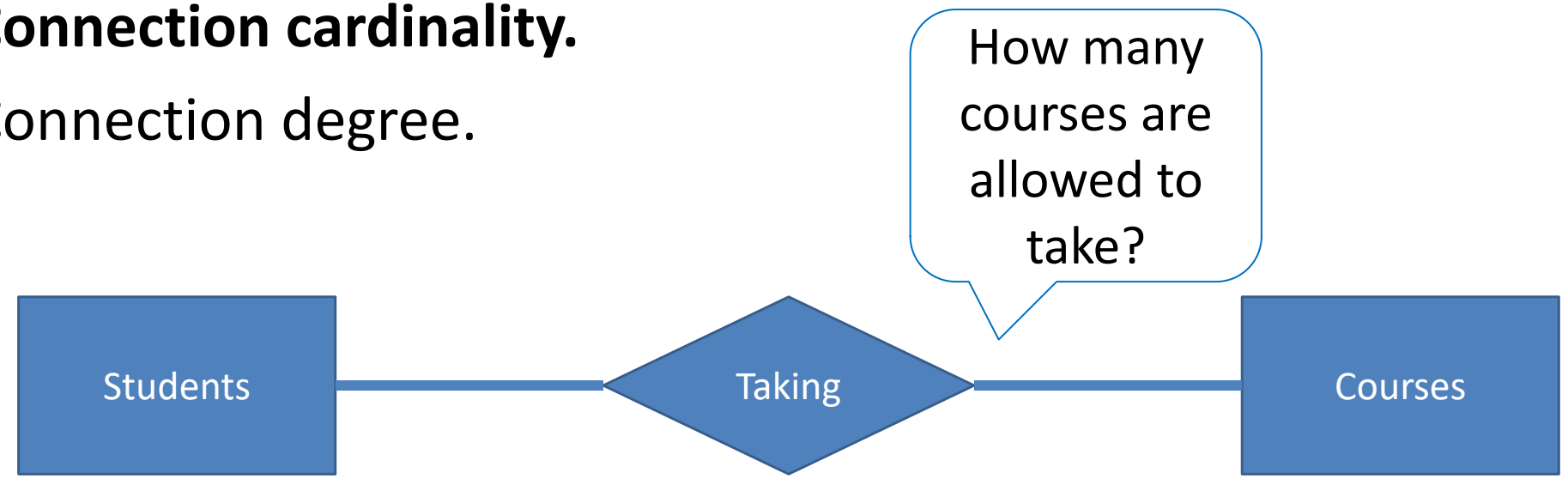
Characterization of connections

Relationships can be characterized by:

- Connection type.
- **Connection cardinality.**
- Connection degree.



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Connection cardinality

Sometimes the type of connection is not enough, and more accurate details are required. For this we will use the cardinality of the connection.

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Example a for connection cardinality

Each student can take between ? courses.

Each course must be attended by at least ? students and no more than ? students.

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Example b for connection cardinality

Each passenger has exactly one seat.

Each seat on the flight can have between 0 and 1 passengers.

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Example b for connection cardinality

There are those who give up the arrow when cardinality appears.

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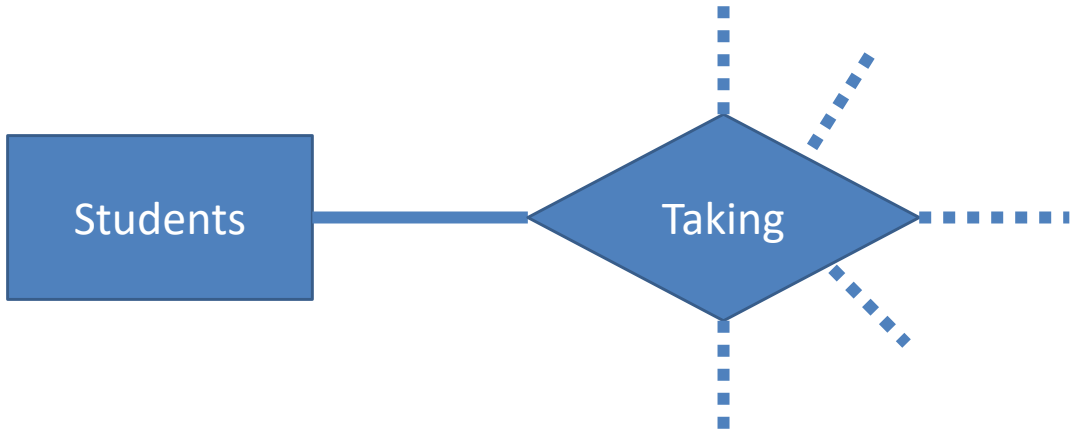
Characterization of connections

Relationships can be characterized by:

- Connection type.
- Connection cardinality.
- **Connection degree.**

A connection can connect several entities



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Connection degree

The degree of connection is defined as the number of entities participating in that connection.

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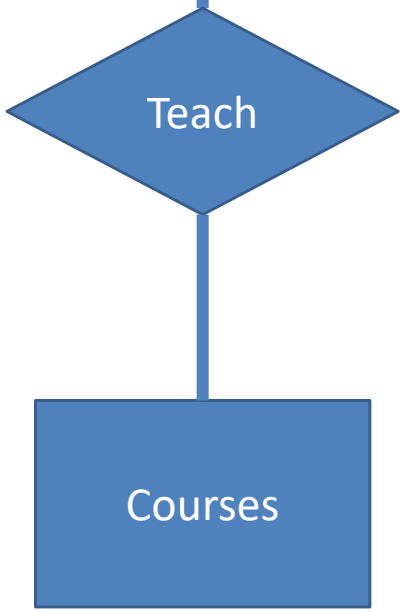
Students, lecturers, and courses

What is the problem?



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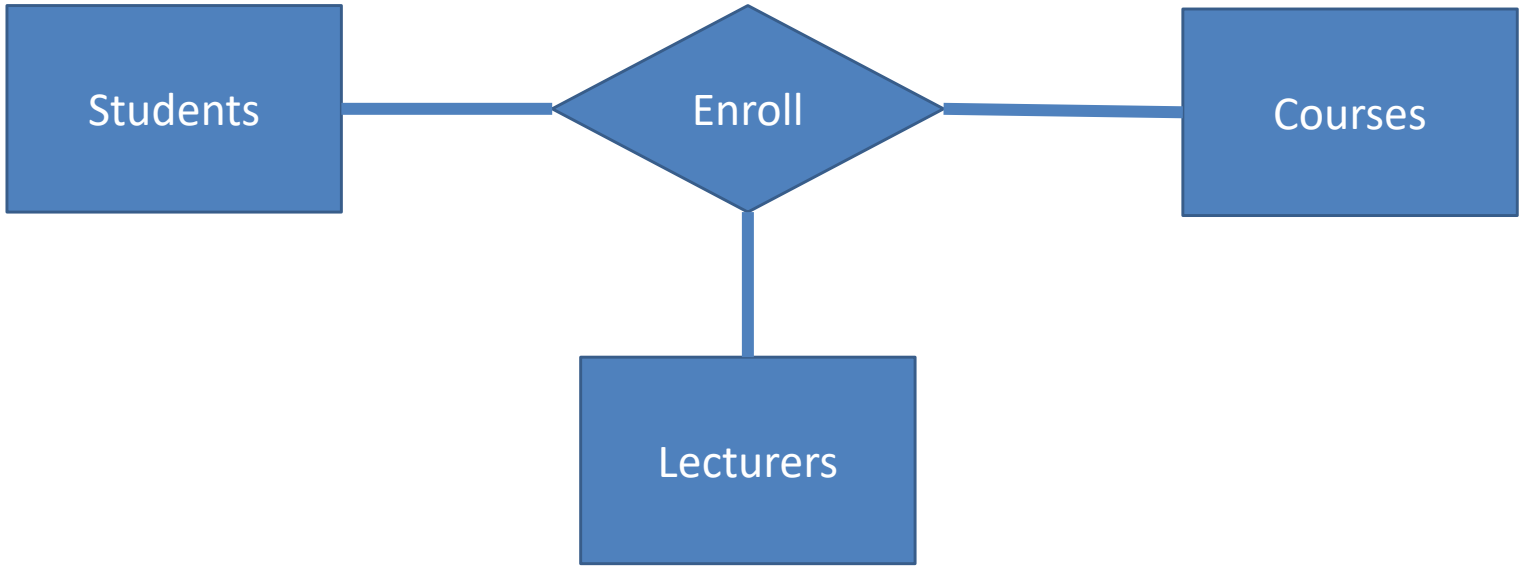
Ternary connection

Ternary connection



- Each course may have more than one lecturer.
- Therefore, a connection between student and lecturer should be explicitly stated.

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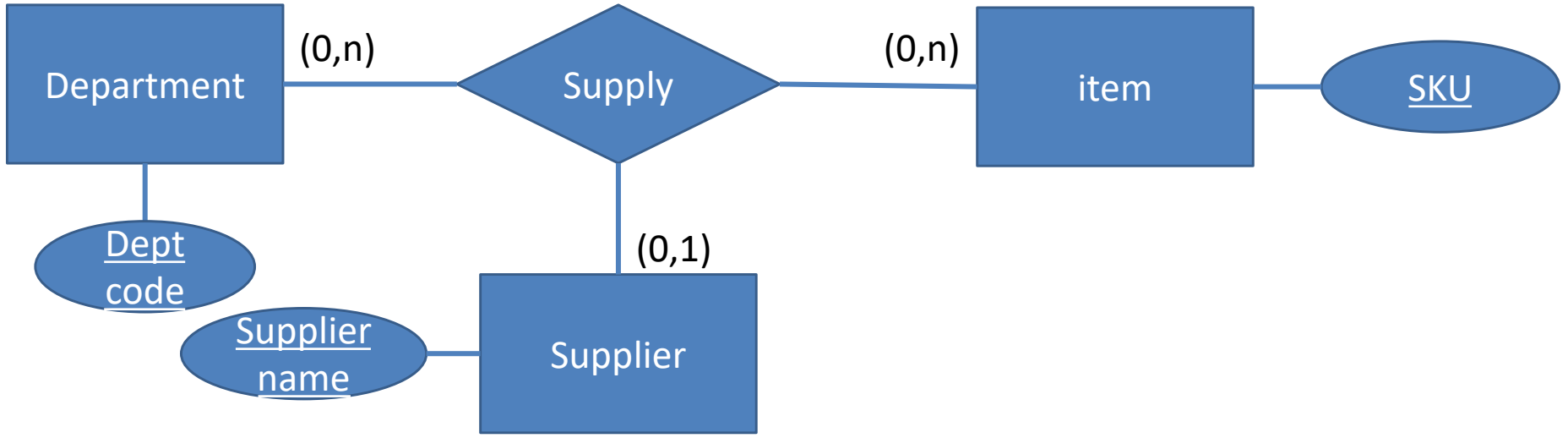
Ternary connection cardinality



- Examine each entity in relation to the other 2.

- In this example there is a m:n:1 relationship:
  - A particular department can get a lot of items from a particular supplier.
  - A particular supplier can supply a particular item to many departments.
  - A particular department can get a particular item from a maximum of one supplier.

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Unary connection

Unary(reflexive/recursive) connection

Sometimes it is necessary to connect one entity to another entity from the same group of entities.

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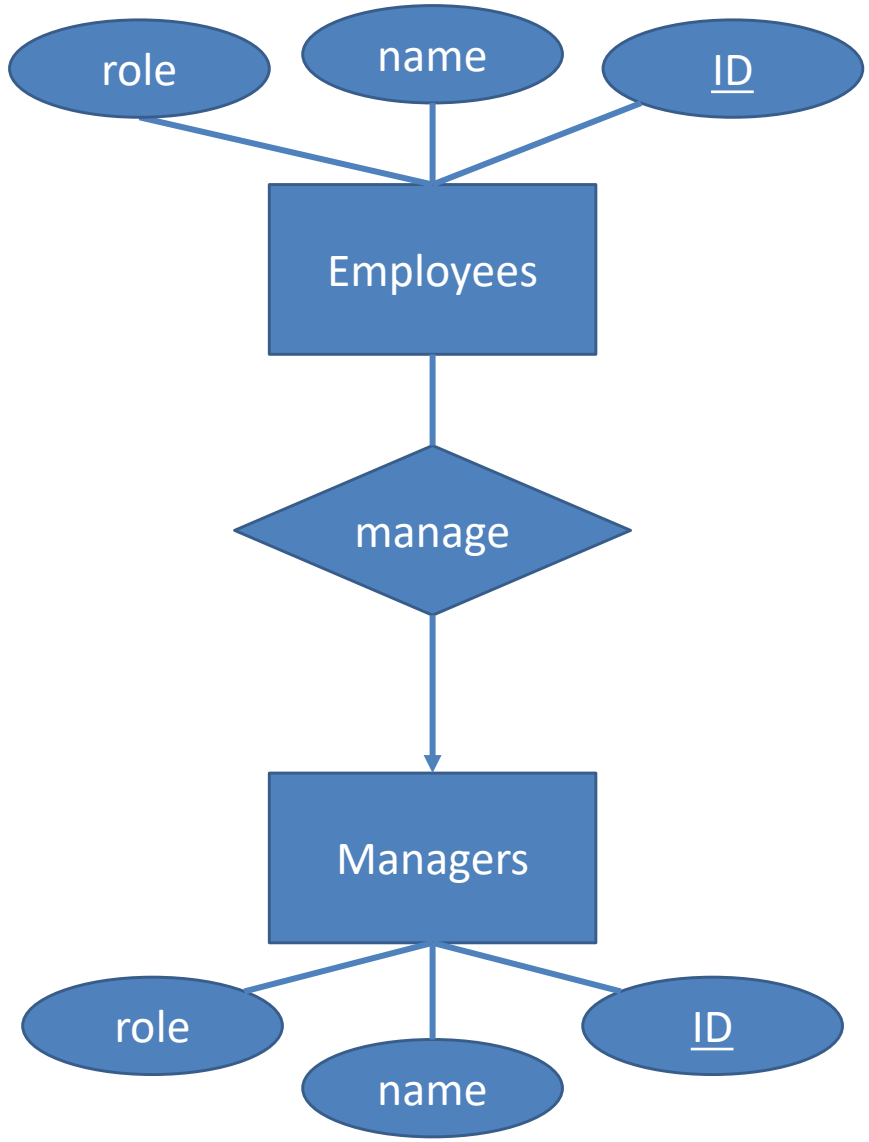
Unary connection - steps



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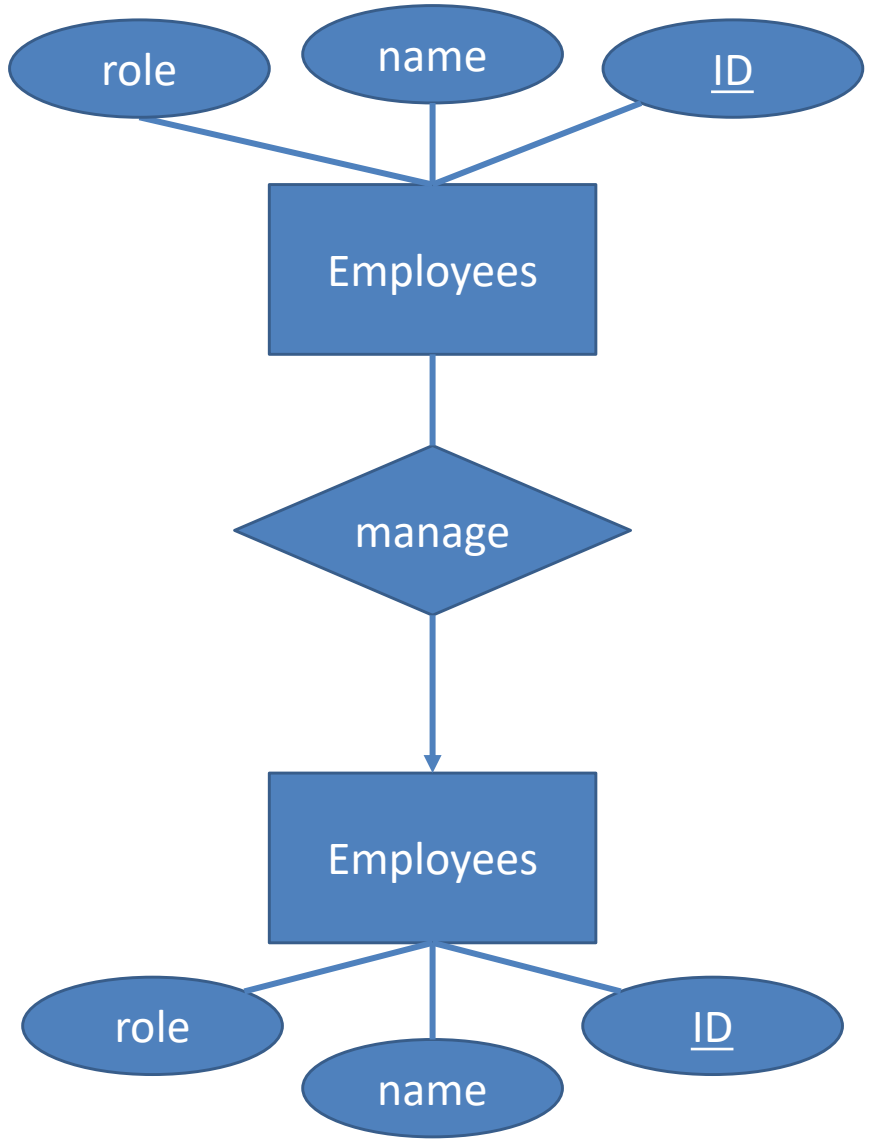
Unary connection - steps



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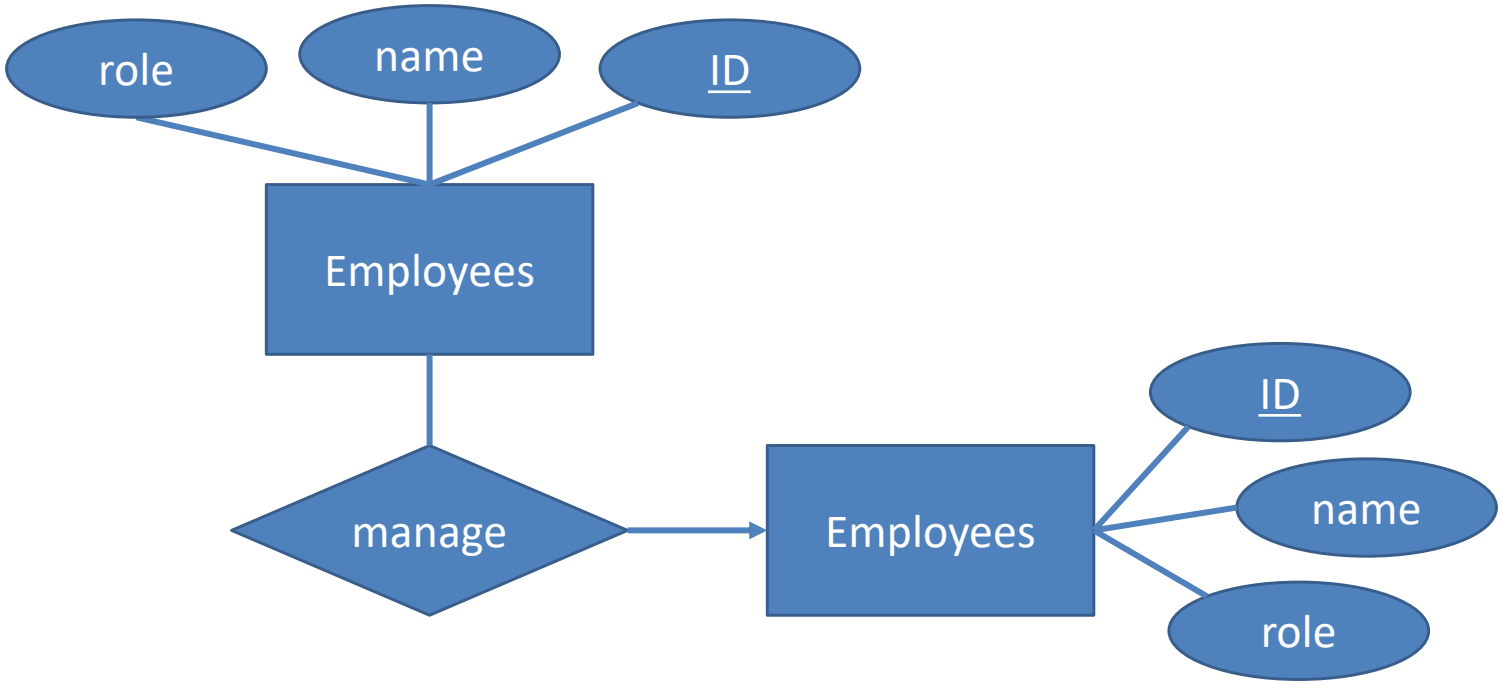
Unary connection - steps



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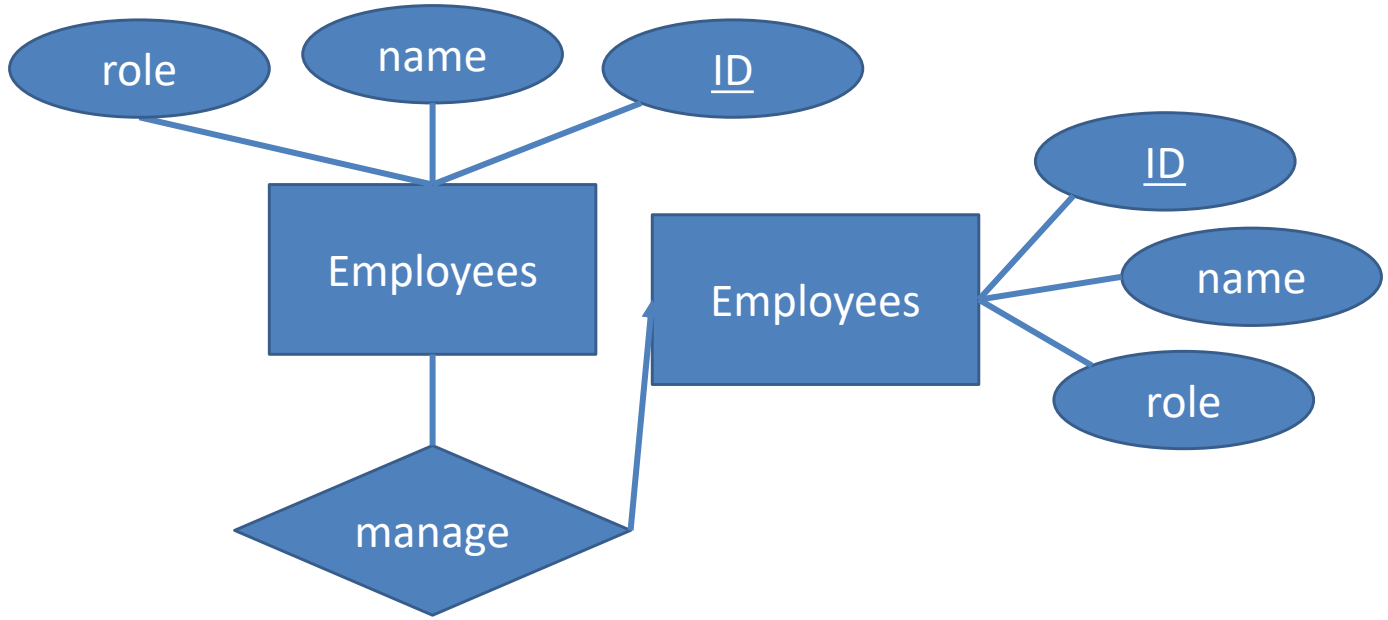
Unary connection - steps



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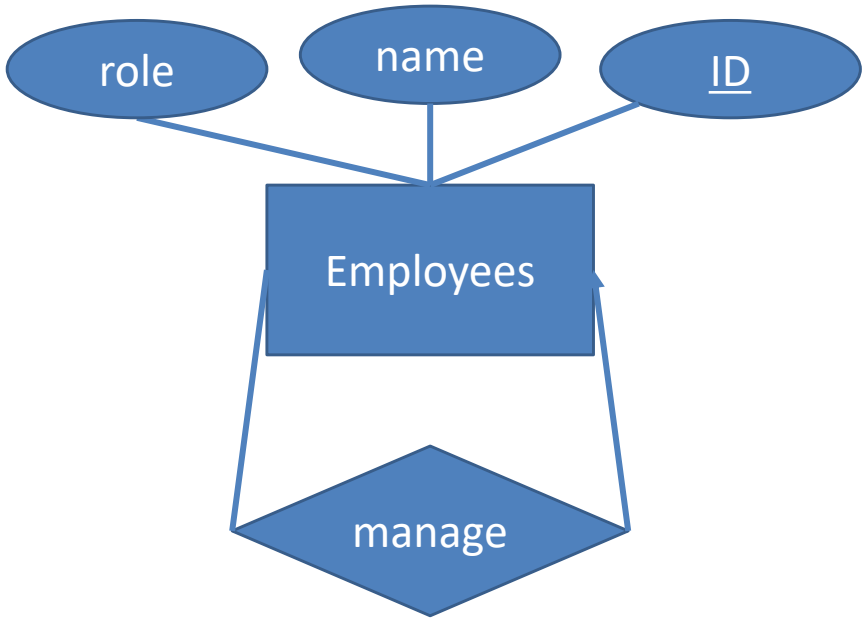
Unary connection - steps



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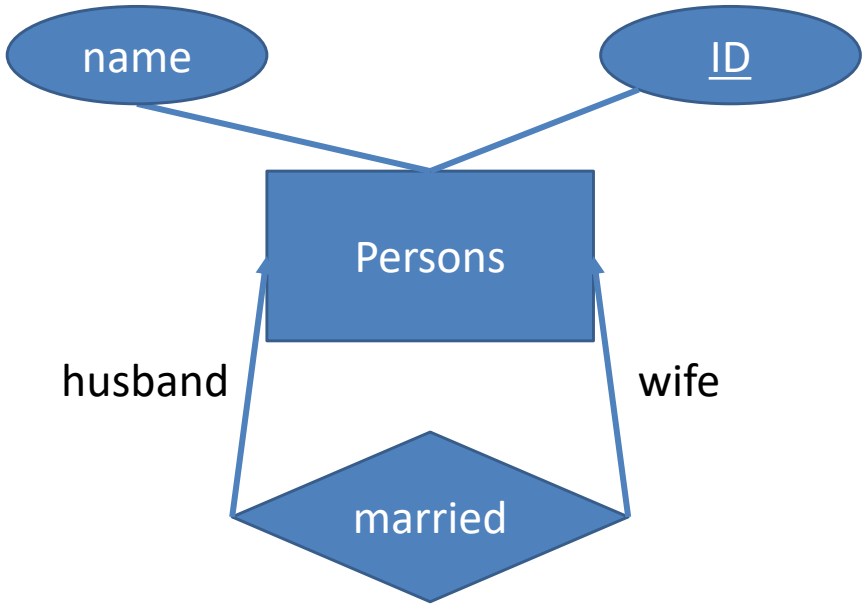
Unary connection example one-2-one



On the edges we will write the relevant role

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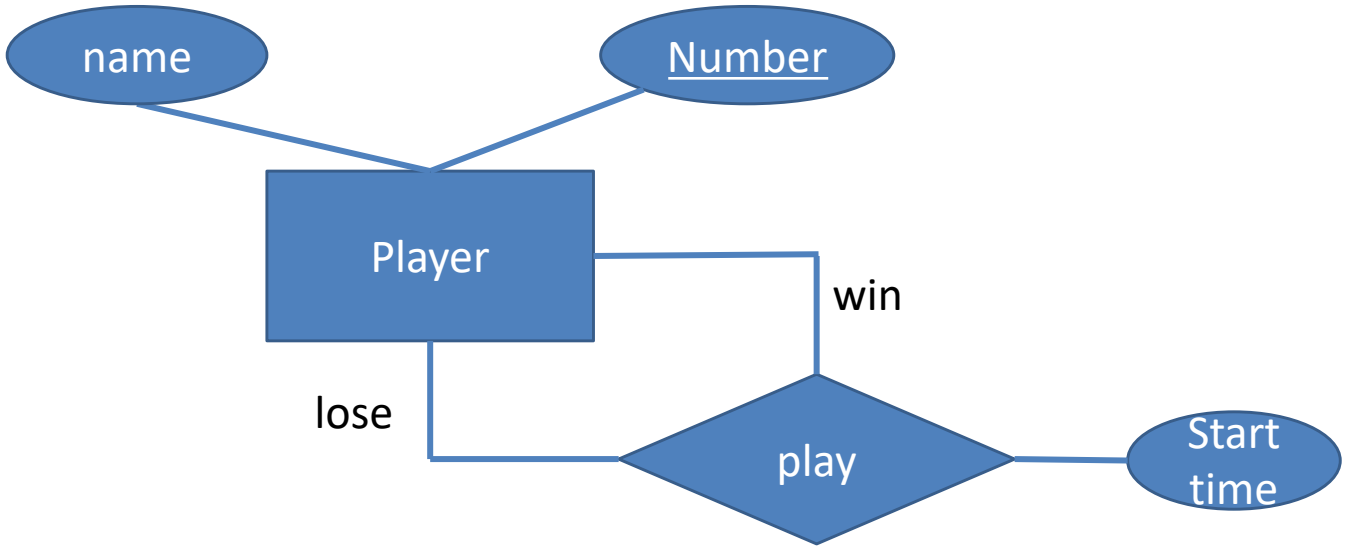
Unary connection example many-2-many



Confusing points: Each pair of players only plays once, and they have the same starting time.

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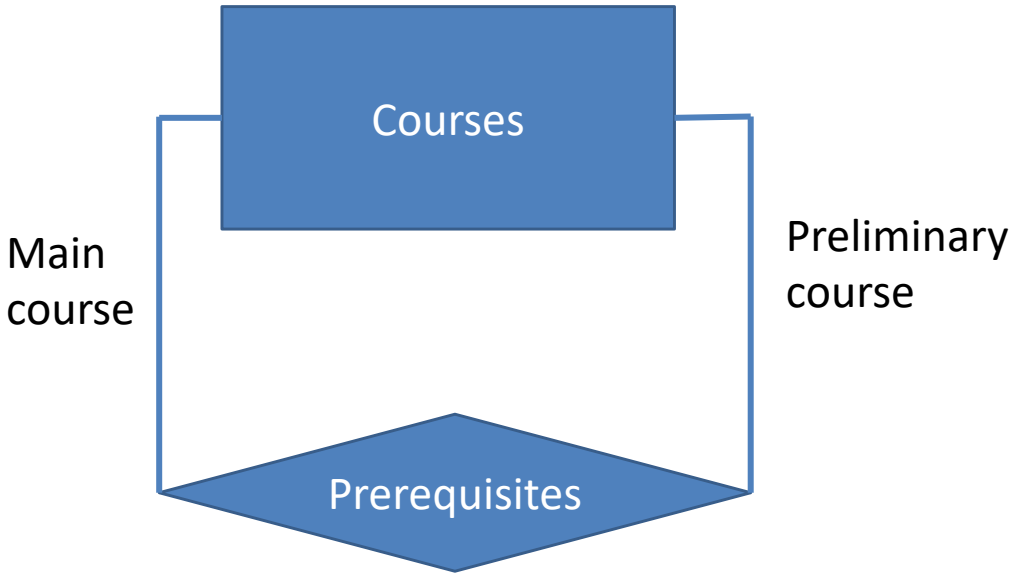
Reflexive connection example



This is a many-to-many relationship because each course can have a number of preliminary courses and each course can be a preliminary course for other courses.

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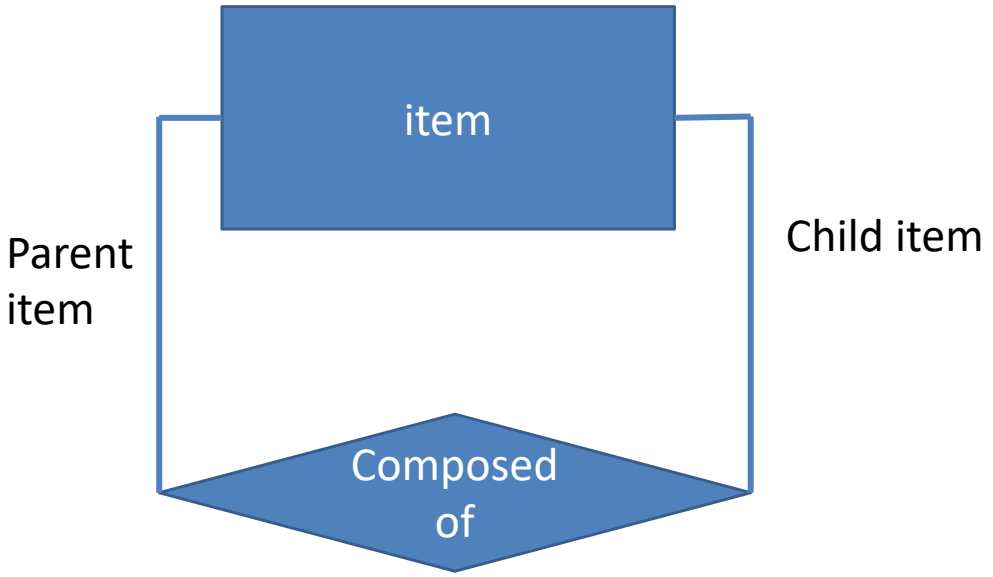
Reflexive connection example – item tree



This is a many-to-many relationship because each item is composed of several items and each item can be used in multiple items.

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(Interim) Summary

- Square - represents a group of entities (students / teachers ...).
- Ellipse - represents an attribute (academic year / academic degree ...).
- Rhombus - represents a connection between entities.
- Lines - linking entities to their attributes and groups of entities; to the connections in which they take part.

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The marking standard in the diagram

- It is worth knowing that different groups use different markings to represent the same markings in the ERD.
- For example, different books - different markings.
- Different software - different markings.

- What matters is the meaning and not the form of the marking.

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Extended ERD

- So far, we have studied the basic model of ERD.
- We will now get to know his familiar extensions.
  - Weak entity and bent entity
  - **Generalization**
  - Aggregation
  - And many more….
- In this course, we will be focusing only on generalization. (due to time limit)

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Generalization

Generalization

- Allows you to define a group of entities several groups of sub-entities that inherit the attributes from the group of super-entities.
  - The general entity group (employees) will be called a **high-level** group or a **basic** group.
  - The more specific entity groups (managers, engineers, clerks) will be called **low-level** groups or **derivative** groups.
- Example:
  - “engineers", "clerks" and "managers" are groups of sub-entities that inherit its behavior from the “employees“ entity group.

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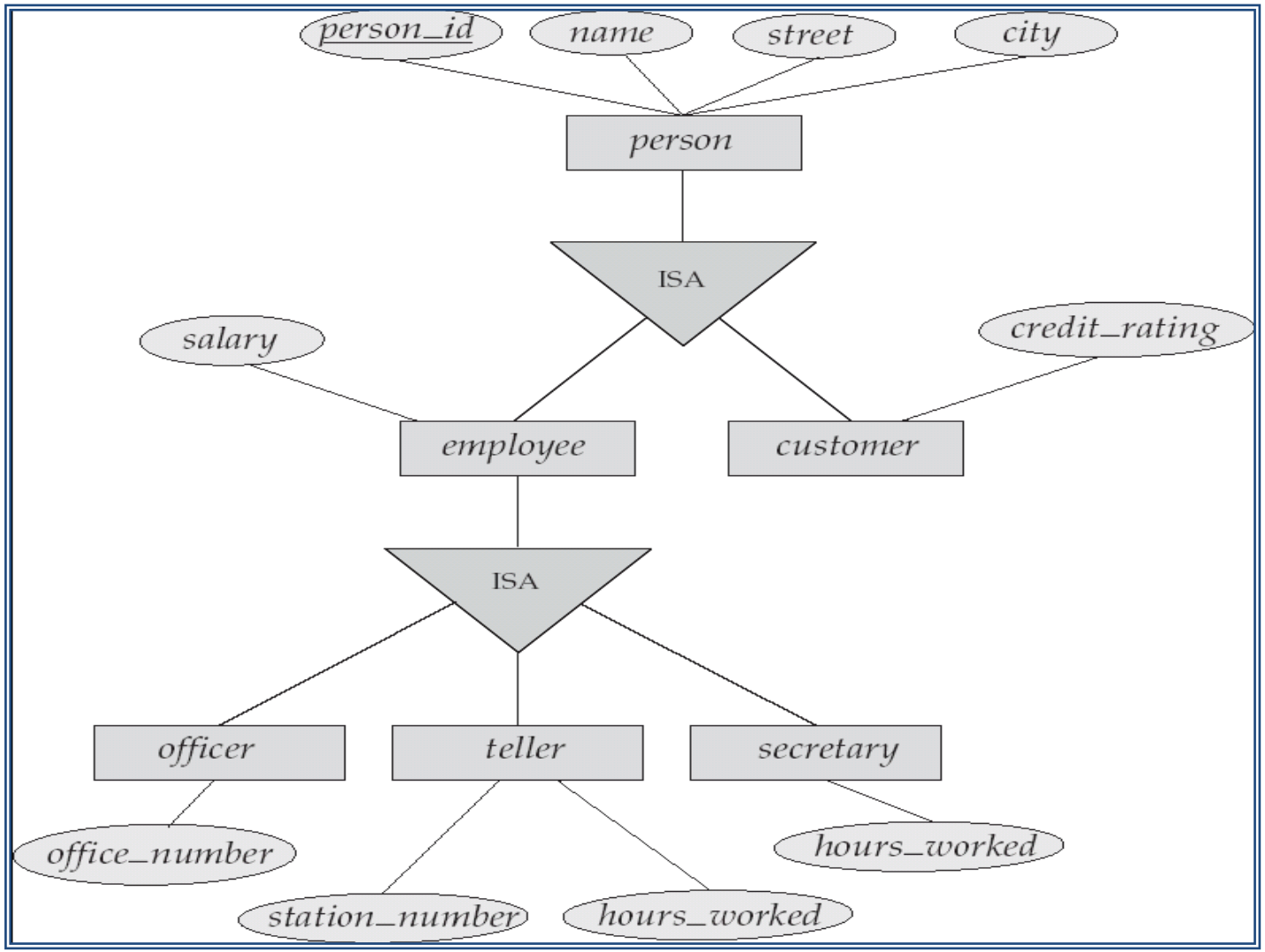
Generalization in ERD



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Keys and attributes

- The sub-entity group inherits all the attributes and connection of the super group.
- The key is defined only in the super entity.
- Each sub-entity group can add its own attributes and connections.

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Types of generalization

- Covering constraint
  - Could there be entities that are only of the parent type?

- Overlapping/Exclusive
  - Could an entity be of the type of more than one child?

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Covering constraint

- Covering constraint defines whether the entities in the subgroups cover **all** entities in the super group.

- An example of a generalization connection that does not cover.
  - The “Employees" super group versus the "Clerk" and "Manager" subgroups.
  - An employee who is not a clerk or manager (for example an engineer).
  - In this case there may be a situation where a particular entity will belong only to the supergroup.

- An example of a generalization link that covers.
  - The super group “university employee" and the subgroups “academic faculty employee", “administrative faculty employee“.
  - Each employee must belong to one of the sub-groups.
  - To mark it we will use a double line

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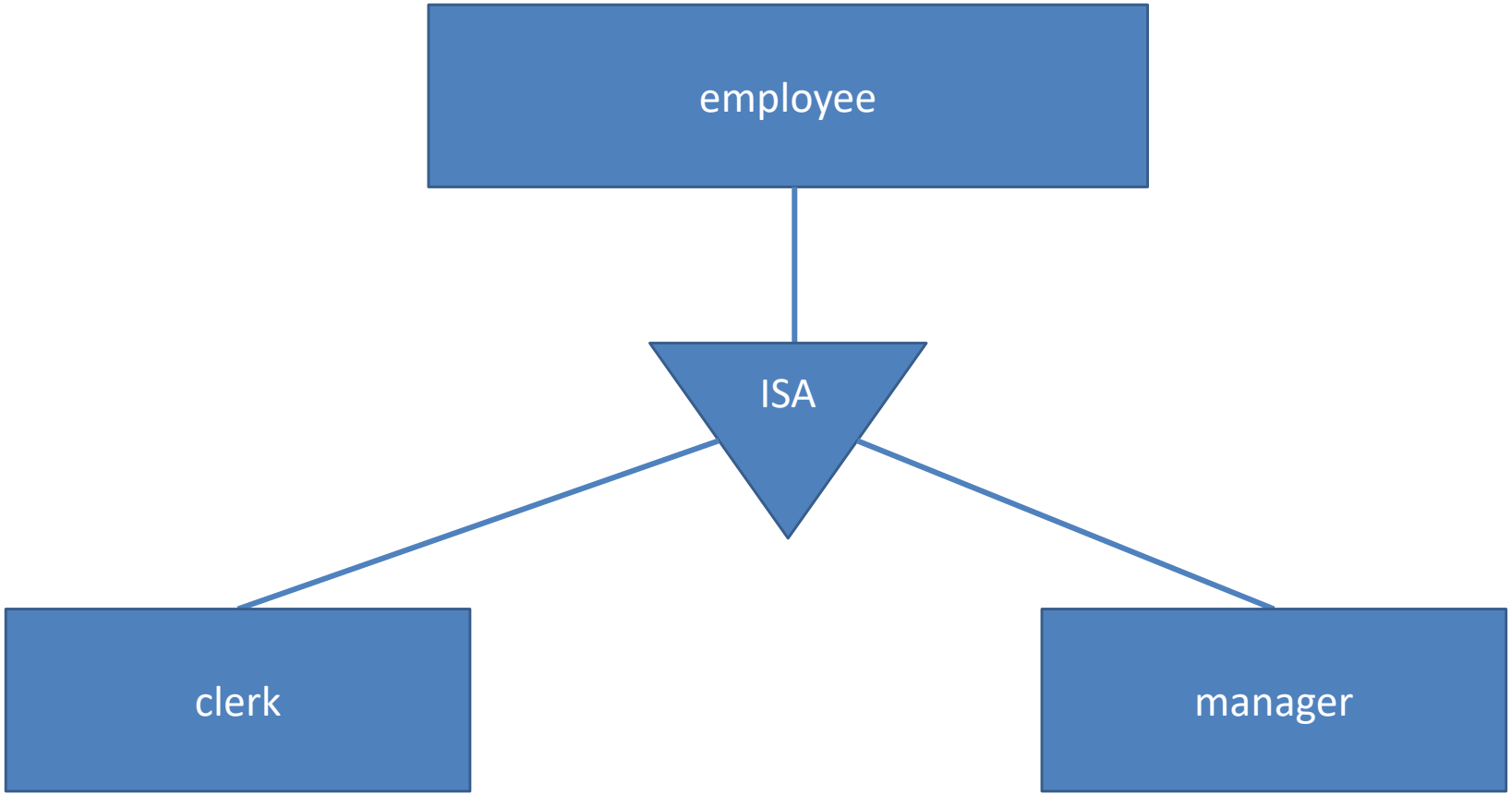
Covering constraint in ERD – not covers all



There could be an employee of a different type.
Such as, engineer for example…

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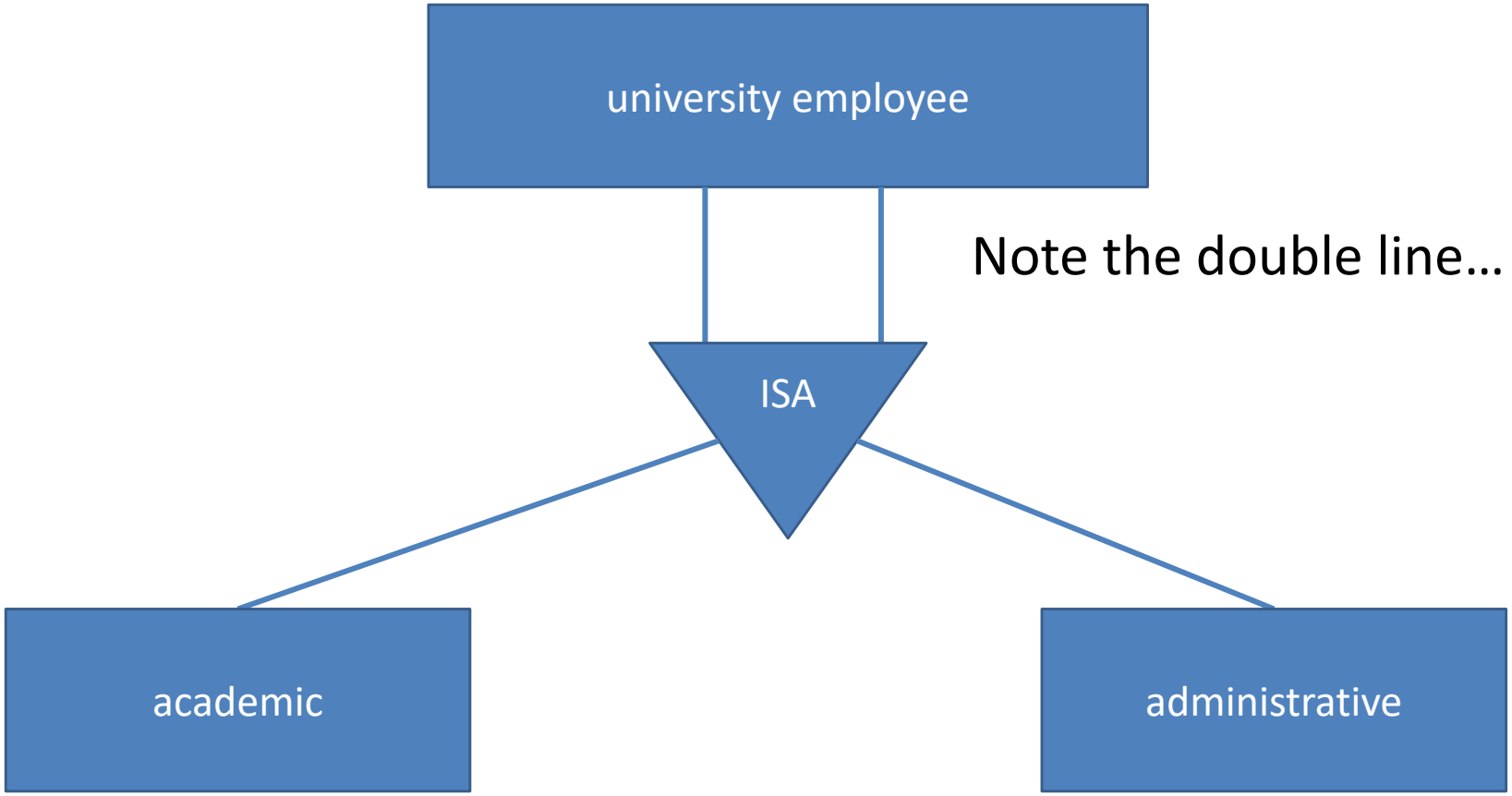
Covering constraint in ERD – covers all



Note the double line…

There could not be a university employee of a different type.
One is either academic or administrative (or both) university employee.

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Overlapping / Exclusive

- Indicates whether a particular entity can belong to only one group or several subgroups.

- Overlapping
  - Example: the supergroup “Human" and the subgroups, "University employee" and "Student“.
  - The same "person" can be both a "university employee" and a "student".

- Exclusive
  - Example: the supergroup "Student" versus the subgroups "Undergraduate student" and "Research student“.
  - To mark it we will use the letter X.

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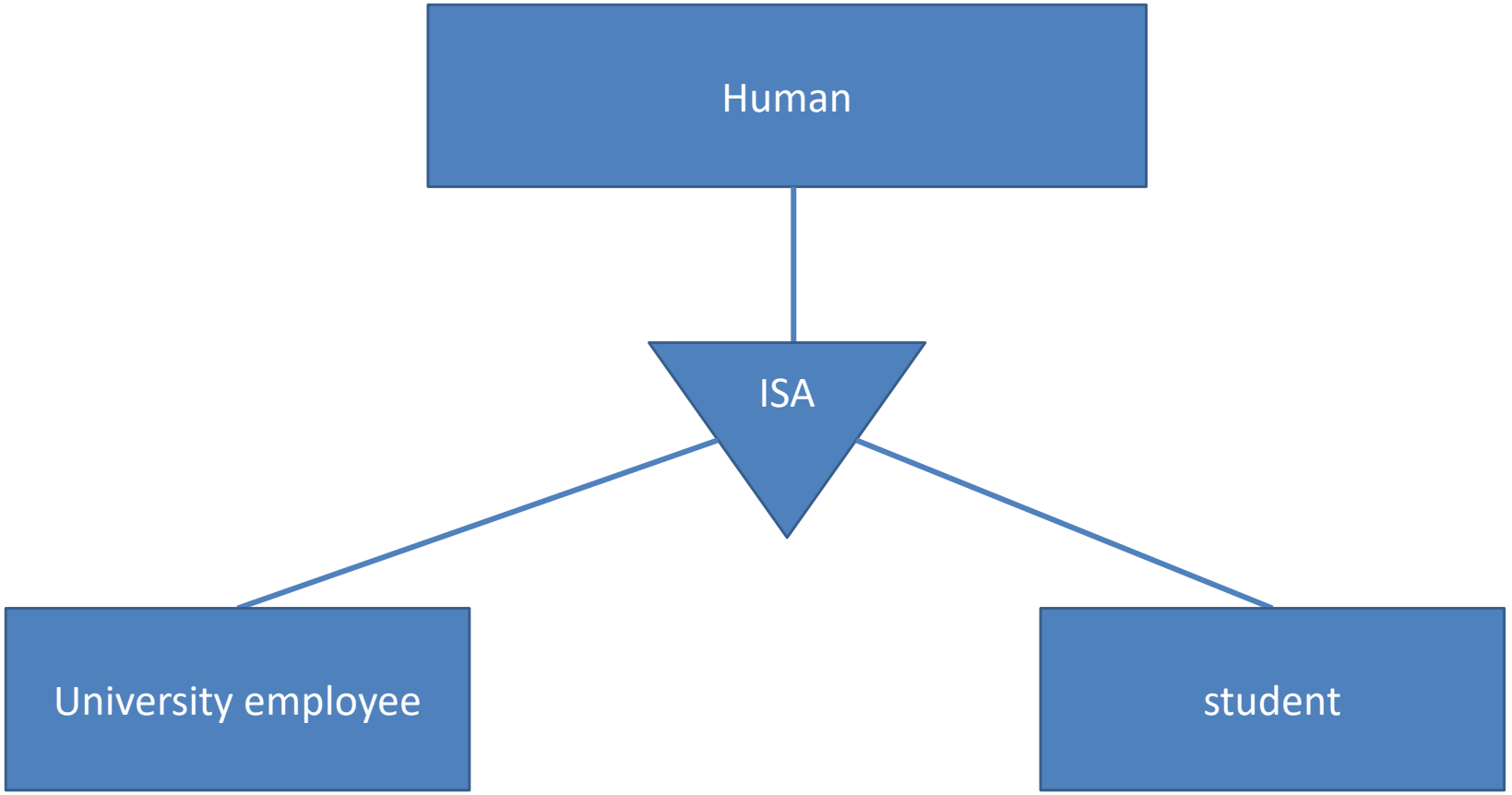
Overlapping in ERD



The human could be both university employee and student.

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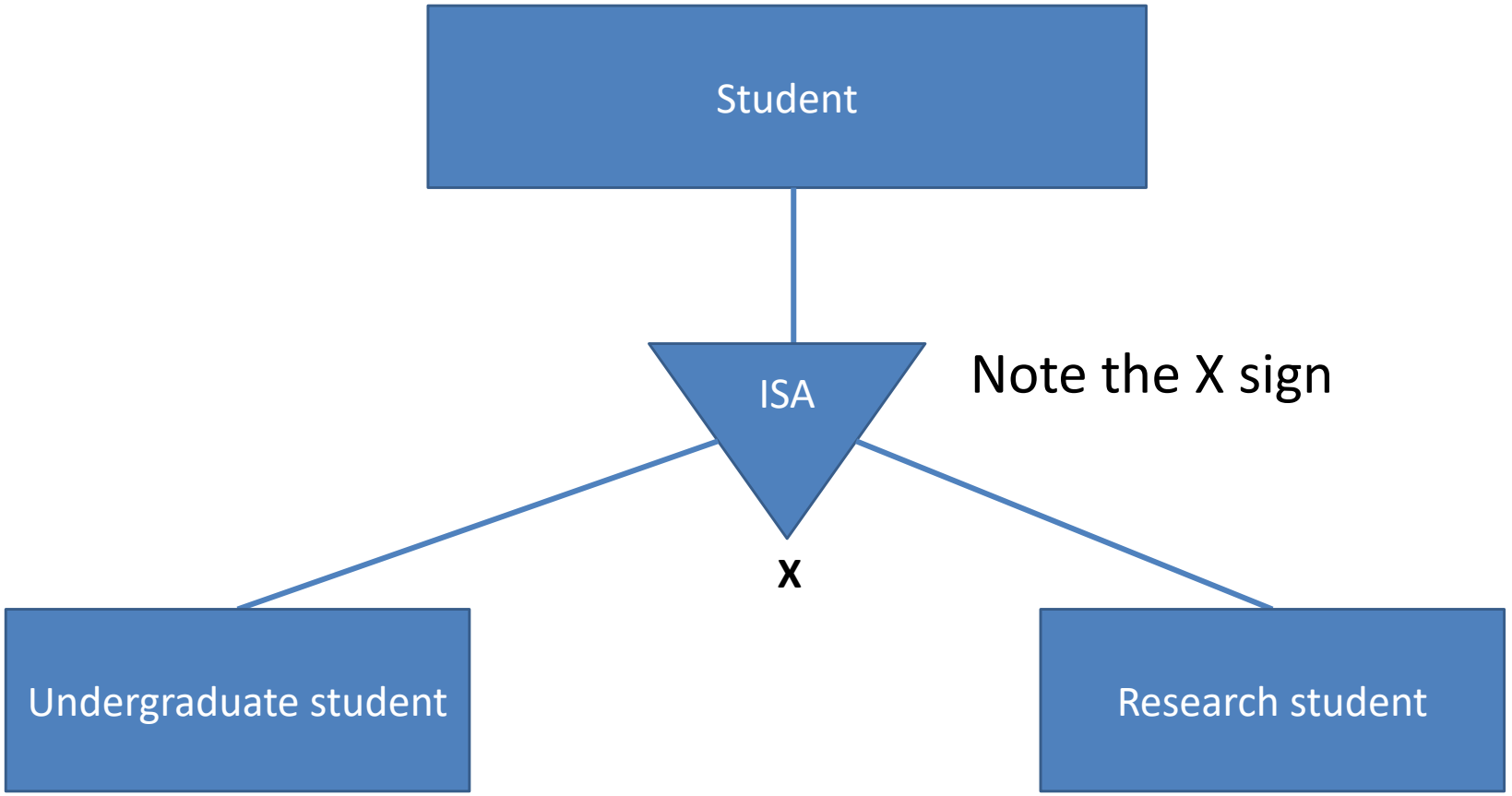
Exclusive in ERD



A student can be either an undergraduate or a research student but not both.

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Combinations of constraints

- There could be various combinations of overlap and coverage, as follows:
  - Overlap allowed and no coverage (default)
  - Overlap is prohibited and there is no coverage.
  - Overlap is allowed and there is coverage.
  - Overlap is prohibited and there is coverage.

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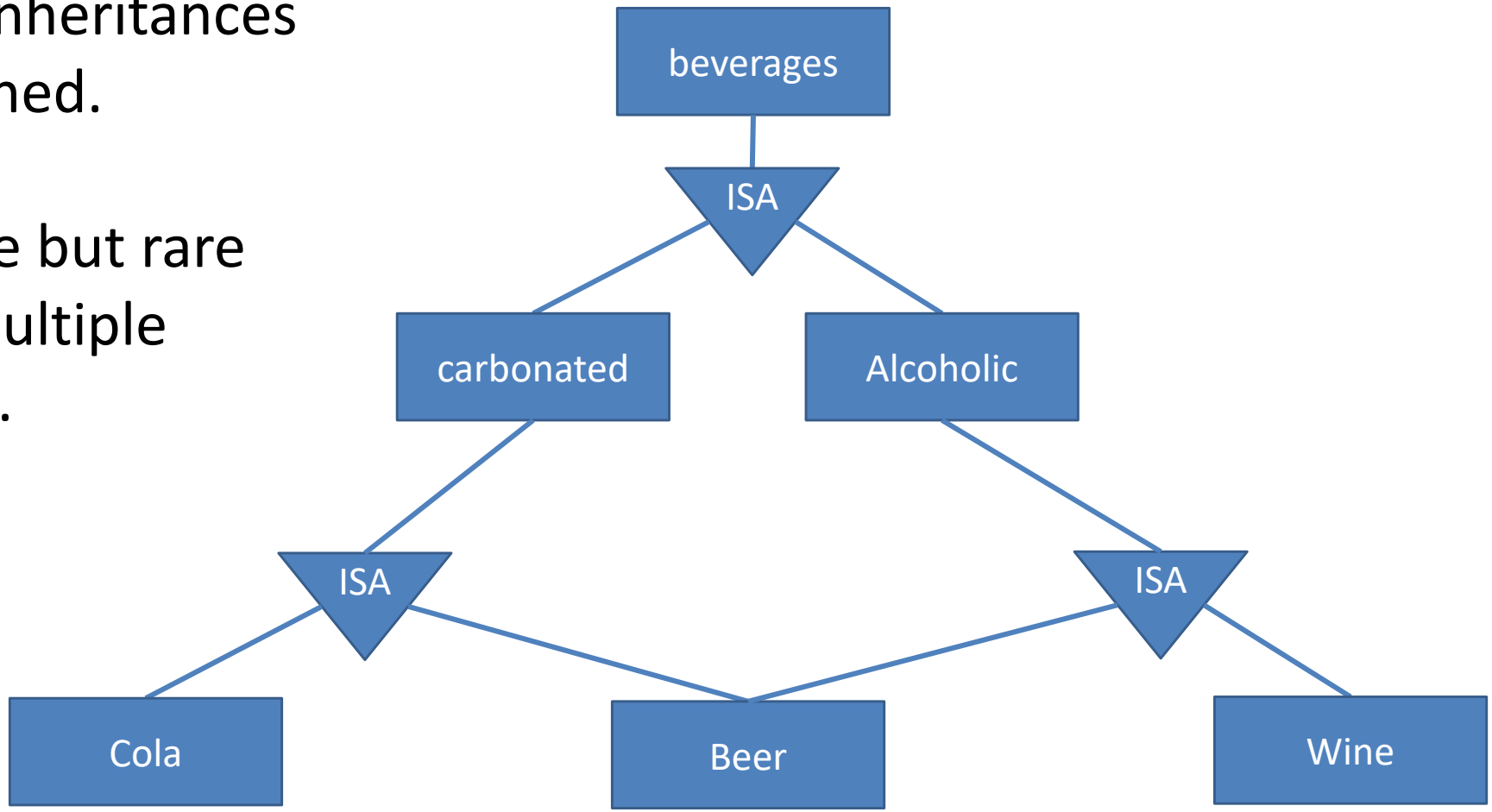
Chain of constraints

- A chain of inheritances can be defined.
- It is possible but rare to define multiple inheritance.



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