Database Management Systems INFO 210

Conceptual Modeling
Lecture 2

Franz Wotawa
TU Graz, Institut for Software Technologie
Inffeldgasse 16b/2
wotawa@ist.tugraz.at

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Office Hours

Prof. Dr. Franz Wotawa
wotawa@ist.tugraz.at

Wednesday, 19:30-21:30
Thursday, 19:30-21:30
WebEx:
https://tugraz.webex.com/meet/wotawa82

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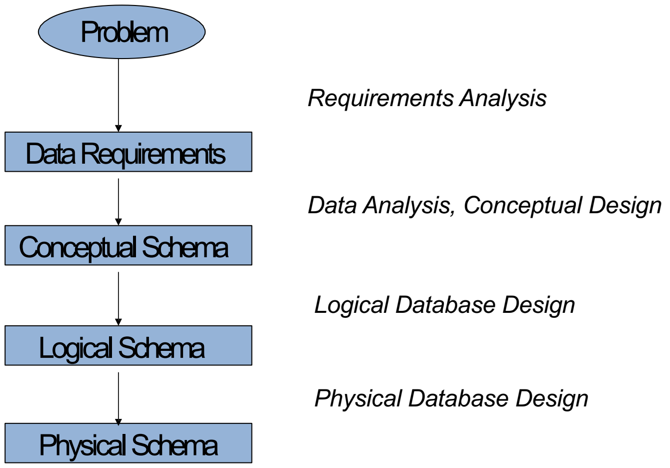
Database Design Goes Through Stages



Problem

Data Requirements

Conceptual Schema

Logical Schema

Physical Schema

Requirements Analysis

Data Analysis, Conceptual Design

Logical Database Design

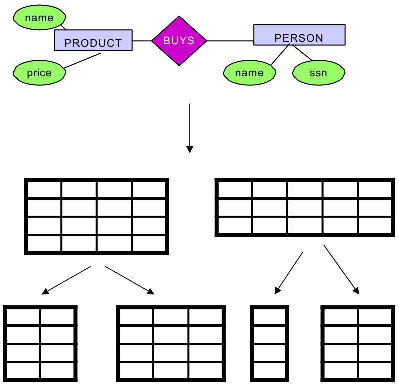
Physical Database Design

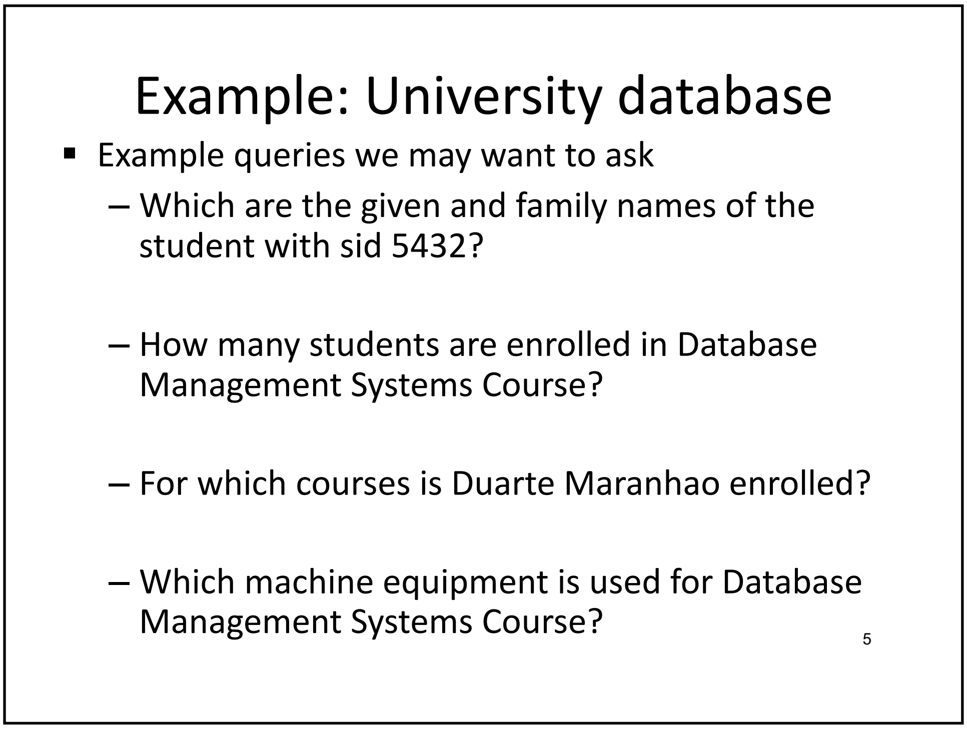
Conceptual and Logic Design

Conceptual Model:

Relational Model:
(plus functional
dependencies)

Normalization:





Example: University database

- Example queries we may want to ask
  - Which are the given and family names of the student with sid 5432?
  - How many students are enrolled in Database Management Systems Course?
  - For which courses is Duarte Maranhao enrolled?
  - Which machine equipment is used for Database Management Systems Course?

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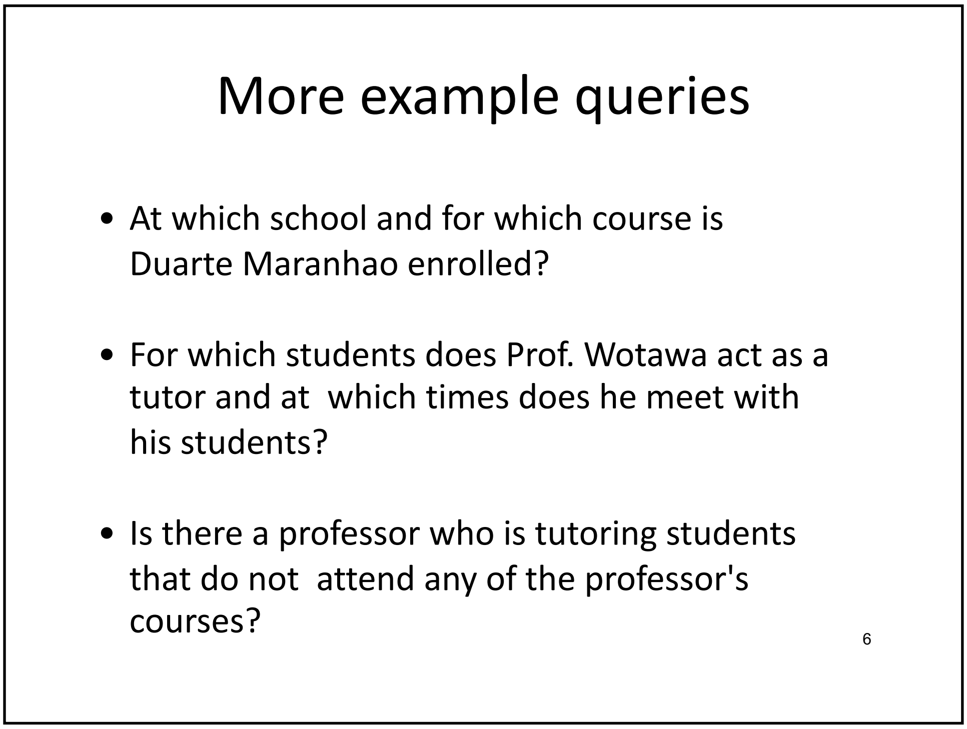

More example queries

- At which school and for which course is Duarte Maranhao enrolled?
- For which students does Prof. Wotawa act as a tutor and at which times does he meet with his students?
- Is there a professor who is tutoring students that do not attend any of the professor's courses?

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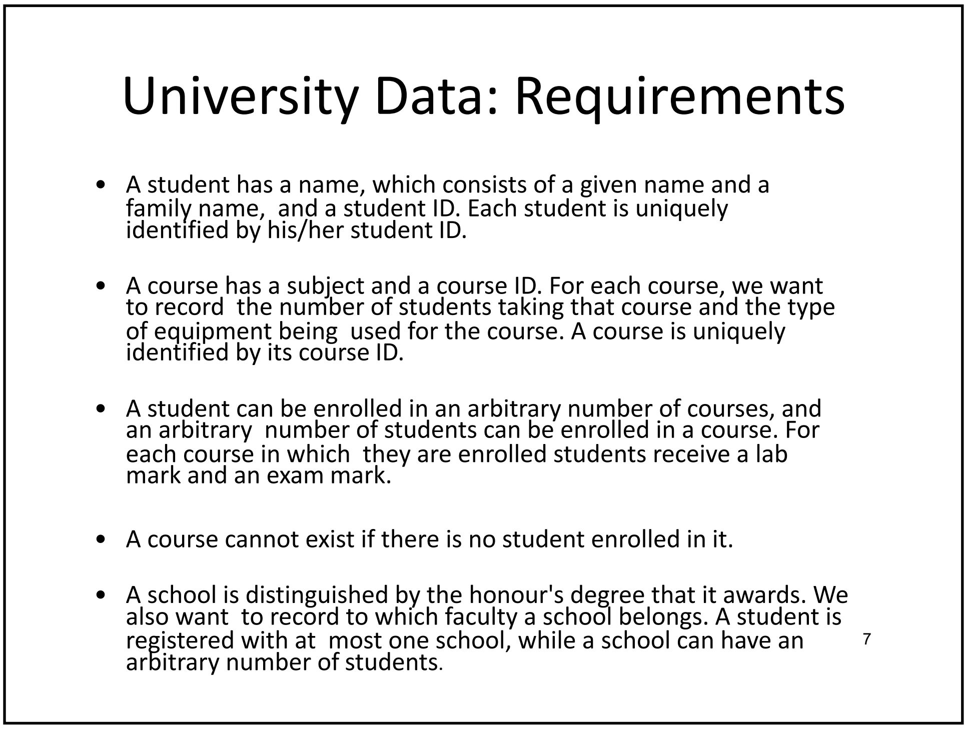

University Data: Requirements

- A student has a name, which consists of a given name and a family name, and a student ID. Each student is uniquely identified by his/her student ID.
- A course has a subject and a course ID. For each course, we want to record the number of students taking that course and the type of equipment being used for the course. A course is uniquely identified by its course ID.
- A student can be enrolled in an arbitrary number of courses, and an arbitrary number of students can be enrolled in a course. For each course in which they are enrolled students receive a lab mark and an exam mark.
- A course cannot exist if there is no student enrolled in it.
- A school is distinguished by the honour's degree that it awards. We also want to record to which faculty a school belongs. A student is registered with at most one school, while a school can have an arbitrary number of students.

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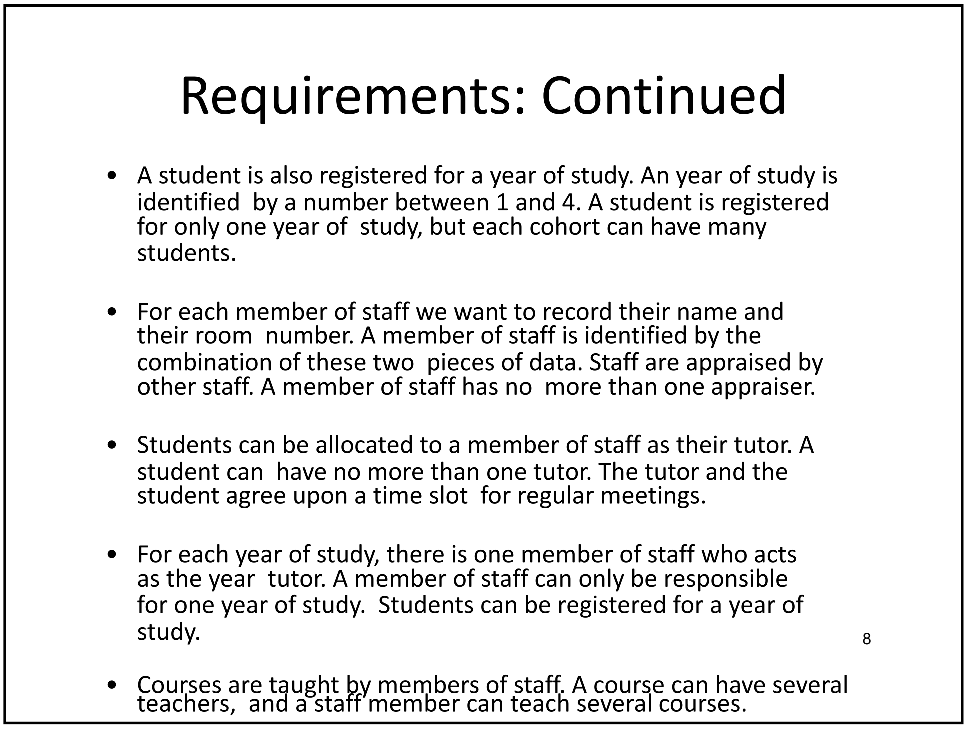

Requirements: Continued

- A student is also registered for a year of study. An year of study is identified by a number between 1 and 4. A student is registered for only one year of study, but each cohort can have many students.
- For each member of staff we want to record their name and their room number. A member of staff is identified by the combination of these two pieces of data. Staff are appraised by other staff. A member of staff has no more than one appraiser.
- Students can be allocated to a member of staff as their tutor. A student can have no more than one tutor. The tutor and the student agree upon a time slot for regular meetings.
- For each year of study, there is one member of staff who acts as the year tutor. A member of staff can only be responsible for one year of study. Students can be registered for a year of study.
- Courses are taught by members of staff. A course can have several teachers, and a staff member can teach several courses.

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Conceptual Design with the ER Model

Questions to ask:

- What are the *entities* (= objects, individuals) in the organization?
- Which *relationships* exist among the entities?
- What information (= *attributes*) do we want to store about these entities and relationships?
- What are the business rules of the organization?
- Which integrity constraints do arise from them?

The answers are represented in an
Entity Relationship Diagram (ER diagram)

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Entities and Entity Set Types

Entity: An object distinguishable from other objects (e.g., an employee)

- An entity is described by a set of attributes.

Examples of entities?
Examples of things that are not entities?

Entity Set/Entity Type: A collection of similar entities (e.g., all employees)

- All entities in an entity set have the same set of *attributes*.
- Each attribute has a *domain*.
- Each entity set has a *key* (i.e., one or more attributes whose values uniquely identify an entity) 9

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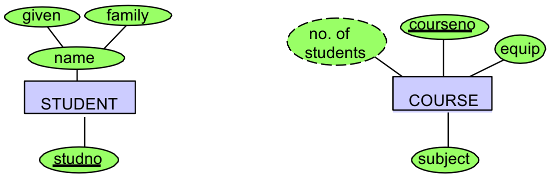
Graphical Representation of Entity Sets



- Entity Sets are drawn as rectangles
- Attributes are drawn using ovals
- Simple attributes contain atomic values
- Composite attributes combine two or more attributes
- Derived attributes are indicated by dashed lines
- The attributes making up the key are underlined

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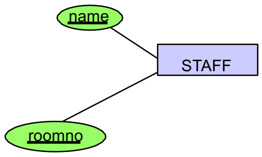
Composite Keys



- Some entities cannot be uniquely identified by the values of a single attribute …
- … but may be identified by the combination of two or more attribute values
- several attributes together make up a compoundkey

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Relationships and Relationships Set/Types

Relationship: An association between two or more entities (e.g., “Joe Smith” is “enrolled” in “CS123”)

- Relationships may have attributes

Examples of relationships?

Relationship Set/Type: A collection of similar relationships

- An *n*-ary relationship type relates *n* entity types $E_1,\ldots,E_n$
- Each relationship involves *n* entities $e_1 \in E_1,\ldots,e_n \in E_n$

Examples of relationship sets?

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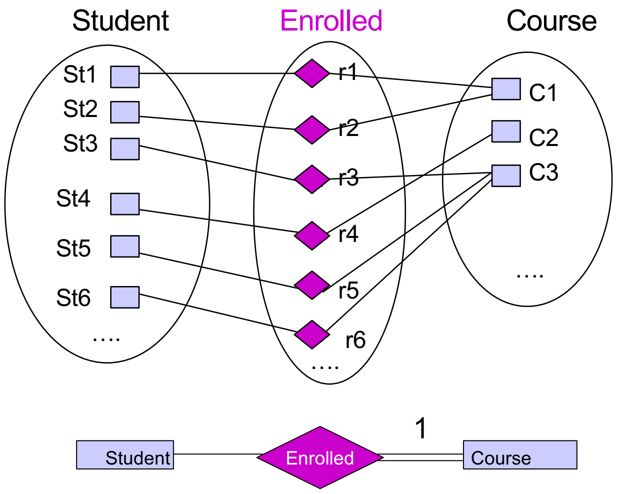
An Instance of a Relationship Type



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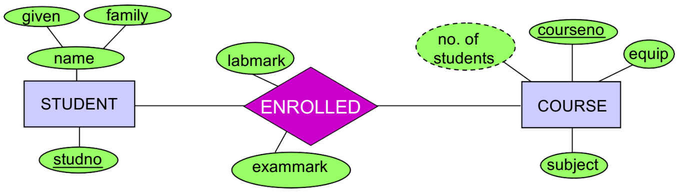
Graphical Representation of Relationship Types



- Relationship sets are drawn as diamonds

How many labmarks can a student have?

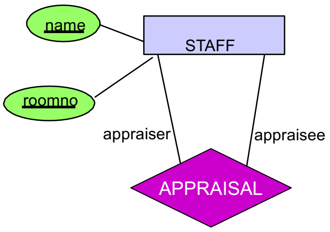
Roles and Recursive Relationships

An entity type can

- participate in several relationship sets

and

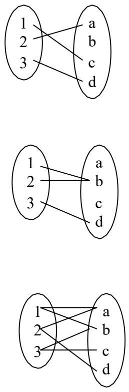
- participate more than once in one relationship set (taking on different “roles”)

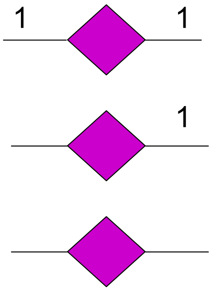


Which are other examples of recursive relationships?

Multiplicity/Cardinality of Relationship Types

- one-one:
- many-one:
- many-many:





Sometimes the letters m, n are used to indicate the "many" side of relationships.

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Participation Constraints

- Participation constraints specify whether or not an entity must participate in a relationship set
- When there is no participation constraint, it is possible that an entity will not participate in a relationship set
- When there is a participation constraint, the entity must participate *at least once*
- Participation constraints are drawn using a *double line* from the entity set to the relationship set

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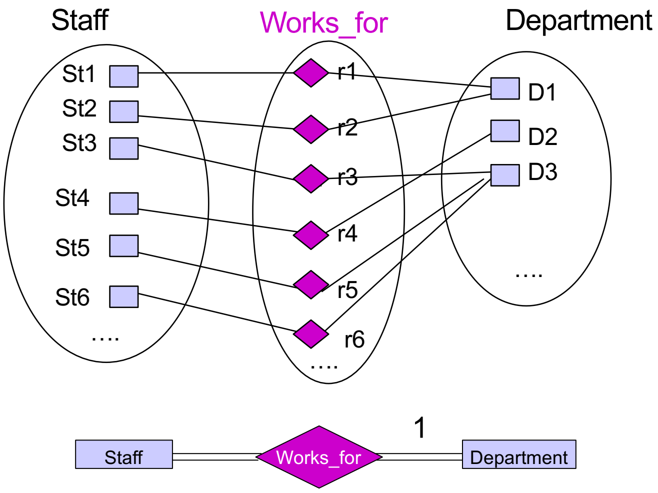
Mandatory Participation



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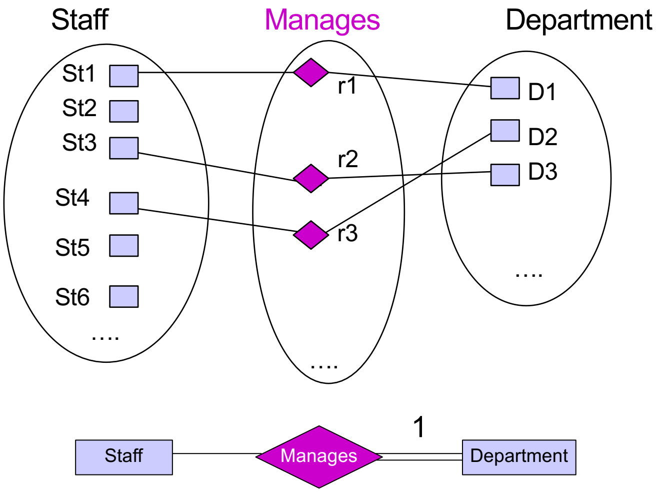
Optional and Mandatory Participation



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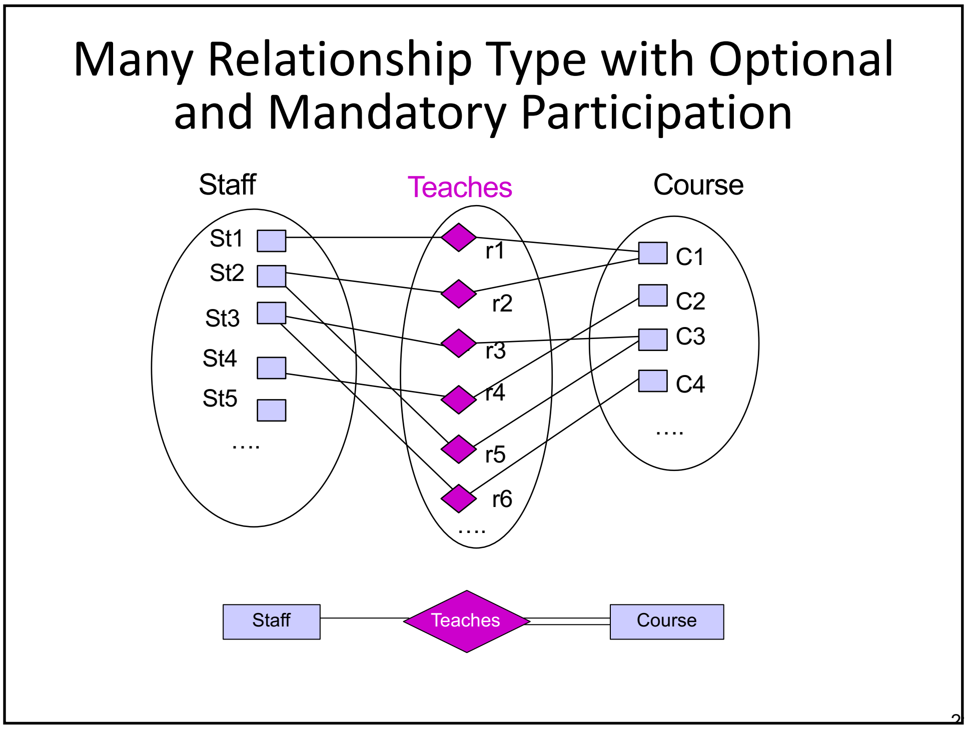

Many Relationship Type with Optional and Mandatory Participation

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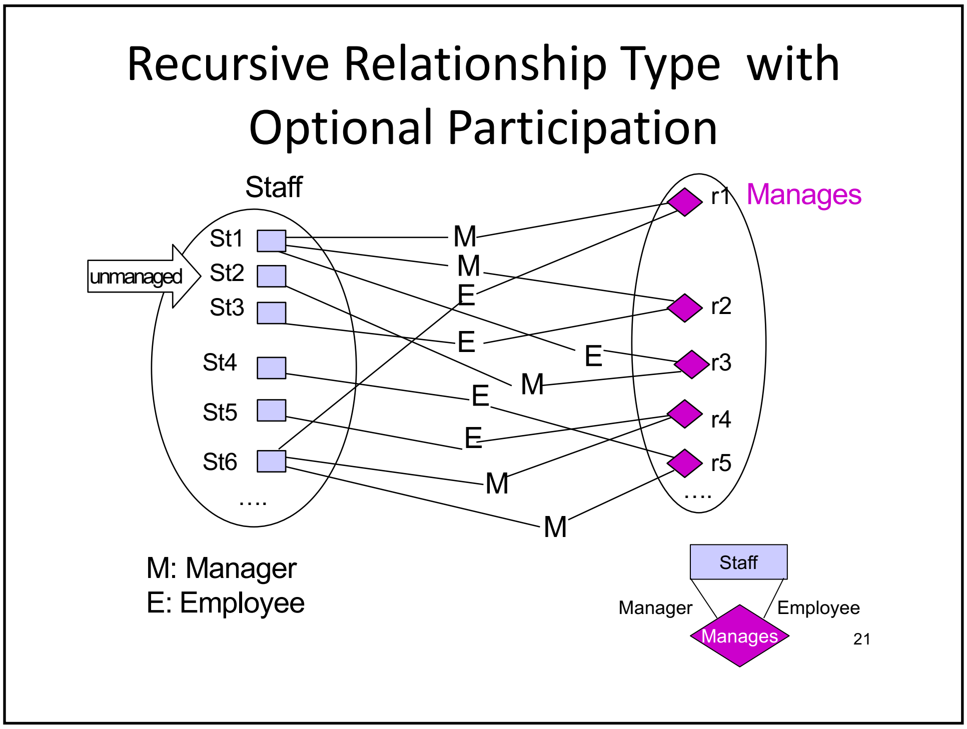

Recursive Relationship Type with Optional Participation

M: Manager
E: Employee

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Summary: Properties of Relationship Types

Degree

- The number of participating entity types

Cardinality ratios

- The number of instances of each of the participating entity types which can partake in a single instance of the relationship type:
  1:1, *1:many*, *many:1*, *many:many*

Participation

- Whether an entity instance has to participate in a relationship instance
- Represented with a double line

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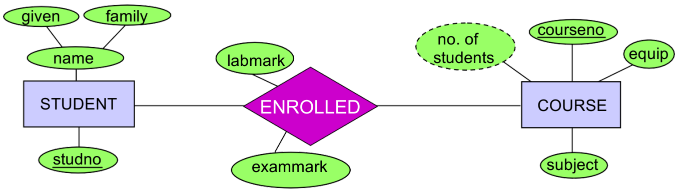
Attributes in ER Modeling

- For every attribute we define
  - *Domain* or *data type*
  - *Format*, *i.e.*, composite or atomic
  - whether it is derived
- Every entity type must have as *key* an attribute or a set of attributes



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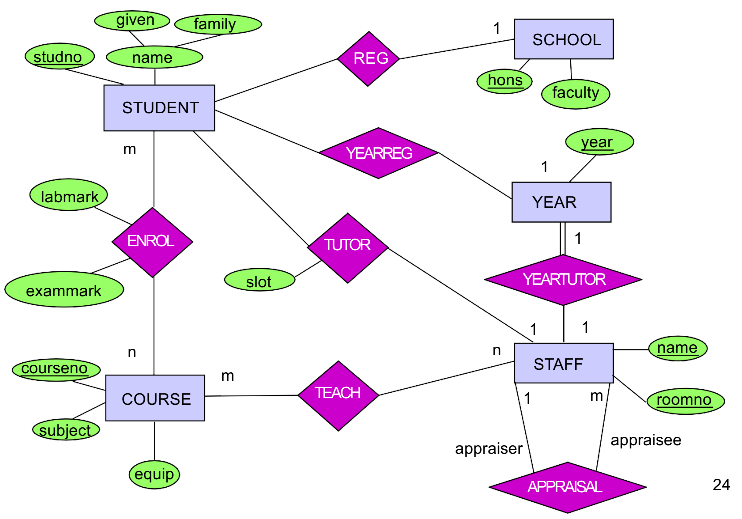
ER Model of the University DB



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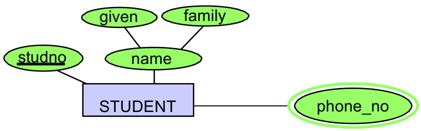
Multivalued Attributes

- Students often have more than one phone number (home, student hall, mobile)
- There is no additional information, other than the number, we need to store
- This captured by a multivalued attribute
- Notation: double-lined oval



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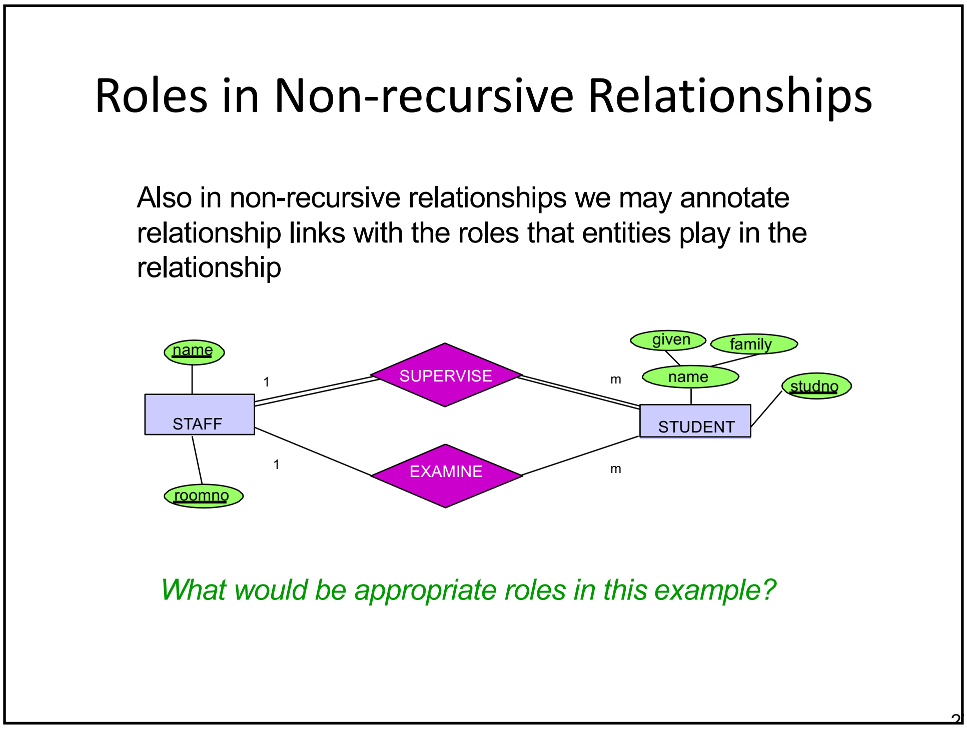

Roles in Non-recursive Relationships

Also in non-recursive relationships we may annotate relationship links with the roles that entities play in the relationship

What would be appropriate roles in this example?

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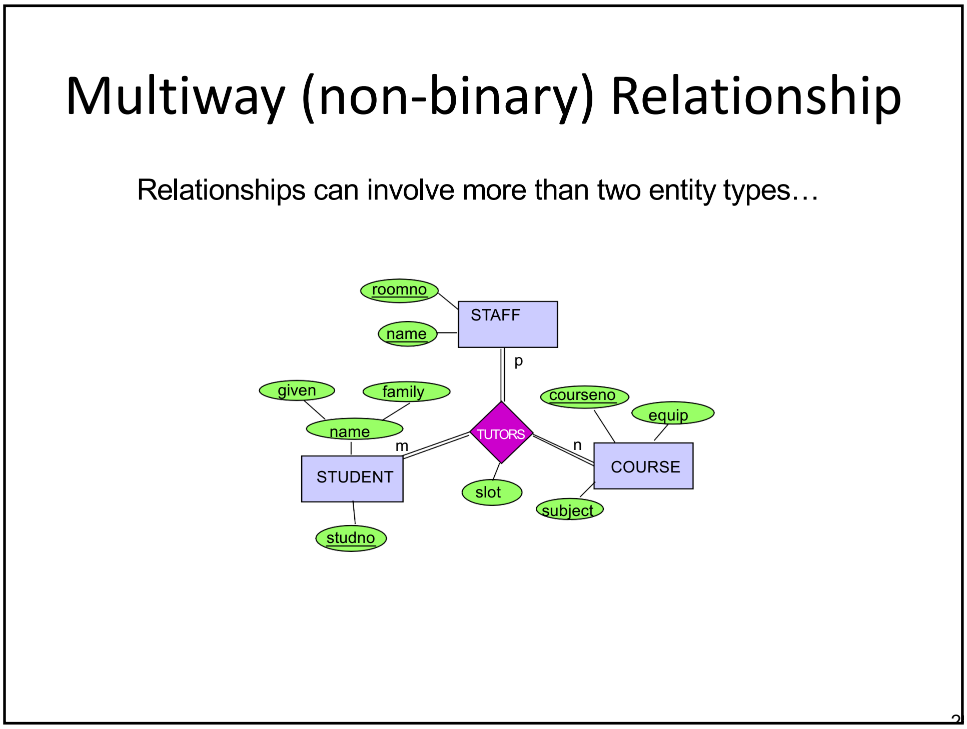

Multiway (non-binary) Relationship

Relationships can involve more than two entity types…

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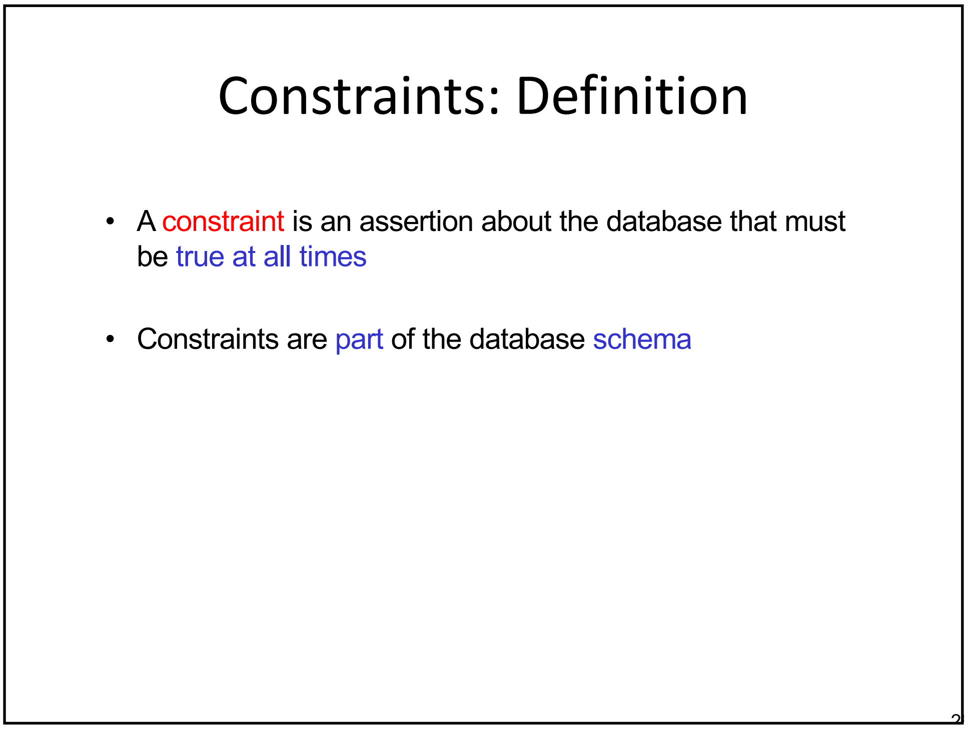

Constraints: Definition

- A constraint is an assertion about the database that must be true at all times
- Constraints are part of the database schema

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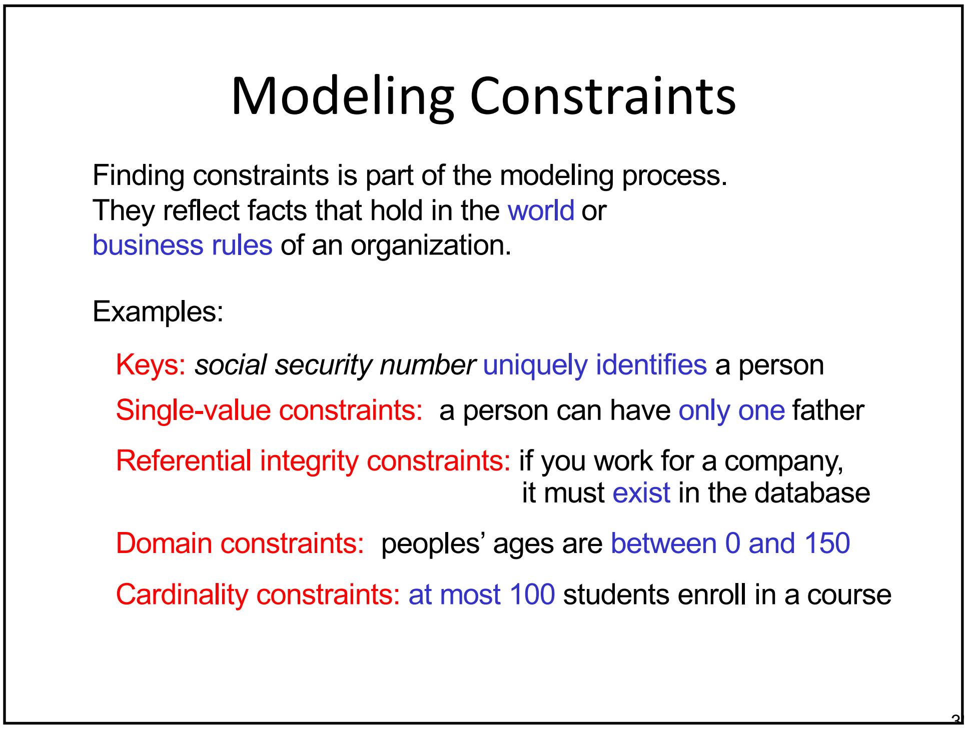

Modeling Constraints

Finding constraints is part of the modeling process. They reflect facts that hold in the world or business rules of an organization.

Examples:

Keys: *social security number* uniquely identifies a person

Single-value constraints: a person can have only one father

Referential integrity constraints: if you work for a company, it must exist in the database

Domain constraints: peoples' ages are between 0 and 150

Cardinality constraints: at most 100 students enroll in a course

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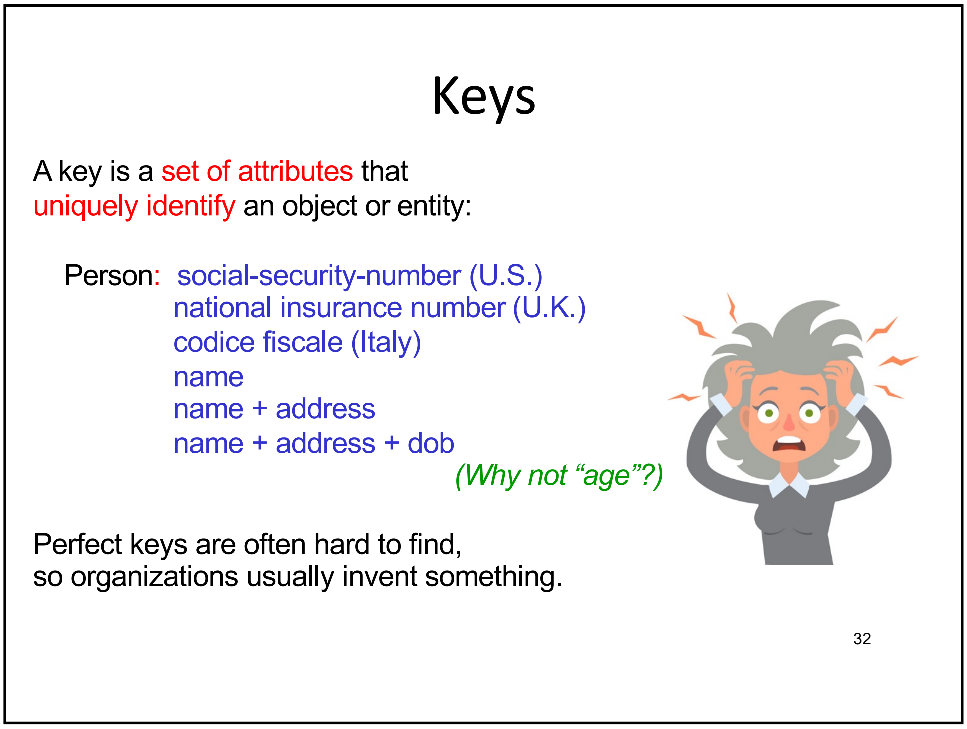

Keys

A key is a set of attributes that uniquely identify an object or entity:

Person: social-security-number (U.S.)
national insurance number (U.K.)
codice fiscale (Italy)
name
name + address
name + address + dob

(Why not "age"?)

Perfect keys are often hard to find,
so organizations usually invent something.

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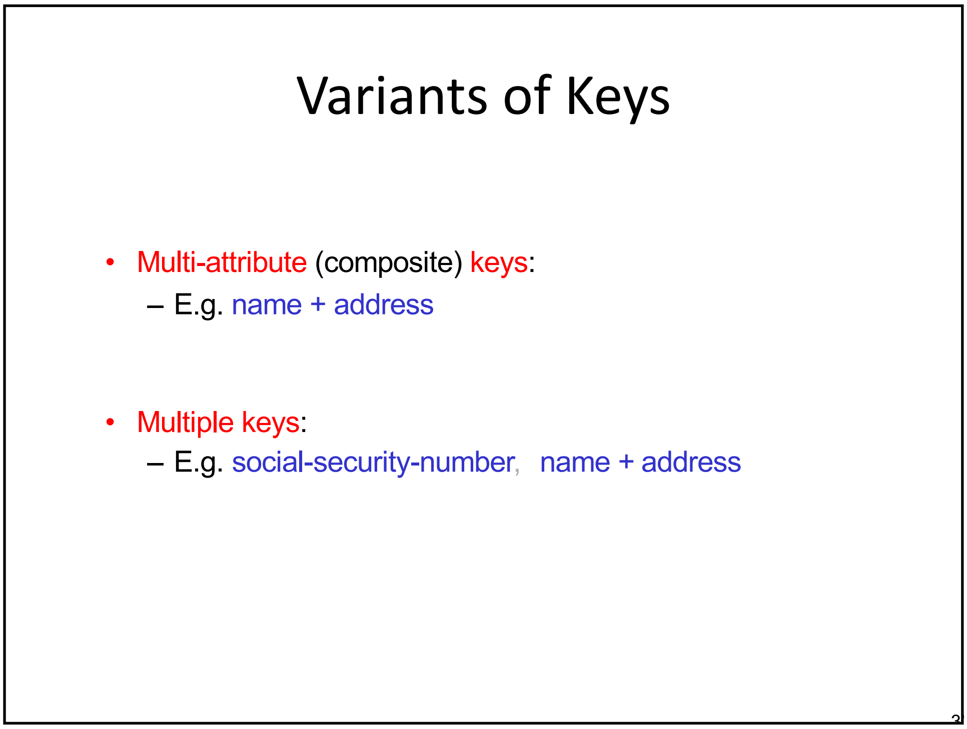

Variants of Keys

- Multi-attribute (composite) keys:
  - E.g. name + address
- Multiple keys:
  - E.g. social-security-number, name + address

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Existence Constraints

Sometimes, the existence of an entity of type X
depends on the existence of an entity of type Y:

Examples:

- Book chapters presume the existence of a book
- Tracks on a CD presume the existence of the CD
- Orders depend on the existence of a customer

We call Y the *dominating* entity type and
X the *subordinate* type

⇒ strong and weak entities

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Strong and Weak Entities

Dominating and subordinate types are modeled as

- Entities

(also "strong", or "identifying" entities)

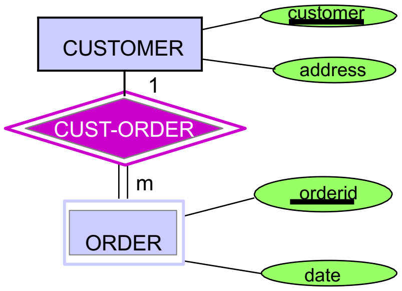
and

- Weak entities

Identifying entity

Supporting, or identifying relationship

Weak entity



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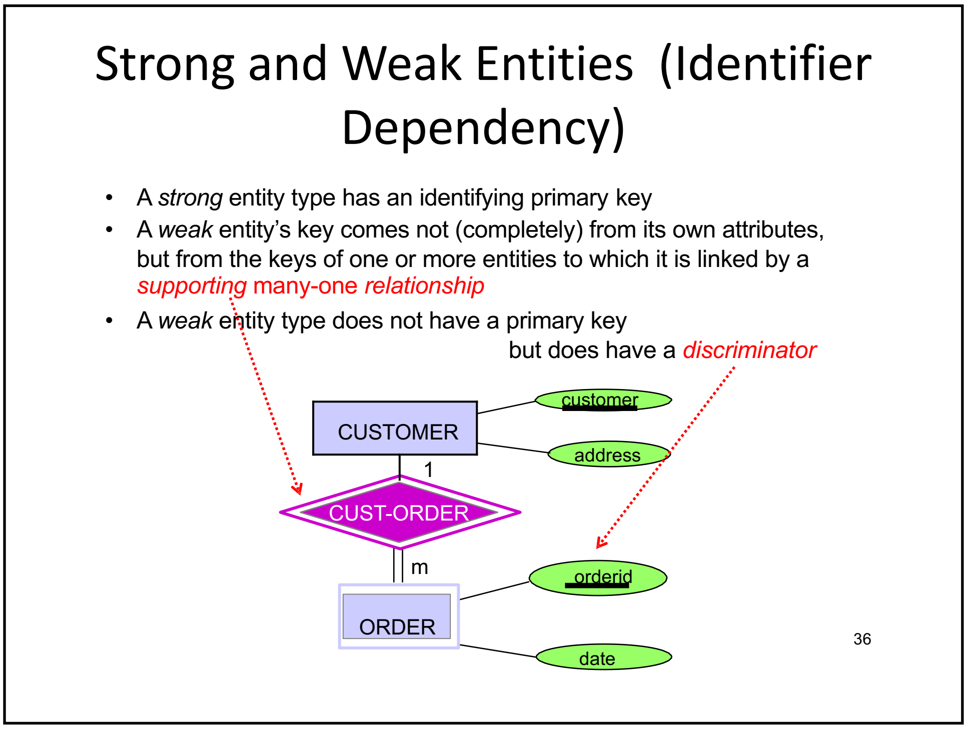

Strong and Weak Entities (Identifier Dependency)

- A *strong* entity type has an identifying primary key
- A *weak* entity's key comes not (completely) from its own attributes, but from the keys of one or more entities to which it is linked by a *supporting* many-one *relationship*
- A *weak* entity type does not have a primary key but does have a *discriminator*

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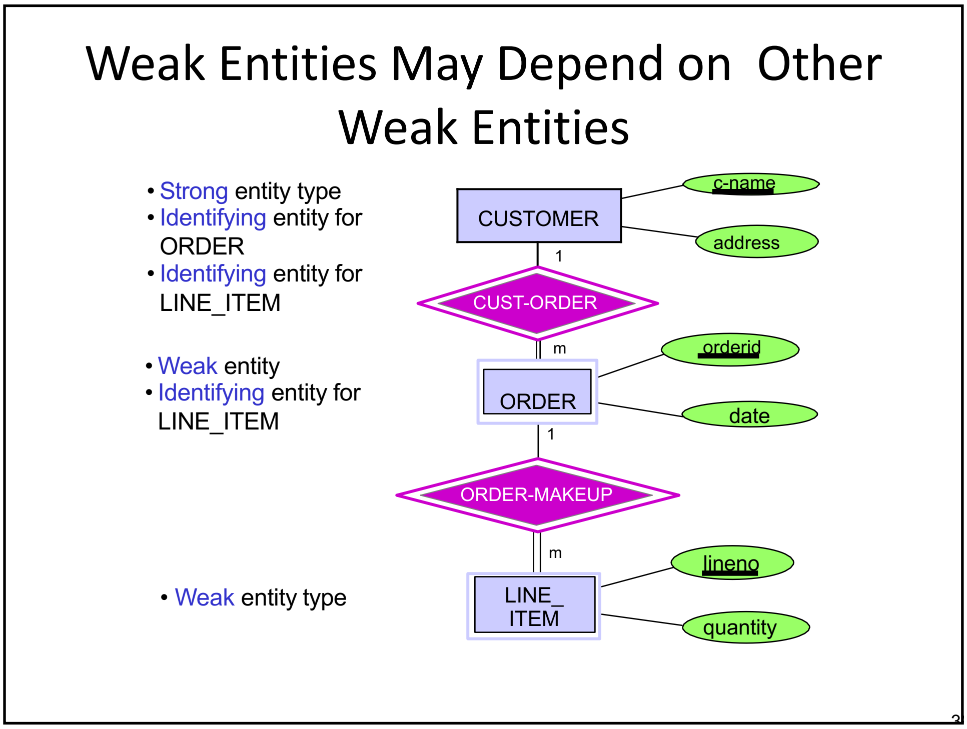

Weak Entities May Depend on Other Weak Entities

- Strong entity type
- Identifying entity for ORDER
- Identifying entity for LINE_ITEM

- Weak entity
- Identifying entity for LINE_ITEM

- Weak entity type

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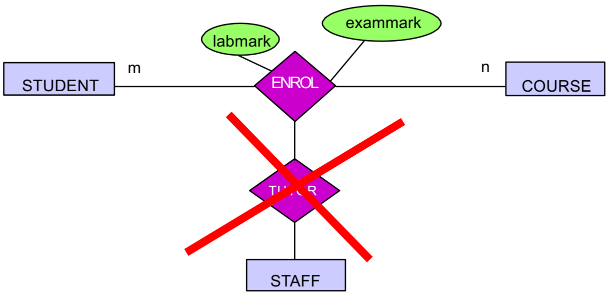
Turning Relationships into Entities

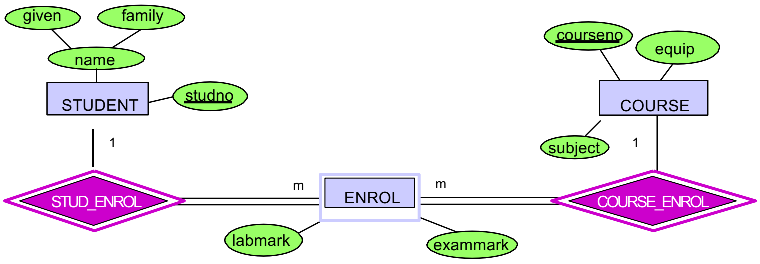
Relationship types are less natural if
- the relationships have many attributes, or
- we want to model a relationship with that relationship type

Example:

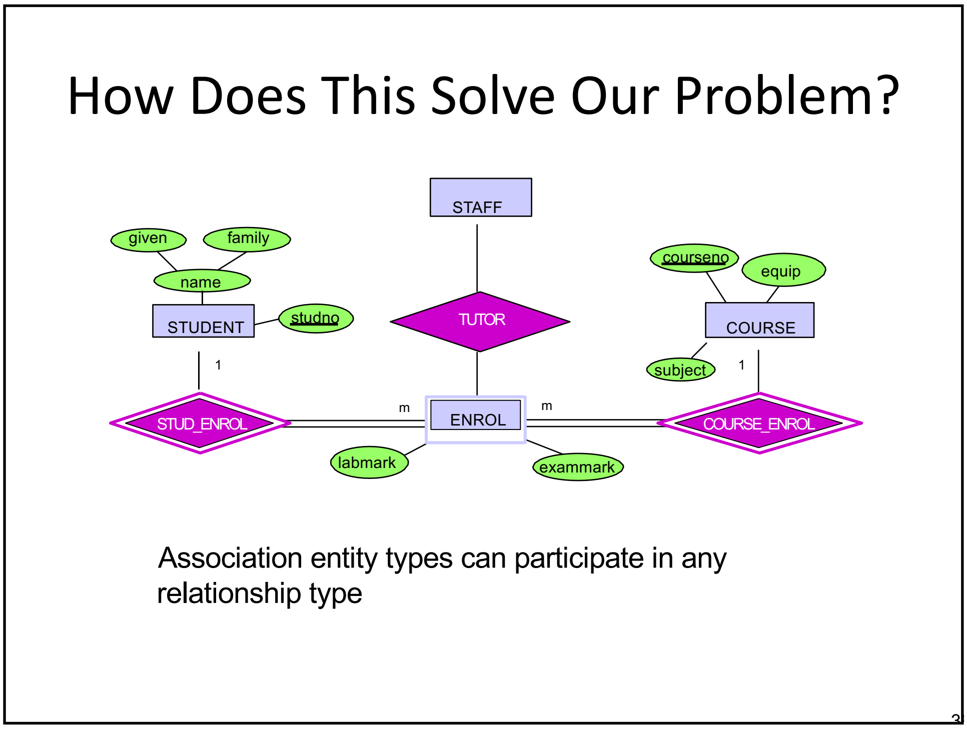


Association Entity Types

An entity type that represents a relationship type:



- The association entity type is a subordinate type
- The participating entity types become dominating types
- Attributes of the relationship become attributes of the entity
- Relationships with the dominating entity types are many-one and mandatory



How Does This Solve Our Problem?

Association entity types can participate in any relationship type

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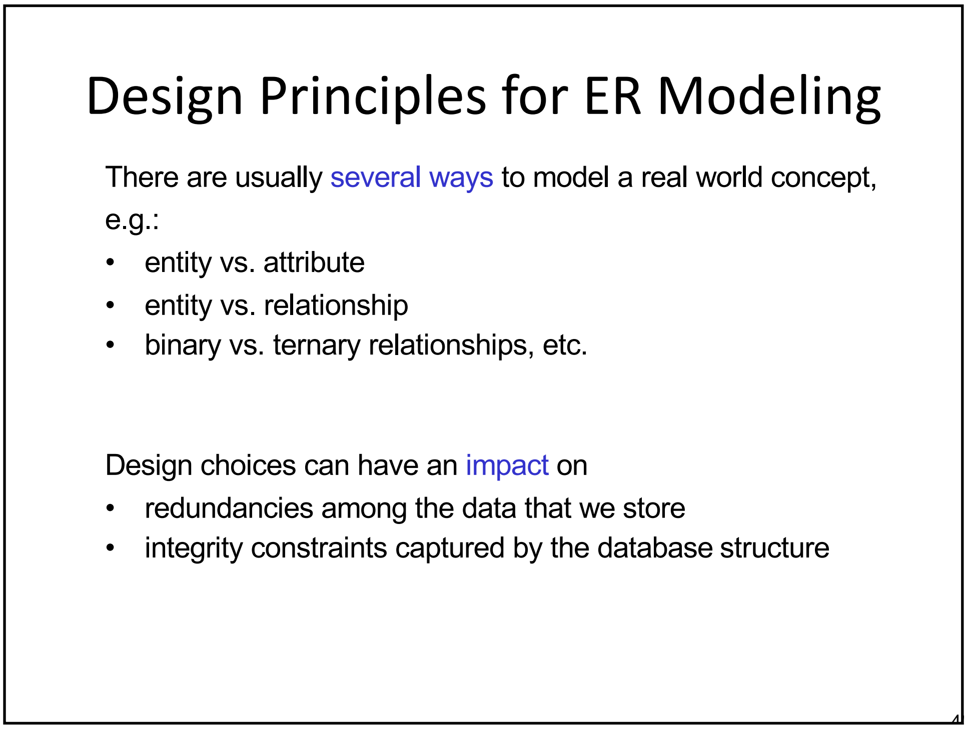

Design Principles for ER Modeling

There are usually several ways to model a real world concept, e.g.:

- entity vs. attribute
- entity vs. relationship
- binary vs. ternary relationships, etc.

Design choices can have an impact on

- redundancies among the data that we store
- integrity constraints captured by the database structure

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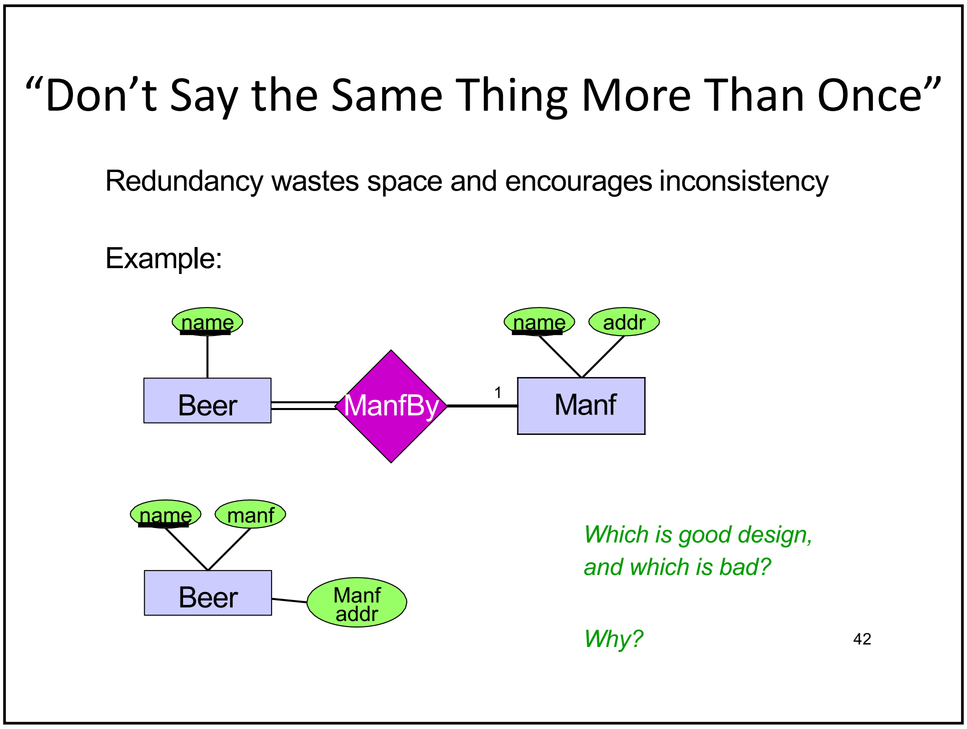

“Don’t Say the Same Thing More Than Once”

Redundancy wastes space and encourages inconsistency

Example:

Which is good design, and which is bad?

Why?

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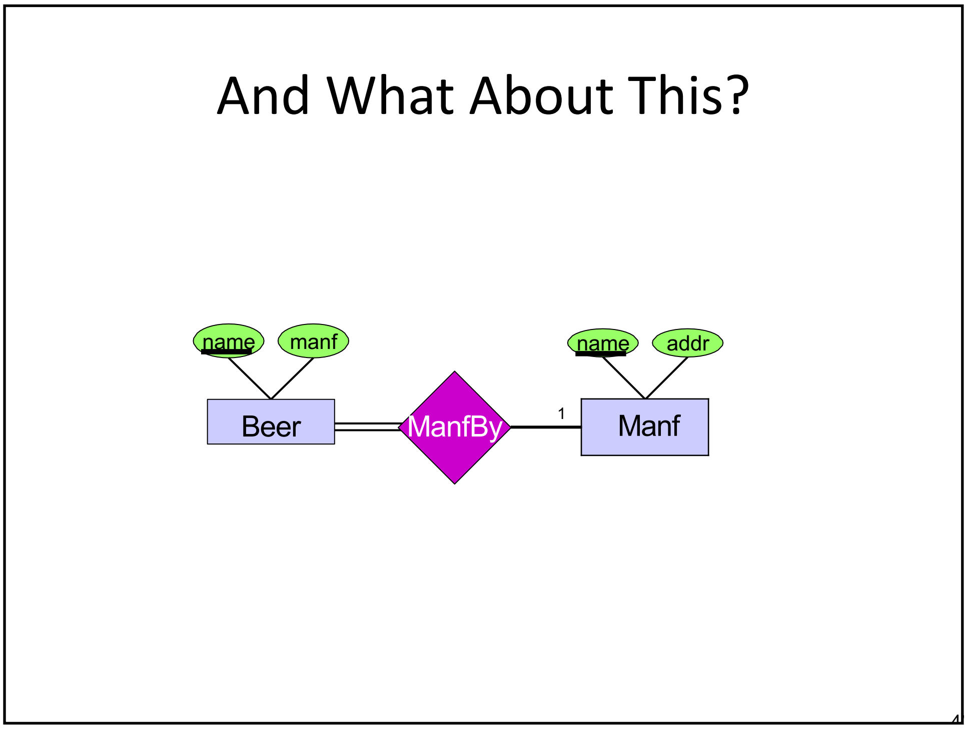

And What About This?

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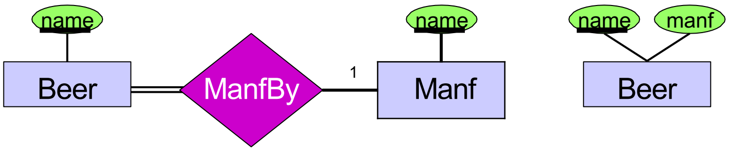
Entities Vs. Attributes

Sometime it is not clear

- which concepts are worthy of being entities, and
- which are handled more simply as attributes

Example:
Which are the pros and cons of each of the two designs below?



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Entity Vs. Attribute: Rules of Thumb

Only make an entity if either:

1. It is more than a name of something; *i.e.*, it has non-key attributes or relationships with a number of different entities, or
2. It is the “many” in a many-one relationship

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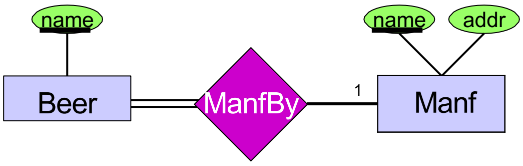
Entity Vs. Attribute: Example

- The following design illustrates both points:



- *Manfs* deserves to be an entity because we record *addr*, a non-key attribute
- *Beers* deserves to be an entity because it is at the "many" end
- If not, we would have to make "set of beers" an attribute of *Manfs*

Hints for ER Modelling

- Identify entity types by searching for nouns and noun phrases
- Assume all entities are strong and check for weak ones on a later pass
- You need an identifier for each strong entity
- Assume all relationships have optional participation and check for mandatory (total) ones on a later pass
- Expect to keep changing your mind about whether things are entities, relationships or attributes
- Keep the level of detail relevant and consistent (for example leave out attributes at first)
- Approach diagram through different views … … and merge them

Use the Schema to Enforce Constraints

- The conceptual *schema* should enforce as many constraints as possible
- Don't rely on future data to follow assumptions

Example:

If the university wants to associate only one instructor with a course,

- don't allow sets of instructors and
- don’t count on departments to enter only one instructor per course

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Superclasses and Subclasses: The Problem

Suppose we want to model that:

- Students can be either undergraduates or graduates
- Among the university employees, there are academic, administrative, and technical staff
- Only undergraduate students have mentors, which are academics

How can we express this in ER diagrams?
How do we translate such diagrams into relations?

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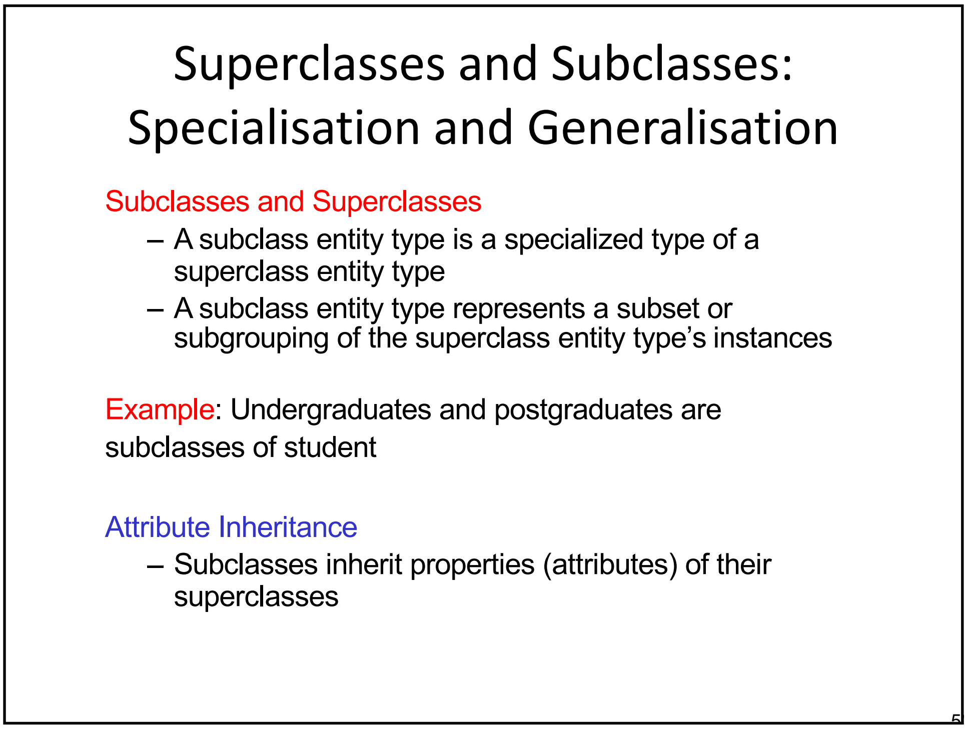

Superclasses and Subclasses: Specialisation and Generalisation

Subclasses and Superclasses

- A subclass entity type is a specialized type of a superclass entity type
- A subclass entity type represents a subset or subgrouping of the superclass entity type's instances

Example: Undergraduates and postgraduates are subclasses of student

Attribute Inheritance

- Subclasses inherit properties (attributes) of their superclasses

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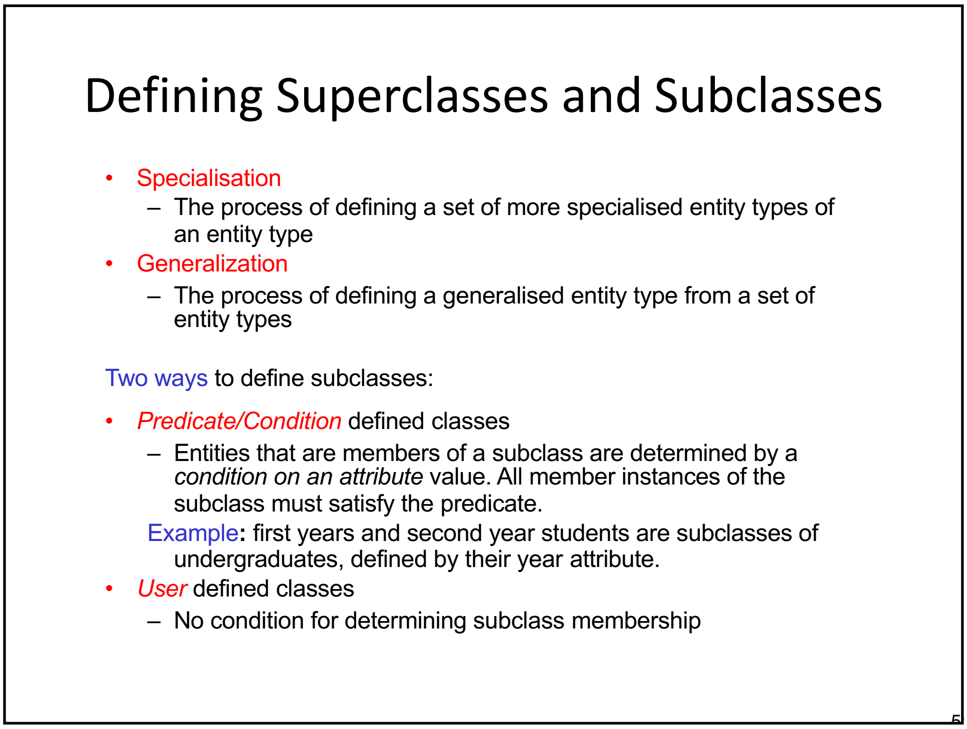

Defining Superclasses and Subclasses

- Specialisation
  - The process of defining a set of more specialised entity types of an entity type
- Generalization
  - The process of defining a generalised entity type from a set of entity types

Two ways to define subclasses:

- *Predicate/Condition* defined classes
  - Entities that are members of a subclass are determined by a *condition on an attribute* value. All member instances of the subclass must satisfy the predicate.

  Example**:** first years and second year students are subclasses of undergraduates, defined by their year attribute.
- *User* defined classes
  - No condition for determining subclass membership

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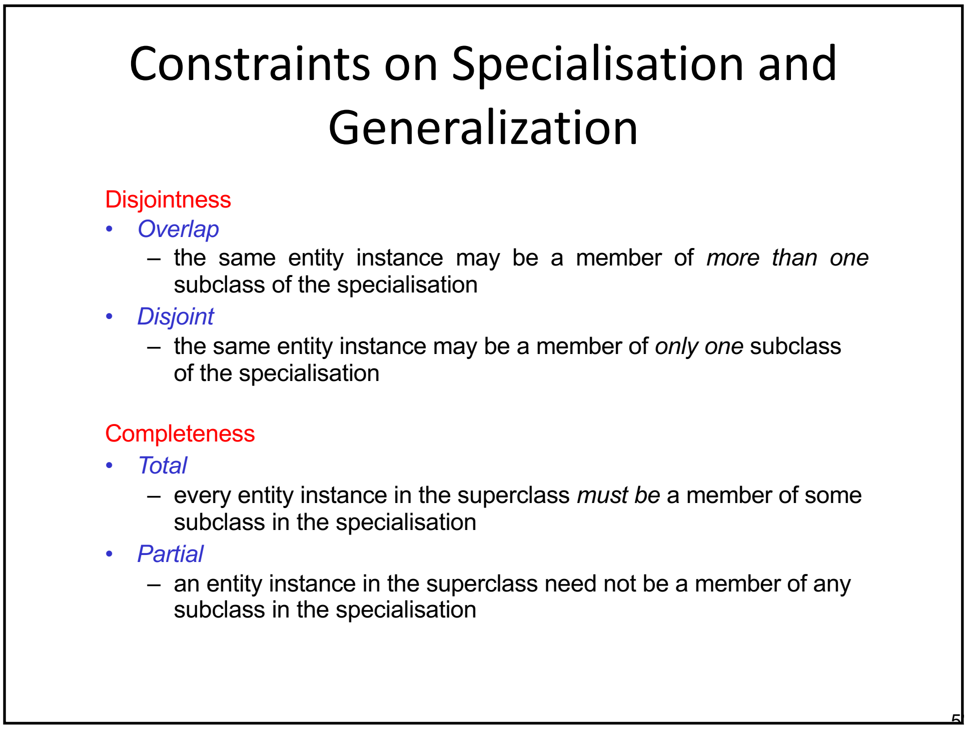

Constraints on Specialisation and Generalization

Disjointness

- *Overlap*
  - the same entity instance may be a member of *more than one* subclass of the specialisation
- *Disjoint*
  - the same entity instance may be a member of *only one* subclass of the specialisation

Completeness

- *Total*
  - every entity instance in the superclass *must be* a member of some subclass in the specialisation
- *Partial*
  - an entity instance in the superclass need not be a member of any subclass in the specialisation

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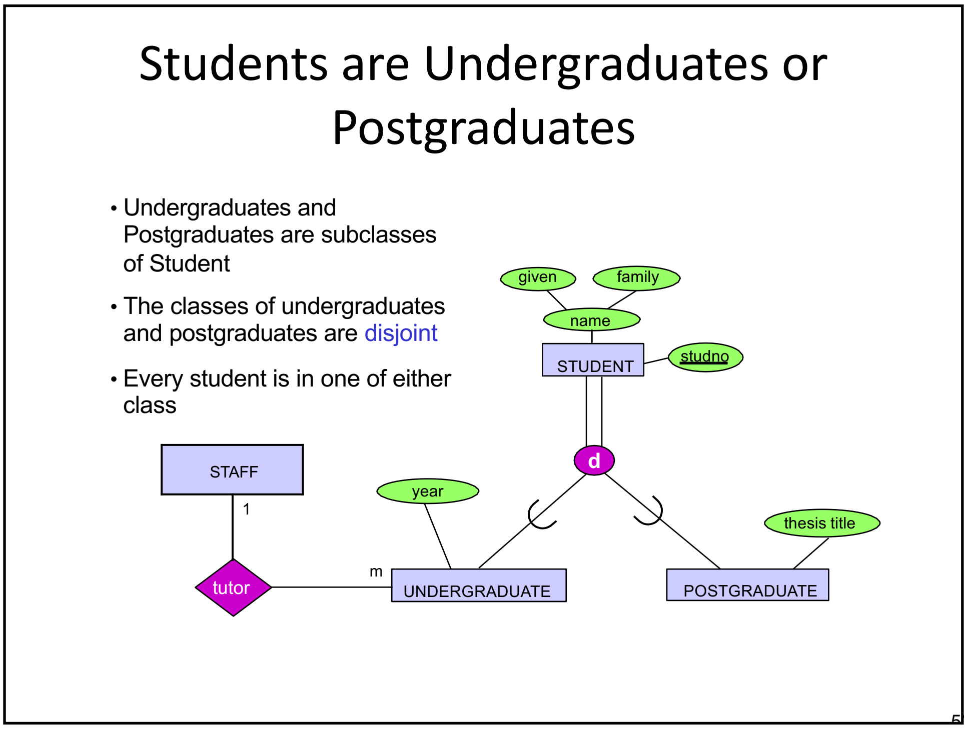

Students are Undergraduates or Postgraduates

- Undergraduates and Postgraduates are subclasses of Student
- The classes of undergraduates and postgraduates are disjoint
- Every student is in one of either class

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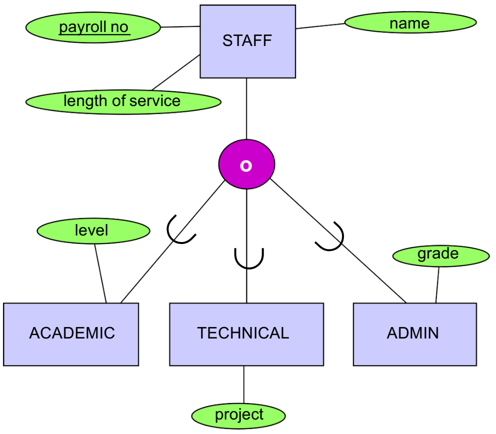
Subclasses of Staff

- Academic, technical, and admin are three subclasses of staff
- The three classes may overlap



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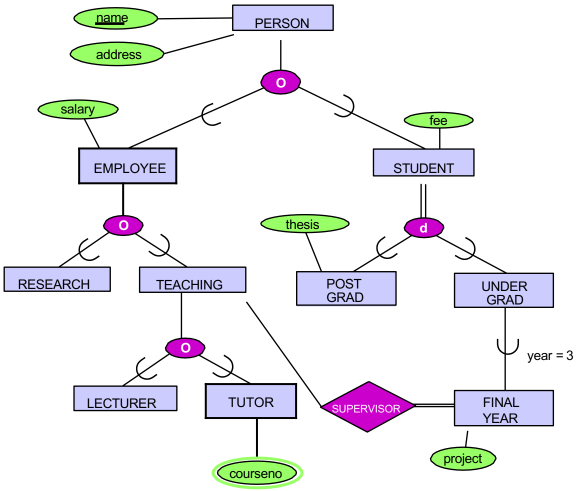
Subclasses in the University Scenario



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