The Entity-Relationship (E-R) model

Lecture topics:

- basic E-R modelling
- extensions to E-R modelling
- designing an E-R schema
- deriving relational schema from E-R diagrams

References:

- text 3rd edition: Chapter 3; Chapter 4, sections 1-2, 7-8; Chapter 9, sections 1-2;
- text 4th edition: Chapter 3; Chapter 4, sections 1-2, 7-8; Chapter 7;

Overview of E-R model

- used for database (conceptual schema) design
- world/enterprise described in terms of:
  - entities
  - attributes
  - relationships
- visualization: *ER-diagram*
- mature methodology (initially described Chen, 1976)

Basic E-R modelling

- **Entity**: a distinguishable object
- **Entity set**: set of entities of same type
- **E.g.**
  - students currently enrolled
  - flights offered by Air Canada
  - burglaries in Ontario during 1999

- Graphical representation of entity sets:

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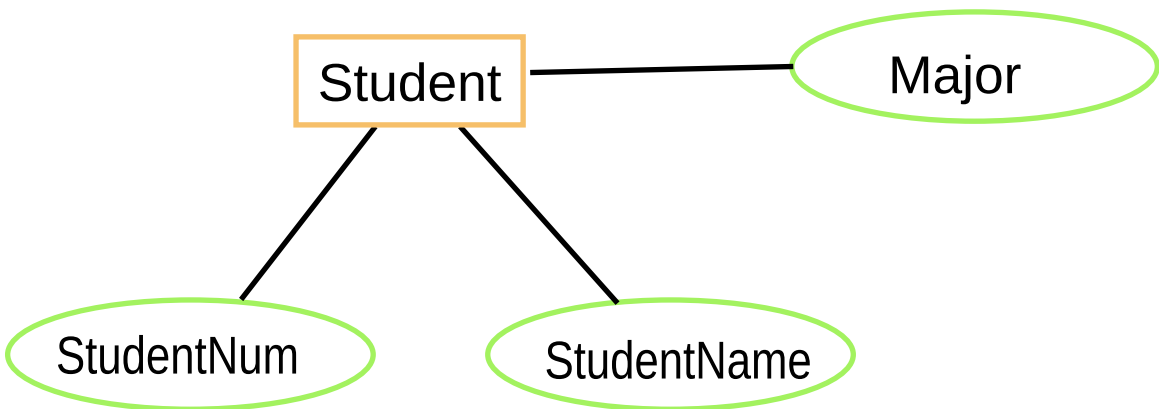
- **Attributes** describe properties of entities
  - **E.g.** for Student entities: StudentNum, StudentName, Major, etc.
- **Domain**: set of permitted values for an attribute
- Graphical representation of attributes:



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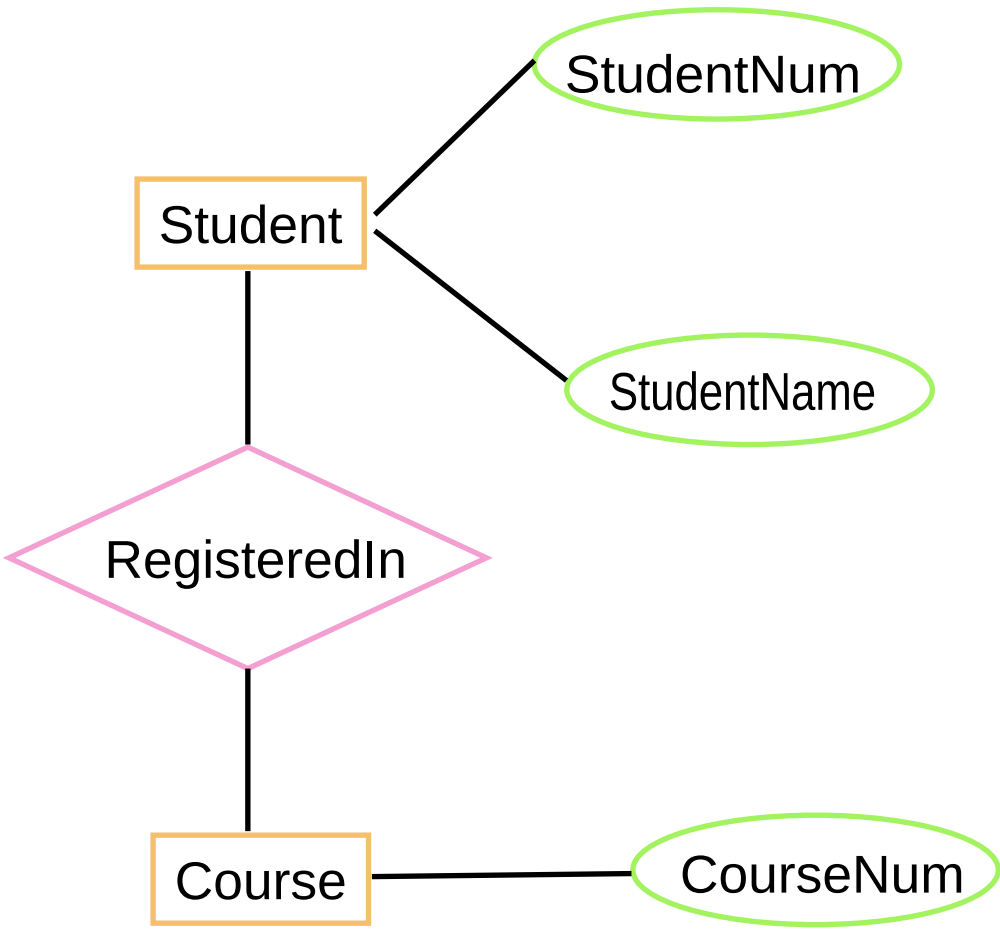
- **Relationship**: representation of the fact that certain entities are related to each other
- **Relationship set**: set of relationships of a given type
- **E.g.**
  - students registered in courses
  - passengers booked on flights
  - parents and their children
  - bank branches, customers, and their accounts
- In order for a relationship to exist, the participating entities must exist

Graphical representation of relationship sets



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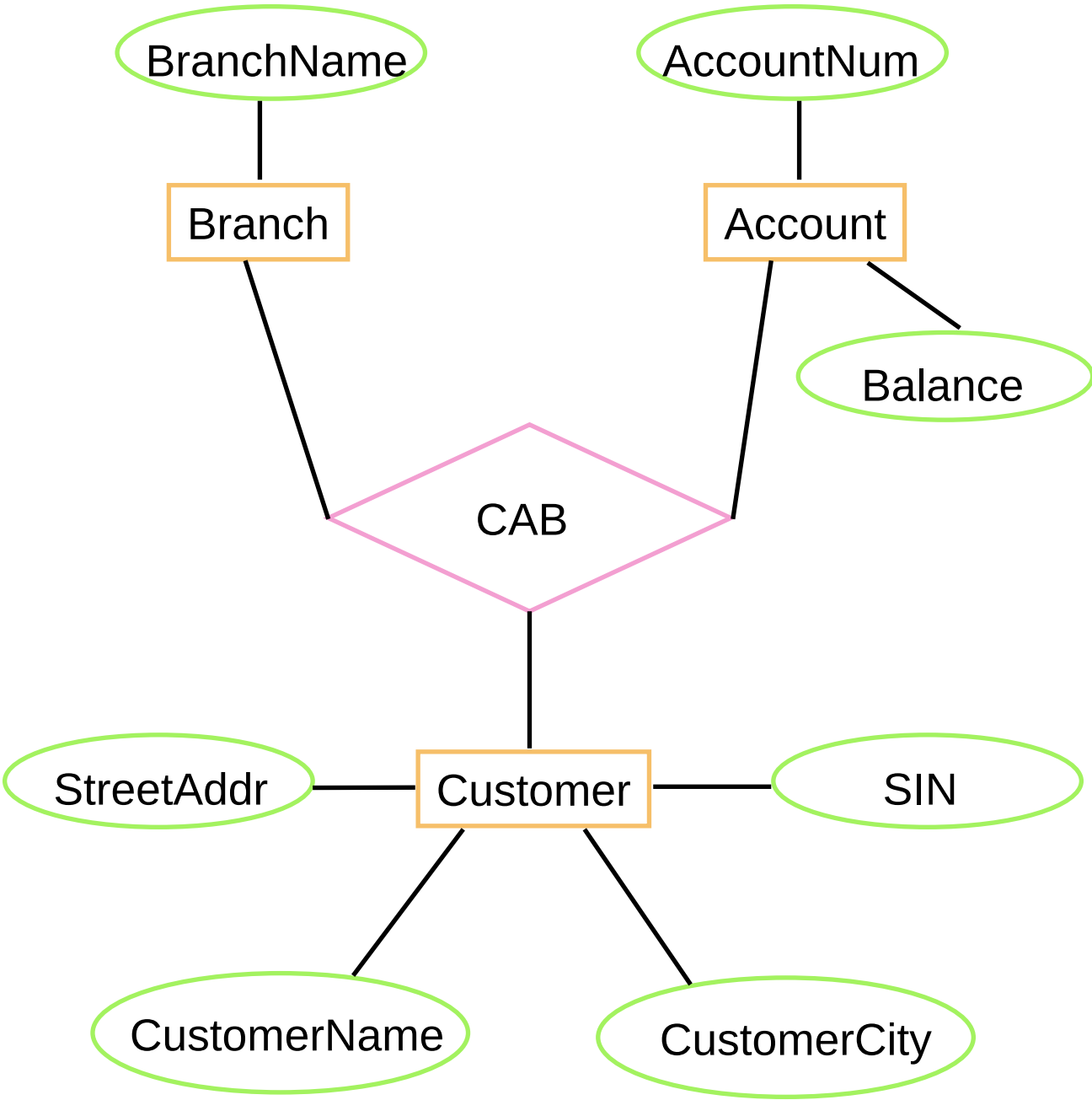
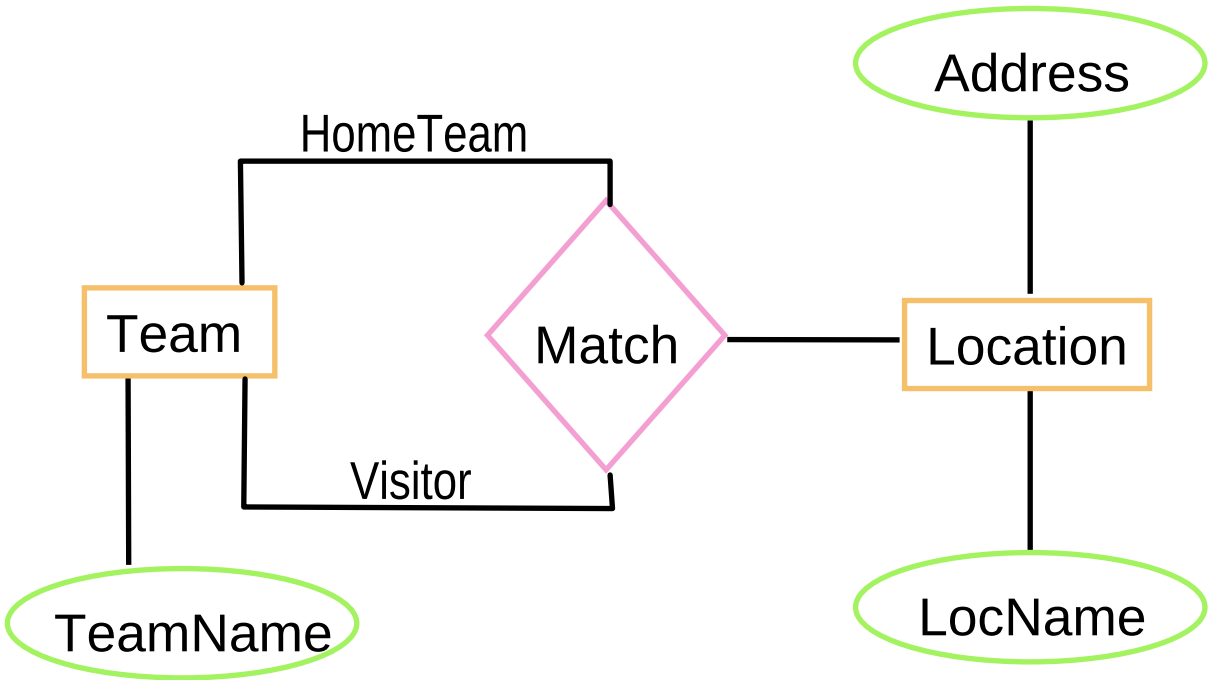

BranchName
AccountNum
Branch
Account
Balance
CAB
StreetAddr
Customer
SIN
CustomerName
CustomerCity

Recursive relationships and role names

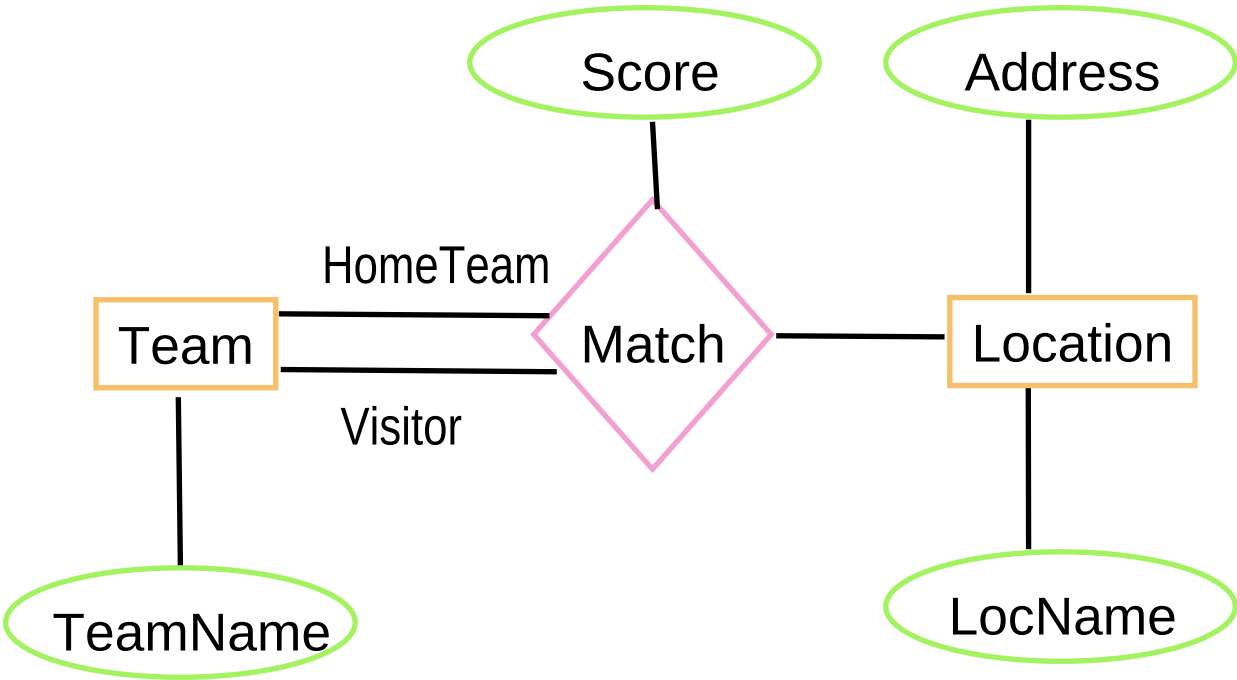
- **Role**: the function of an entity set in a relationship set
- **Role name**: an explicit indication of a role
- **E.g.**



- Role labels are needed whenever an entity set has multiple functions in a relationship set.

Relationships and attributes

- Relationships may also have attributes:

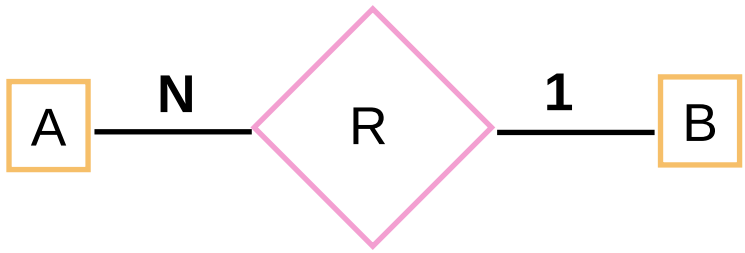


Constraints in E-R models

- binary relationship cardinalities
- general cardinality constraints
- primary keys
- existence dependencies

Binary relationship cardinality

- relationships between two entity sets, A and B
- **many-to-one (N:1)**: each entity in A can be related to at most one entity in B, but an entity in B may be related to many entities in A
- E-R diagram notation:



- **E.g.**

- similarly: **one-to-many (1:N)**

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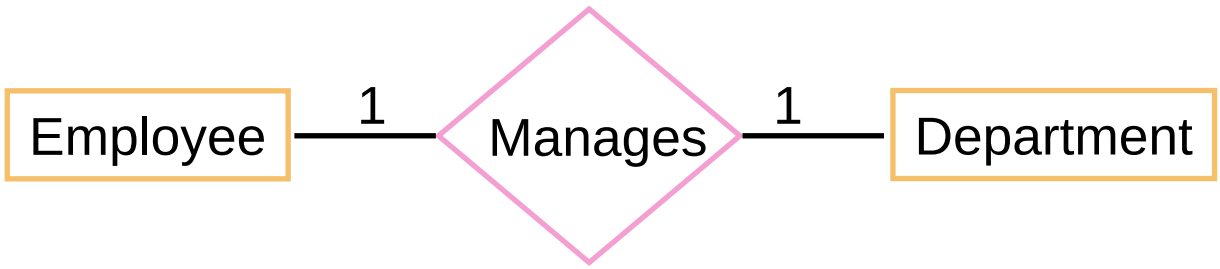
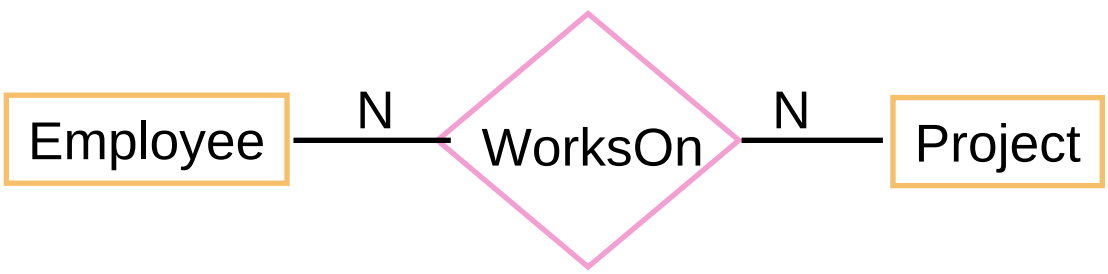
- **one-to-one (1:1)**: each entity in A can be related to at most one entity in B, and vice versa
- **E.g.**

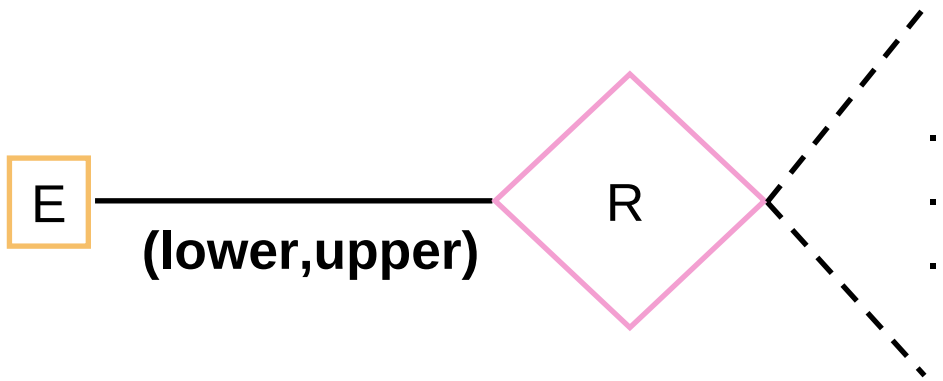


- **many-to-many (N:N):** an entity can be related to many entities in the other set, and vice versa
- **E.g.**

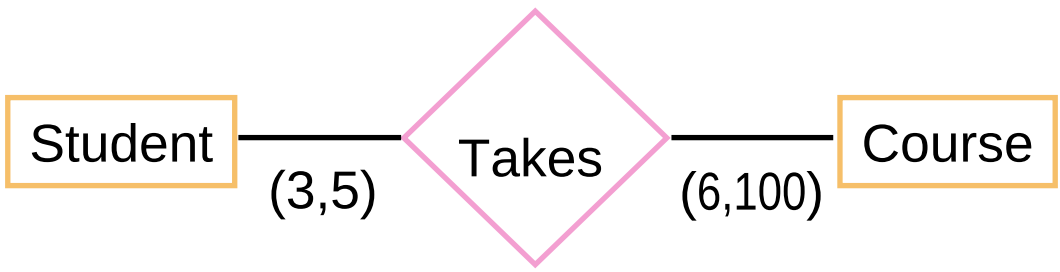


General cardinality constraints

- Determine lower and upper bounds on the number of relationships of a given relationship set in which a component entity may participate
- E-R diagram notation:

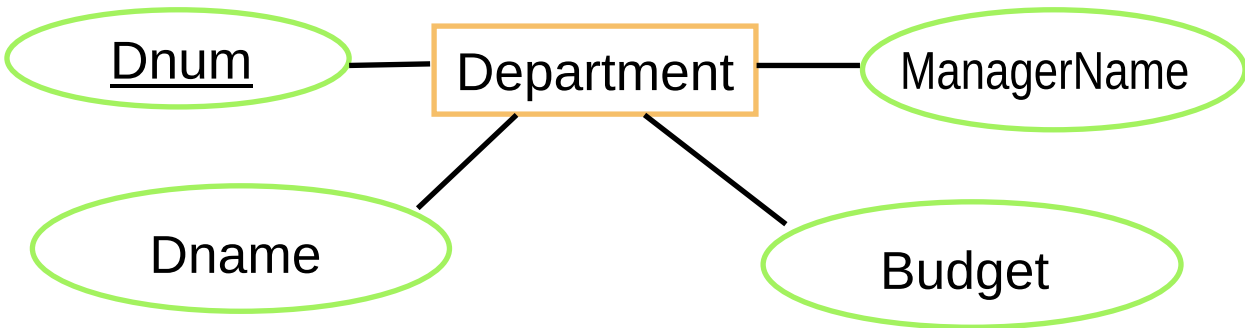


- **E.g.**

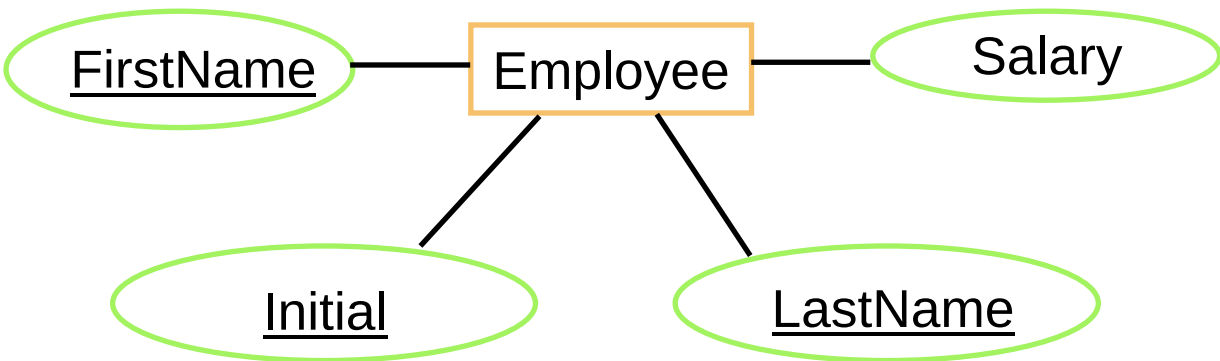


Primary keys

- as in relational model, each entity must be distinguishable from any other entity in its set by its attributes
- **Primary key**: selection of attributes chosen by designer as a primary identifier of entities in entity set
- **E.g.**

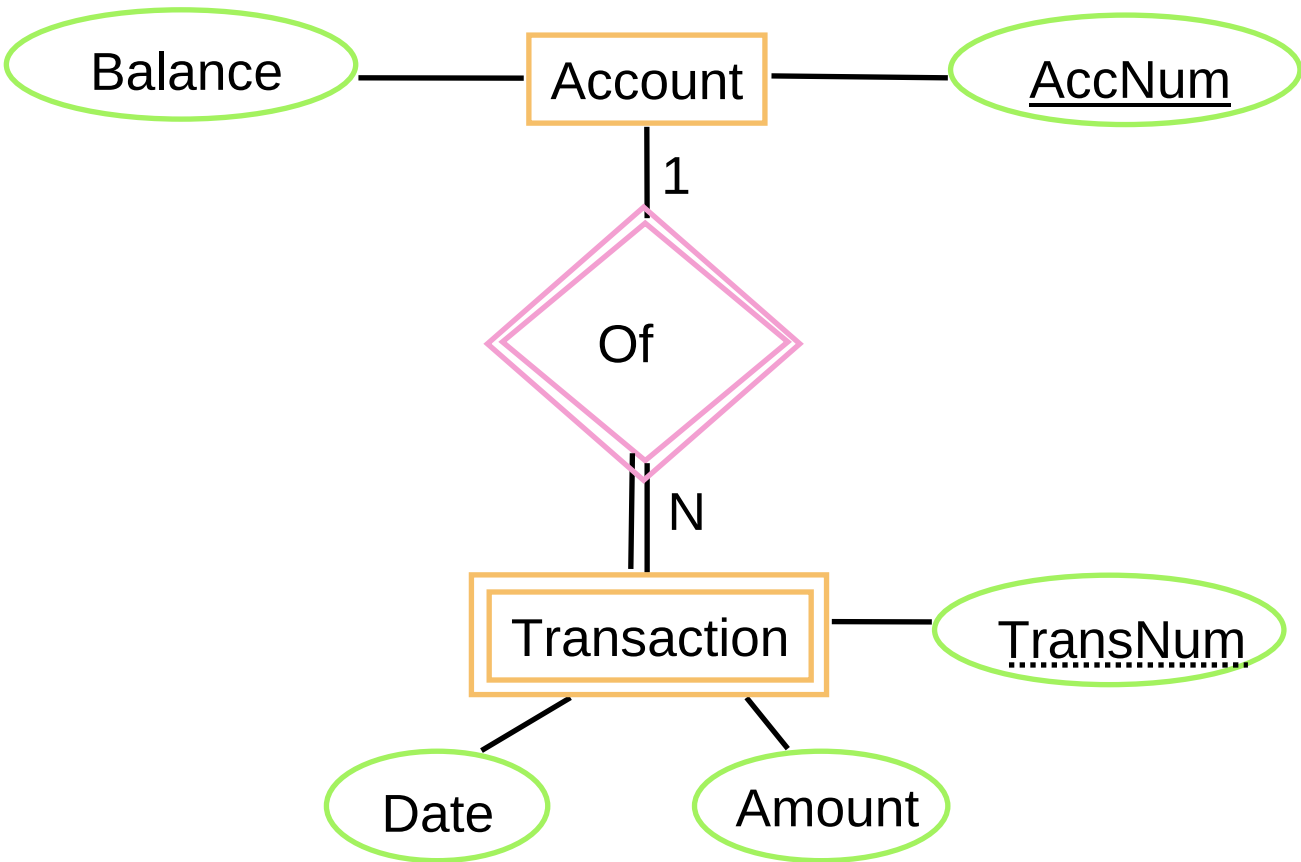


- **E.g.**



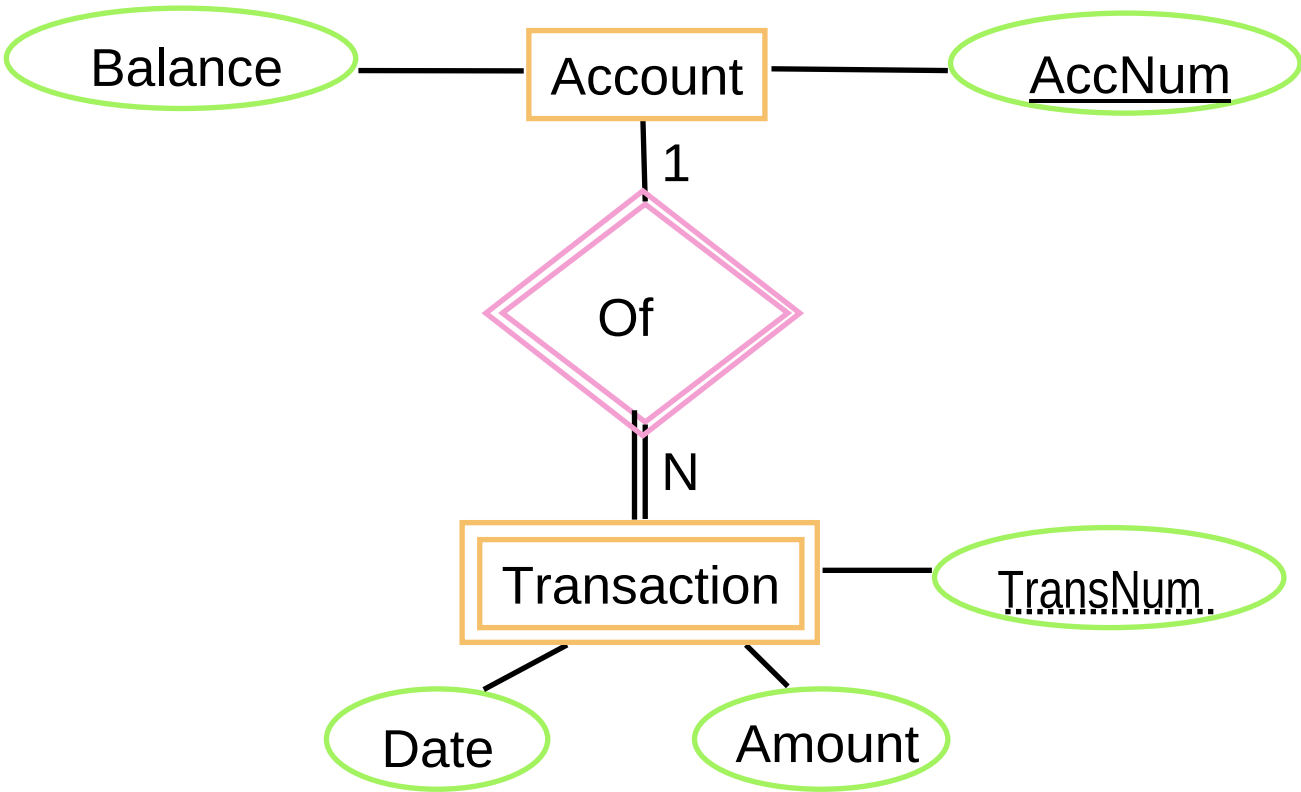
Existence dependencies

- Sometimes the existence of an entity depends on the existence of another entity
- If *x* is **existence dependent** on *y*, then
  - *y* is a **dominant entity**
  - *x* is a **subordinate entity**
- **E.g.** "Transactions are existence dependent on accounts."



Primary keys of subordinate entity sets

- **Weak entity set**: an entity set with subordinate entities
- **Strong entity set**: an entity set with no subordinate entities
- primary identifier of weak entity sets combines with primary identifier of associated strong entity set
- **E.g.** "All transactions *for a given account* have a unique transaction number."



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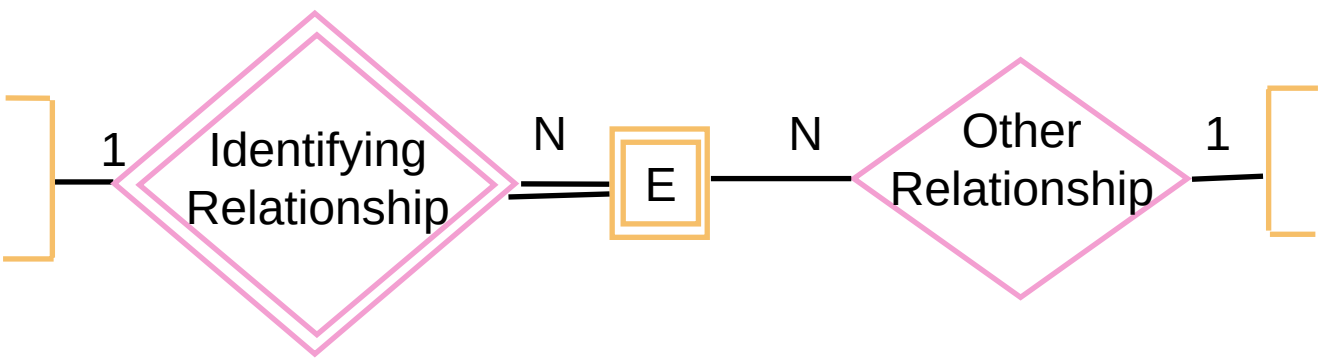
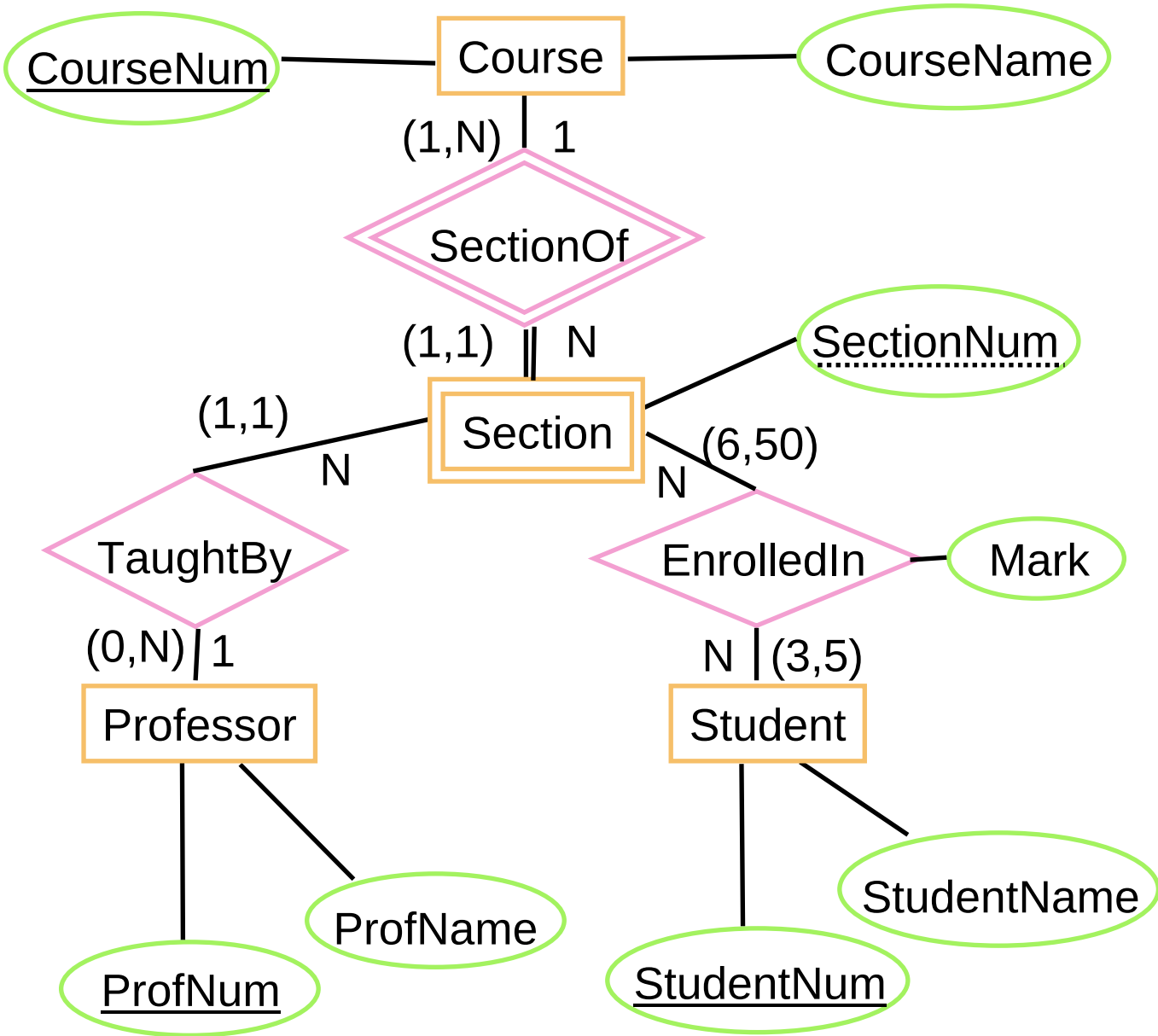
- A weak entity must have an N:1 relationship to a distinct entity set
- **Discriminator** of a weak entity set: set of attributes that distinguish subordinate entities of the set, for a particular dominant entity
- Primary key for a weak entity set: discriminator + primary key of entity set for dominating entities
- ER diagram notation: (distinguishing an identifying relationship)



Example E-R diagram

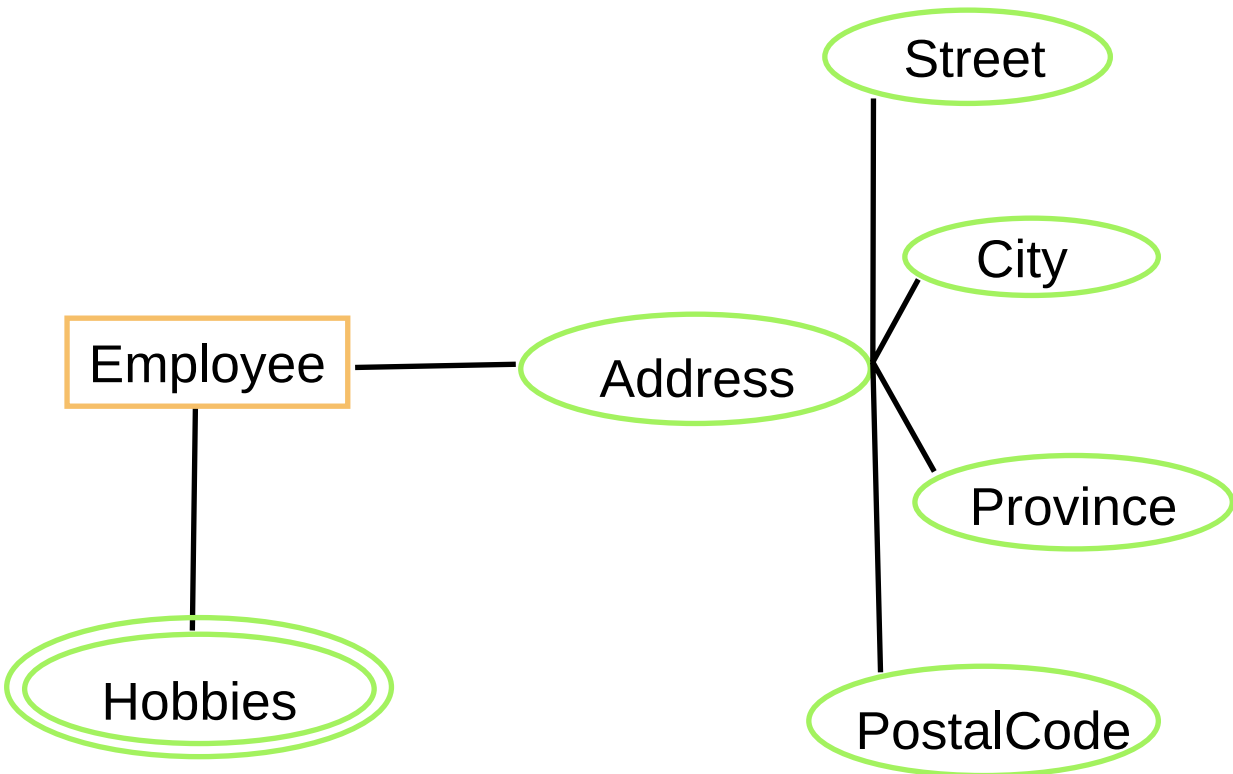


Extensions to E-R modeling

- Structured attributes
- Aggregation
- Specialization
- Generalization

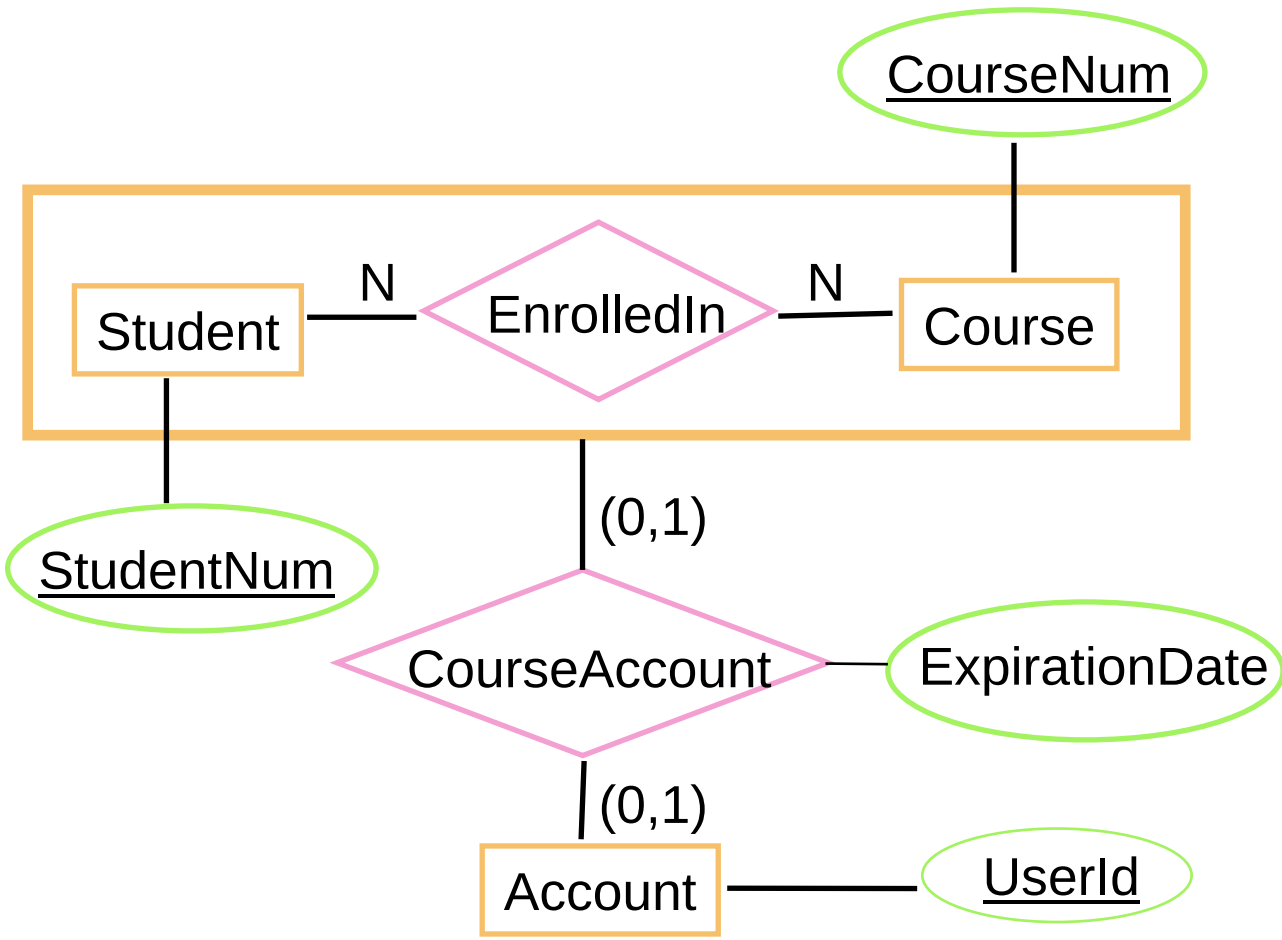
Structured attributes

- **Composite attributes**: attributes composed of two or more other attributes
- **Multi-valued attributes**: attributes that are set-valued
- **E.g.**



Aggregation

- Relationships can be viewed as higher-level entities
- **E.g.** “Accounts are assigned to a given student enrollment.”



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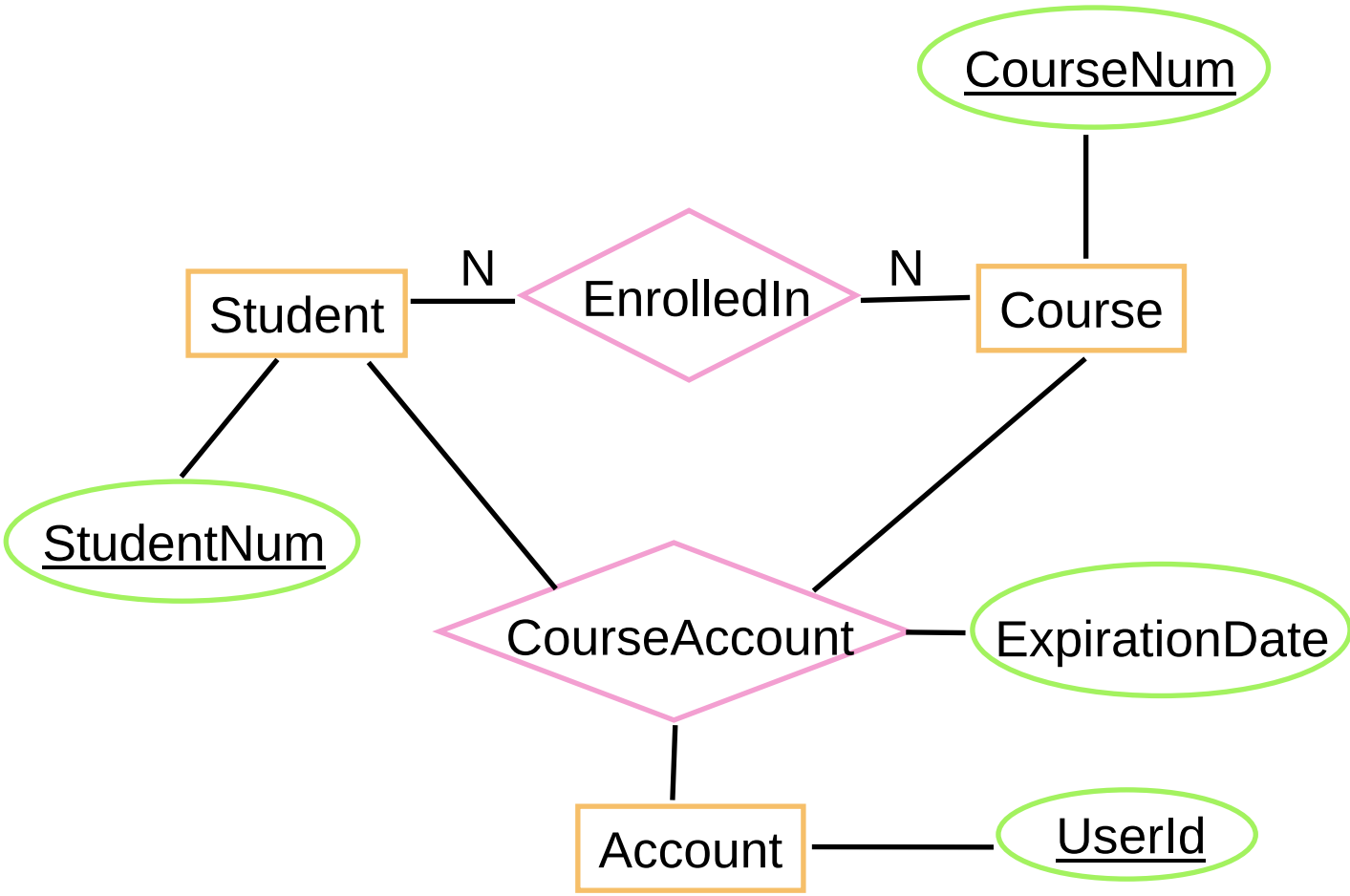
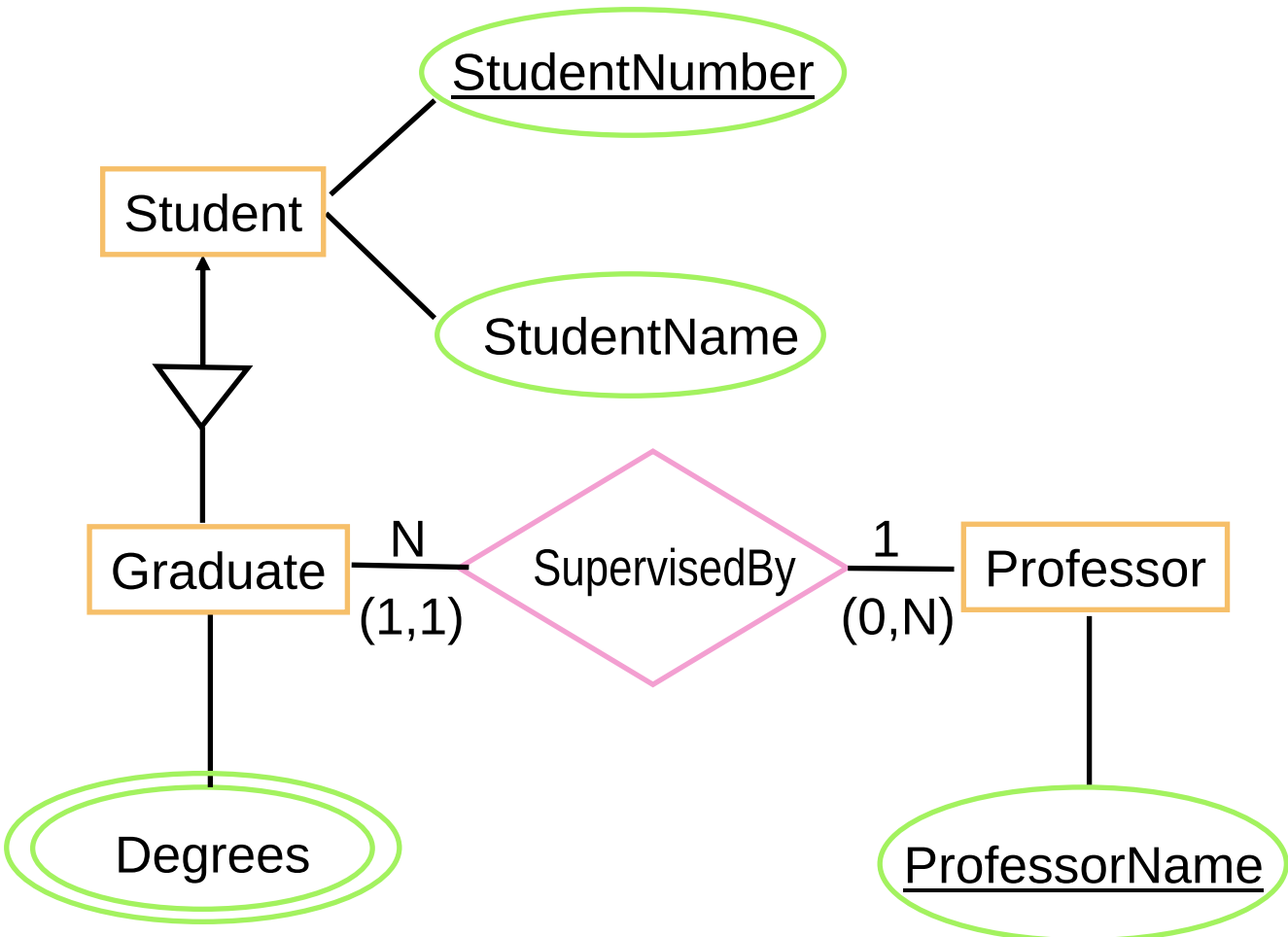
- same, without aggregation:



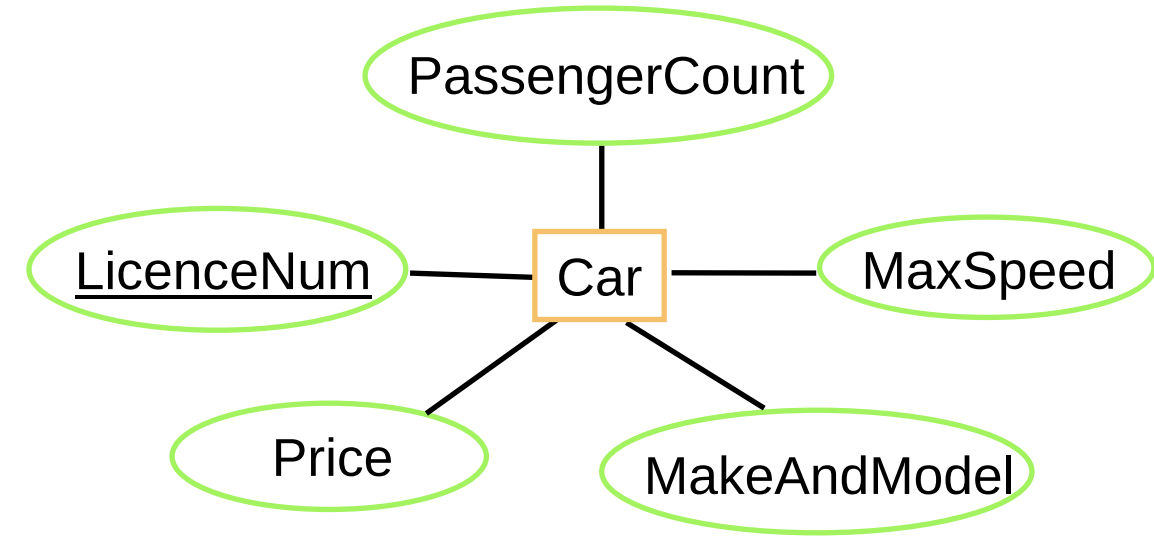
Specialization

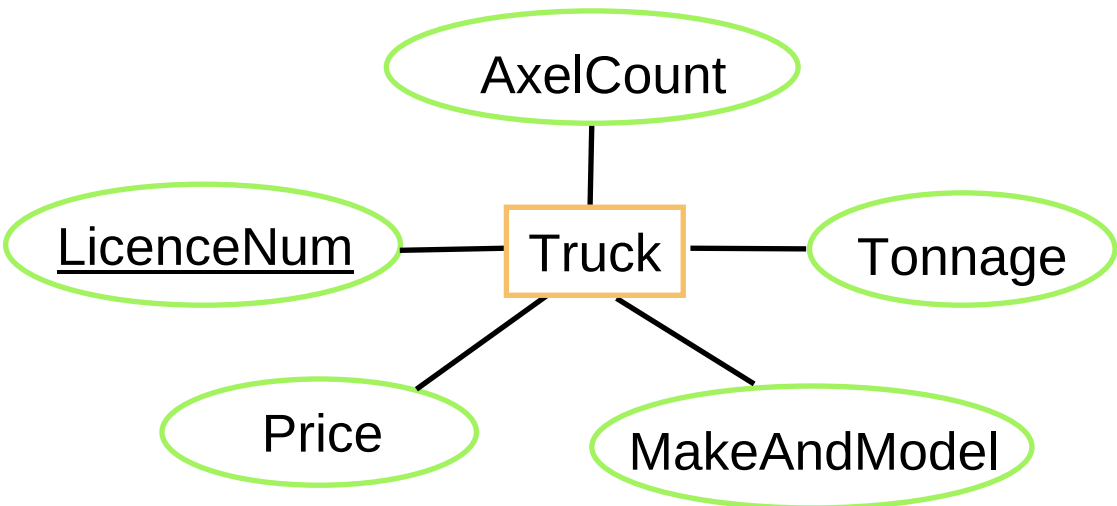
- A more specialized kind of entity set may be derived from a given entity set
- **E.g.** “Graduate students are students that have a supervisor and a number of degrees.”



Generalization

- Two or more existing entity sets can be abstracted as a more general kind of entity set
- **E.g.** “A vehicle abstracts the notion of a car and a truck.”





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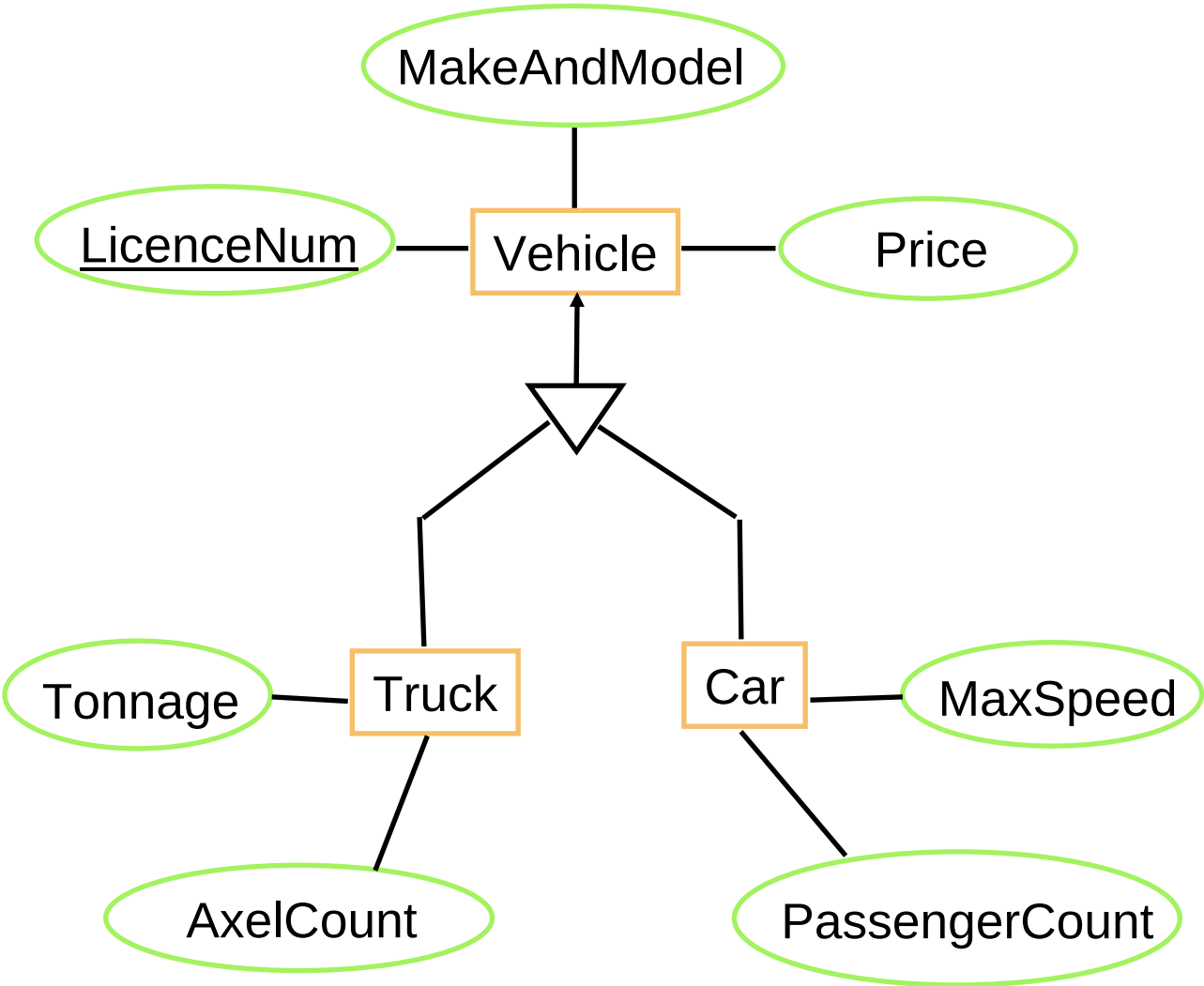
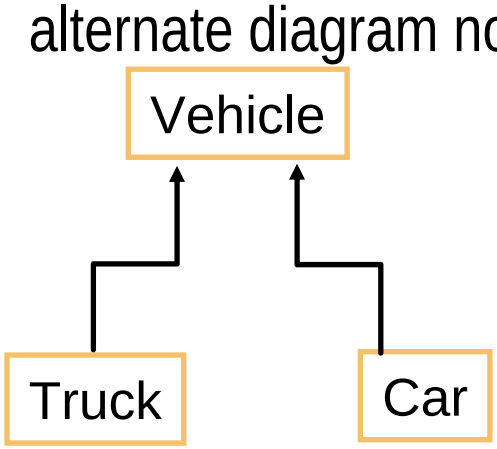
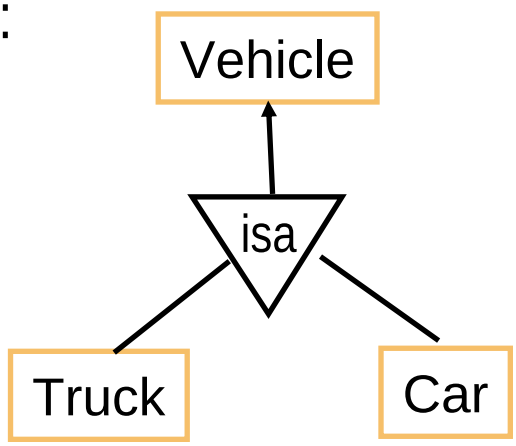


- alternate diagram notations:





Designing an E-R schema

- usually many ways to design an E-R schema

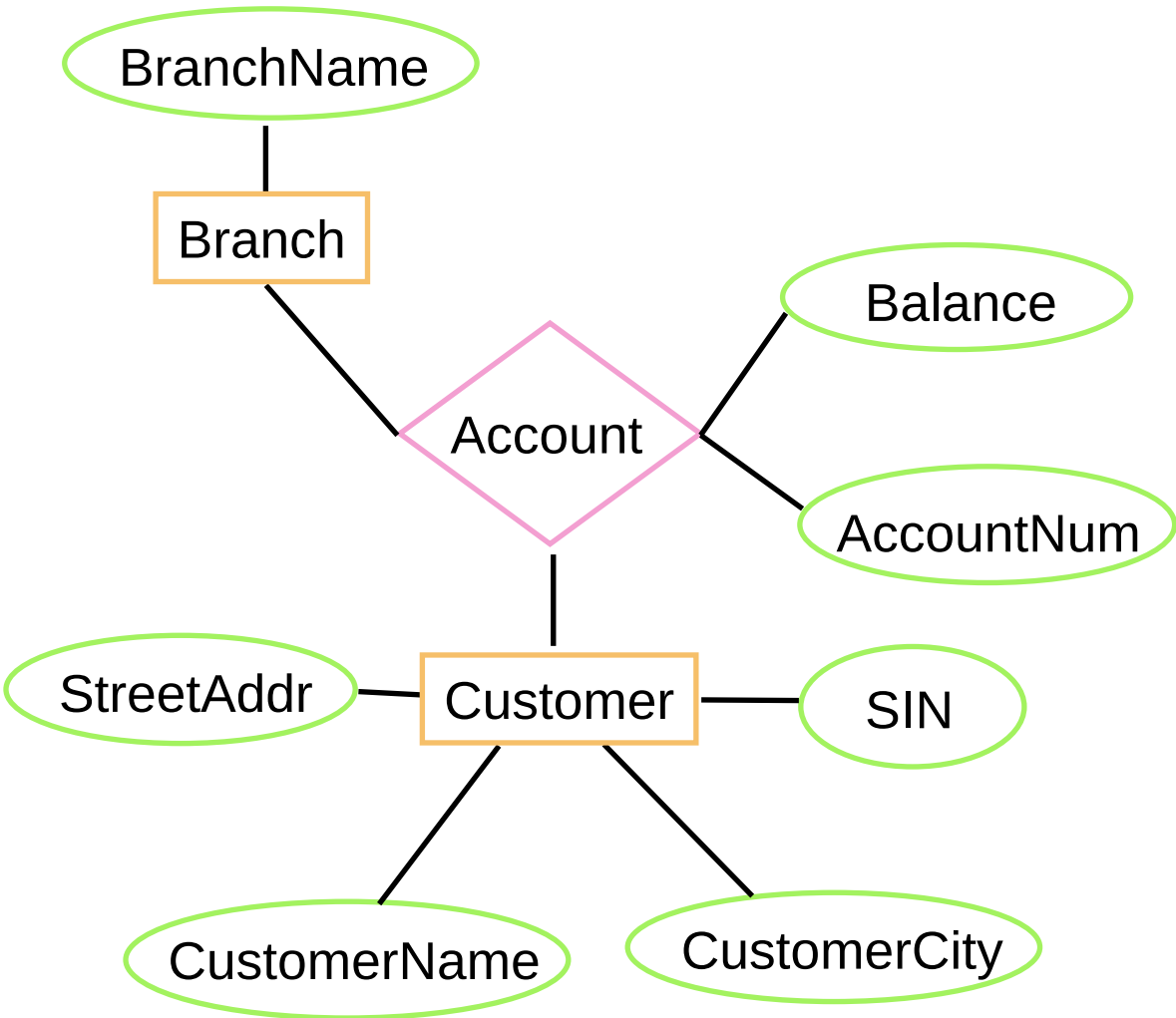
- points to consider:
  - use attribute or entity set?
  - use entity set or relationship set?
  - degrees of relationships?
  - extended features?

Choosing between attributes and entity sets

- no simple answer!
- **E.g.** model employees' phones by a PhoneNumber attribute, or by Phone entity set related to Employee entity set?
  - is it (could it be) a separate object?
  - do we maintain information about it?
  - can several of its kind belong to another single entity?
  - does it make sense to delete such an object?
  - can it be missing from some of the entity set's entities?
  - can it be shared by different entities?
- "yes" to any of the above implies introducing a new entity set

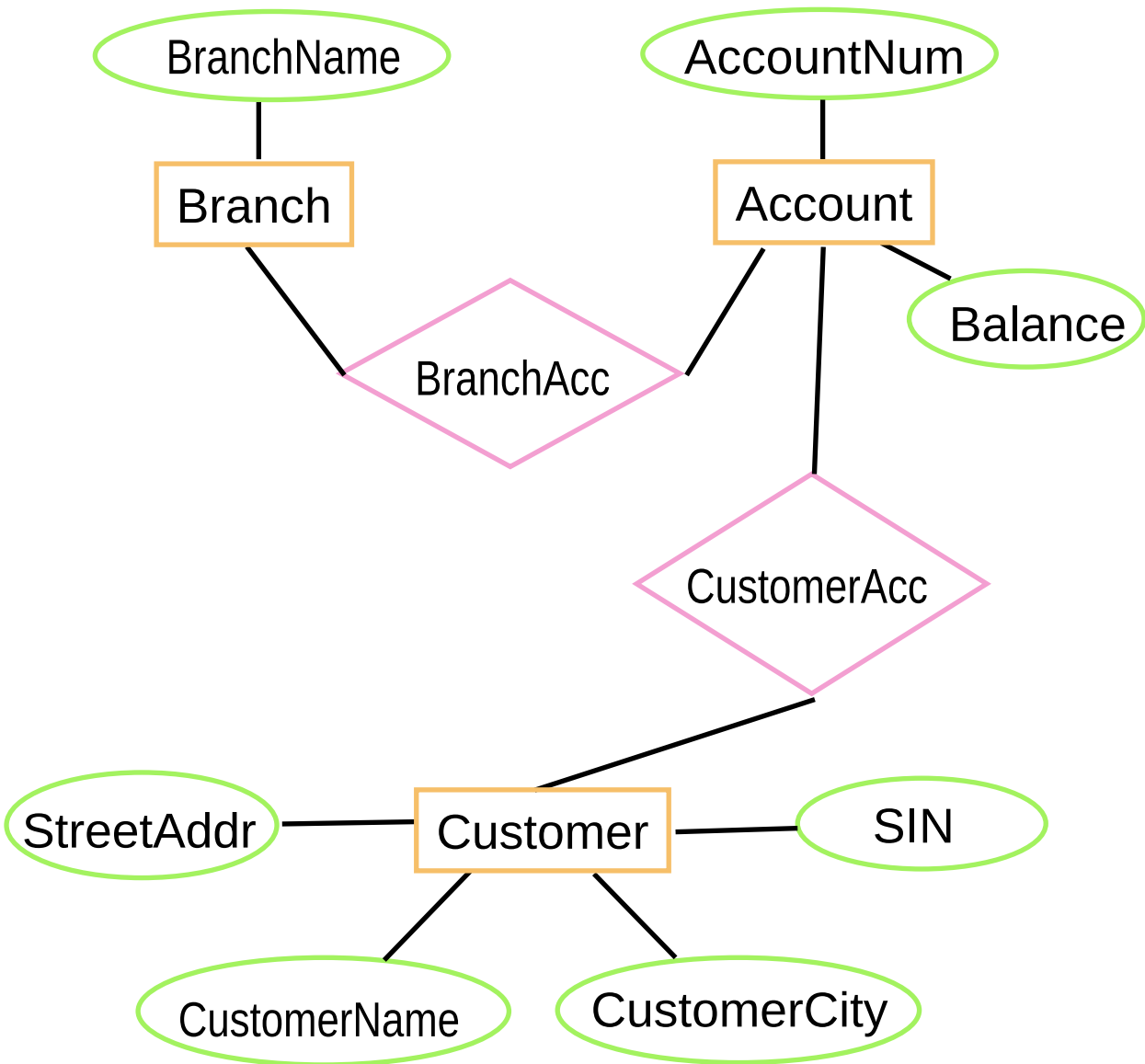
Choosing between entity sets and relationship sets

- again no simple answer!
- **E.g.** Instead of representing accounts as entities, we could represent them as relationships



Use of non-binary relationships

- Can always represent a relationship on *n* entity sets with *n-1* binary relationships



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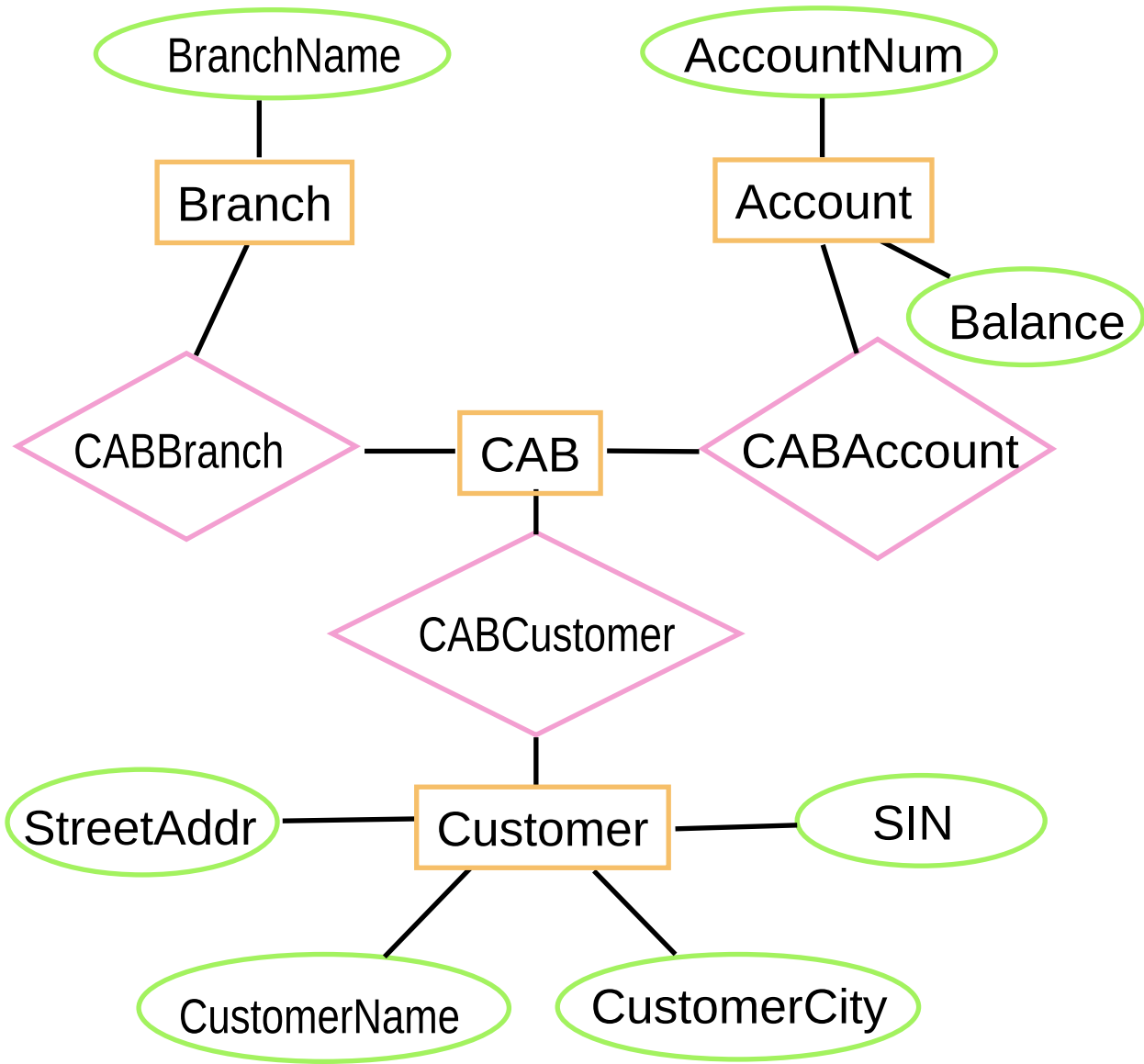
- Another representation:



Use of extended E-R features

- Can improve modularity and abstraction if used with care
- Excessive use can complicate design

A simple methodology

- recognize entity sets
- recognize relationship sets and participating entity sets
- recognize attributes of entity sets and attributes of relationship sets
- define binary relationship types and existence dependencies
- define general cardinality constraints, keys and discriminators
- draw diagram

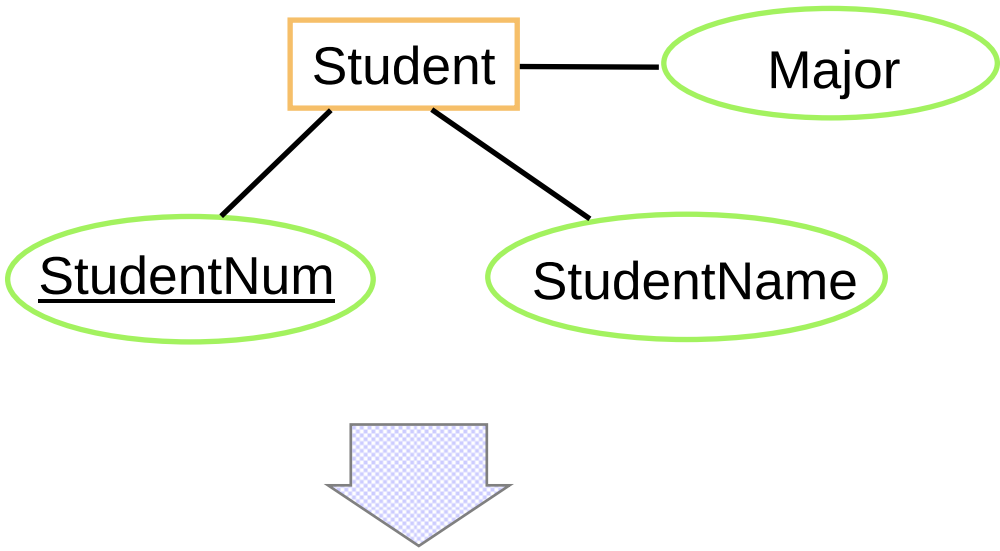
For each step, maintain a log of assumptions motivating the choices, and of restrictions imposed by the choices.

Translating E-R diagrams to relational schema

- General approach is straightforward:
  - each entity set becomes a table
  - each attribute (of an entity) becomes a table column
  - each relationship set becomes either table columns or table by itself

Representing strong entity sets

- Entity set E with attributes a_1, ..., a_n $\rightarrow$ table E with attributes a_1, ..., a_n
- Entity of type $E \leftrightarrow$ row in table E
- Primary key of entity set $\rightarrow$ primary key of table
- **E.g.**

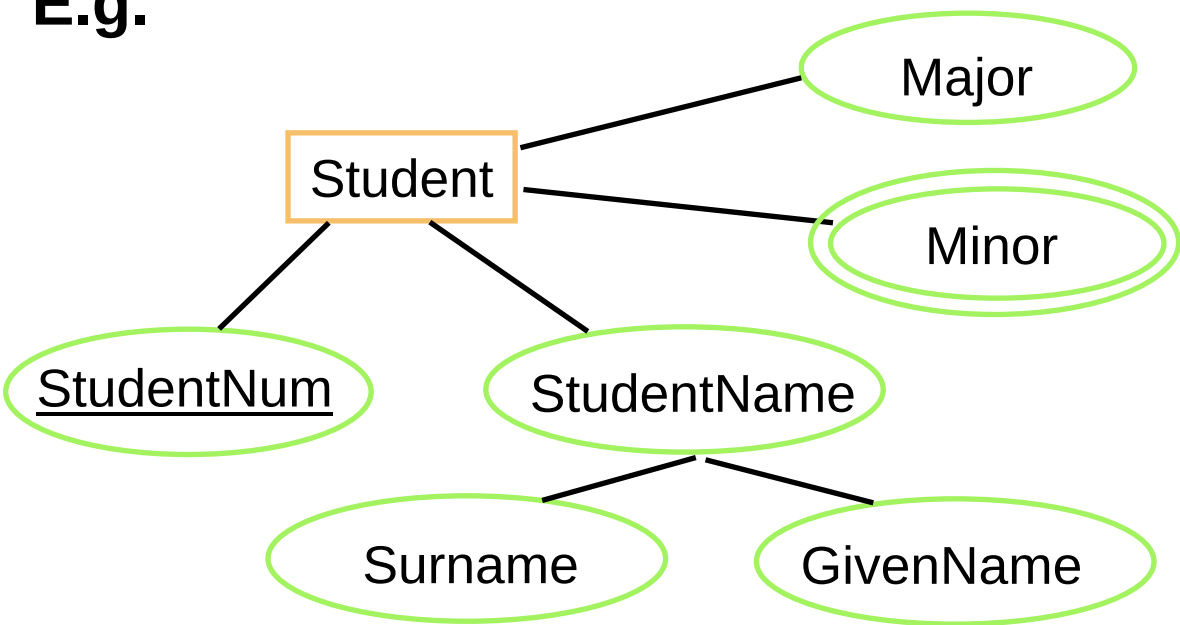


Student

StudentNum	StudentName	Major

Structured attributes

- Composite attributes, multi-valued attributes
- **E.g.**



Student

StudentNum	Surname	GivenName	Major

Minors

StudentNum	Minor

Representing Weak Entity Sets

- Weak entity set *E* $\rightarrow$ table *E*
- Columns of table *E* include:
  - attributes of the weak entity set
  - attributes of the identifying relationship set (if any)
  - primary key attributes of entity set for dominating entities
- Primary key of weak entity set $\rightarrow$ primary key of table

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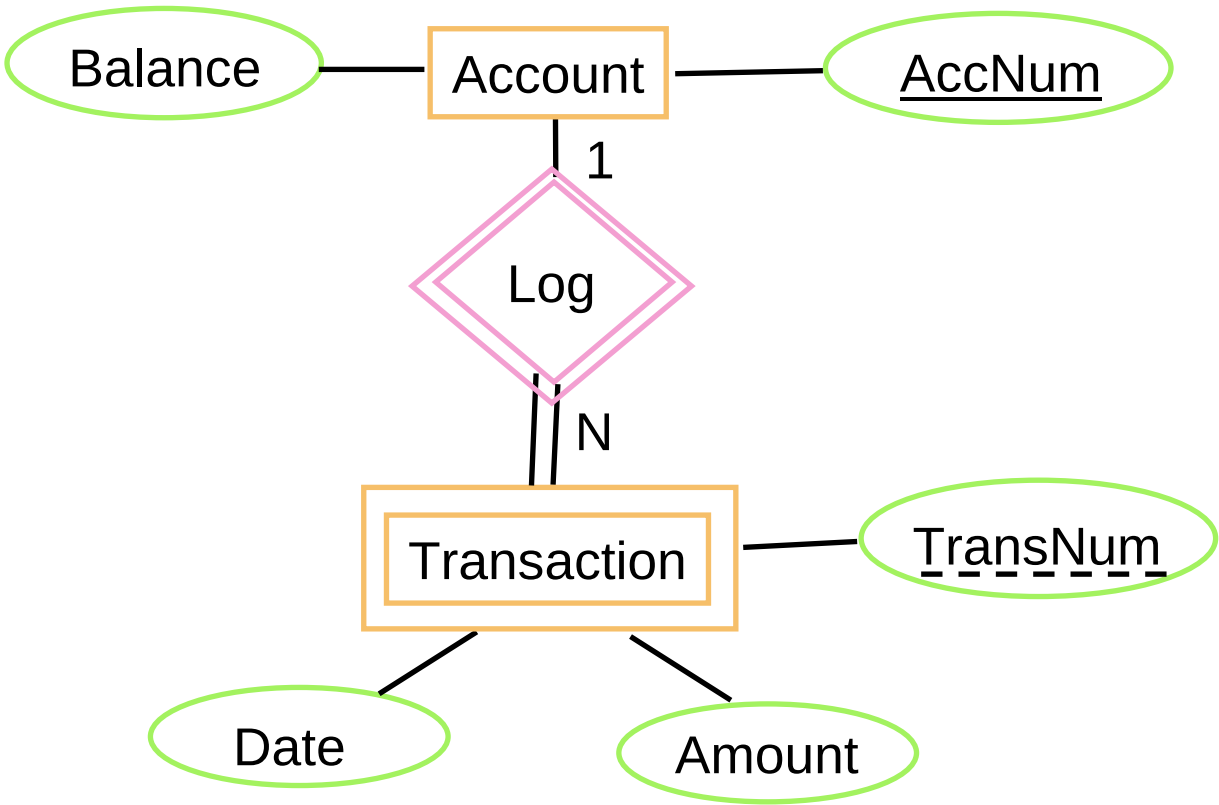
- **E.g.**



Account

AccNum	Balance

Transaction

TransNum	AccNum	Date	Amount

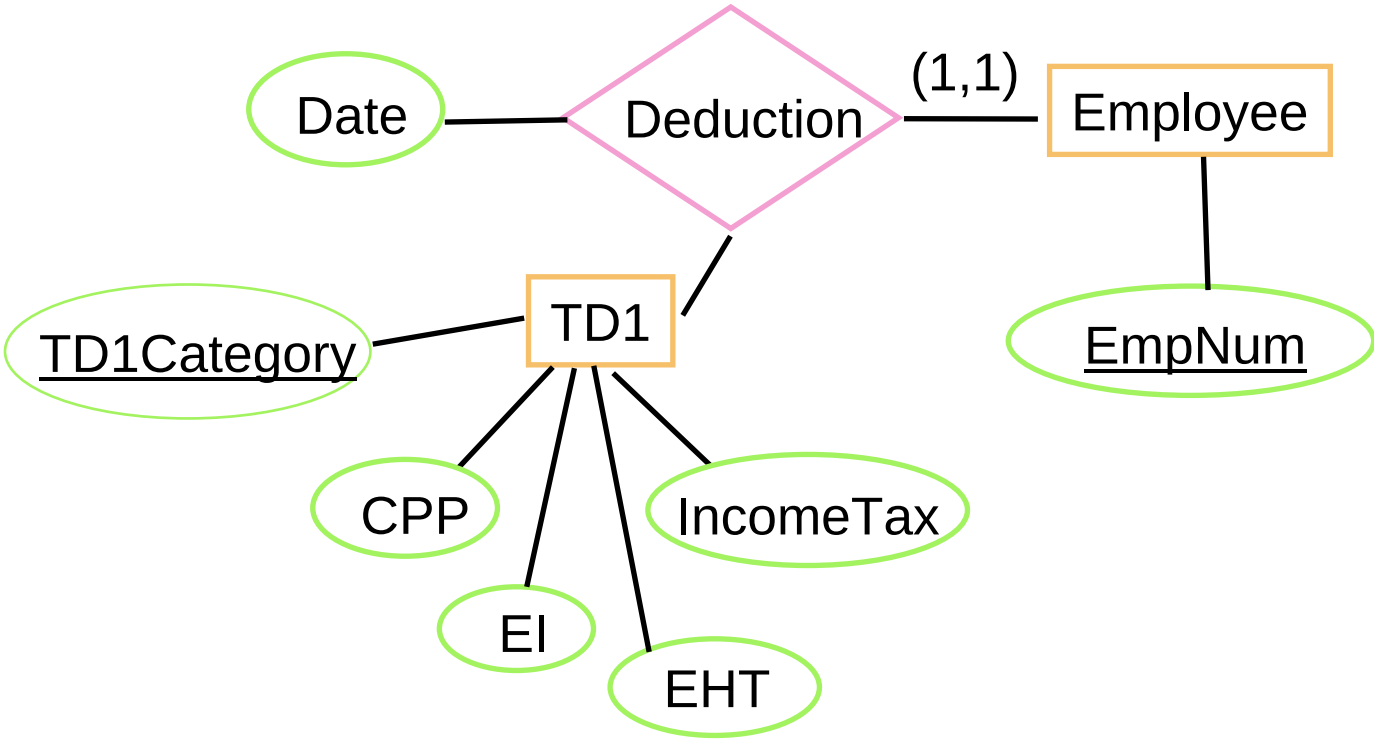
Representing relationship sets

- If the relationship set is an identifying relationship set for a weak entity set then no action needed

- If some component entity set *E* has general cardinality constraint (1,1), add columns to table *E*:
  - attributes of the relationship set
  - primary key attributes of remaining component entity sets

...continued

- **E.g.**



Employee

EmpNum	Date	TD1Category

TD1

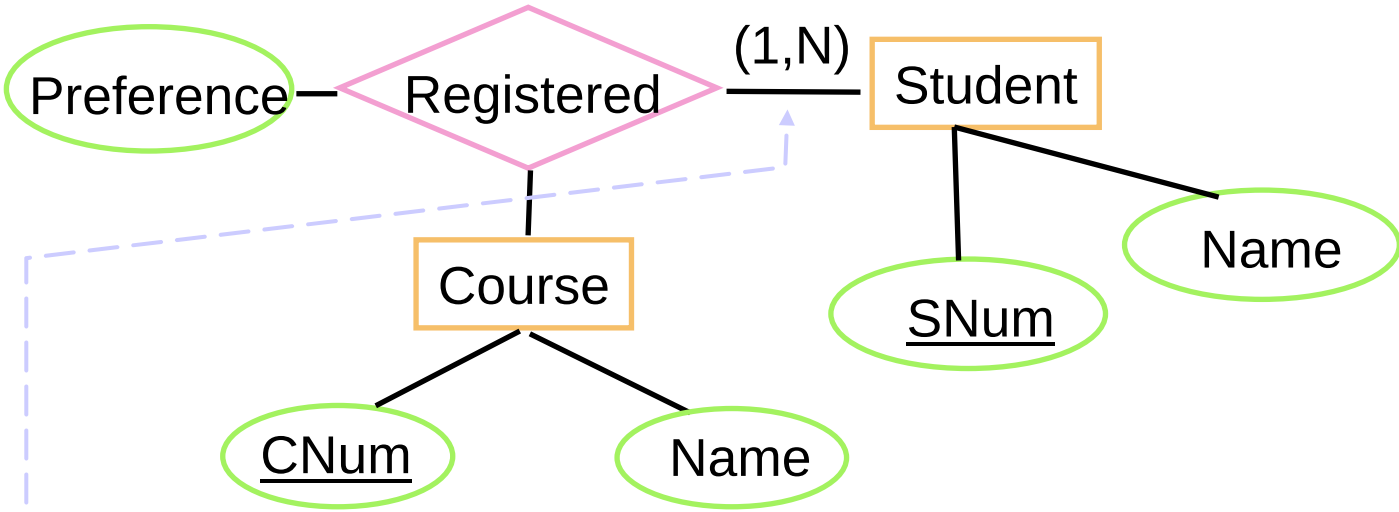
TD1Category	CPP	EI	EHT	IncomeTax

...continued

- Otherwise: relationship set $R \rightarrow$ table R
- Columns of table *R* include:
  - attributes of the relationship set
  - primary key attributes of each component entity set
- Primary key of table *R*:
  - if some component entity set *E* has the general cardinality constraint (0,1), choose the primary key attributes for *E*
  - otherwise, choose the primary key attributes of each component entity

...continued

- **E.g.**



Student

SNum	Name

Course

CNum	Name

Registered

- Cardinality (1,N):

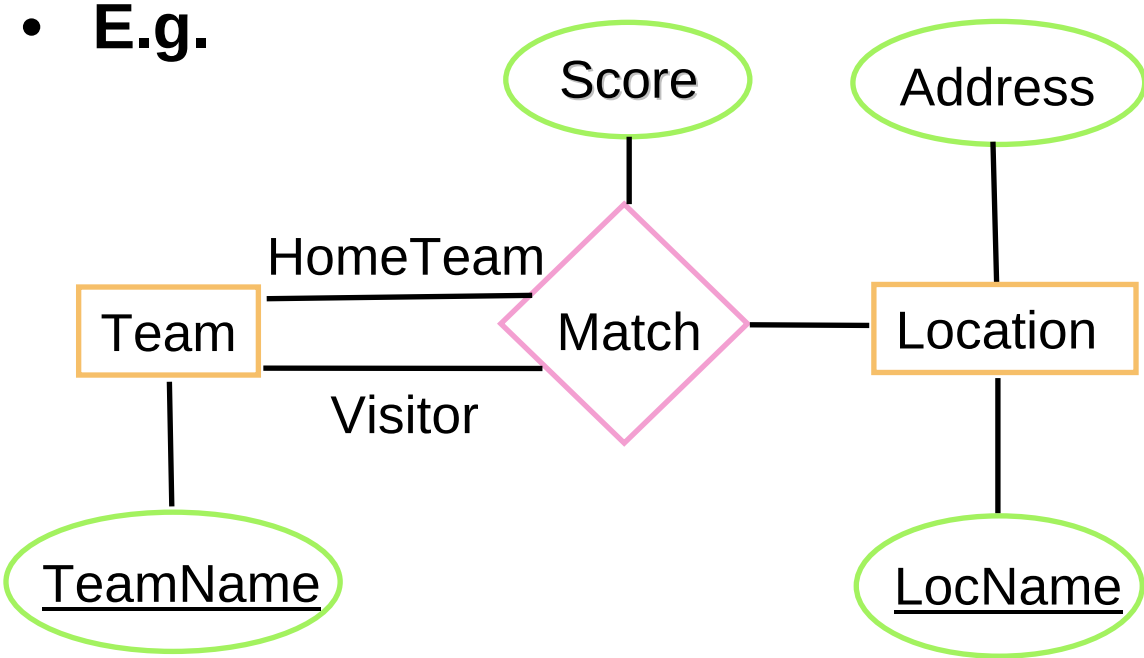
SNum	CNum	Preference

- Cardinality (0,1):

SNum	CNum	Preference

...continued

- **E.g.**



Location

LocName	Address

Team

TeamName

Match

HomeTeamName	VisitorTeamName	LocName	Score

- Note that the role name of a component entity set is prepended to its primary key attributes

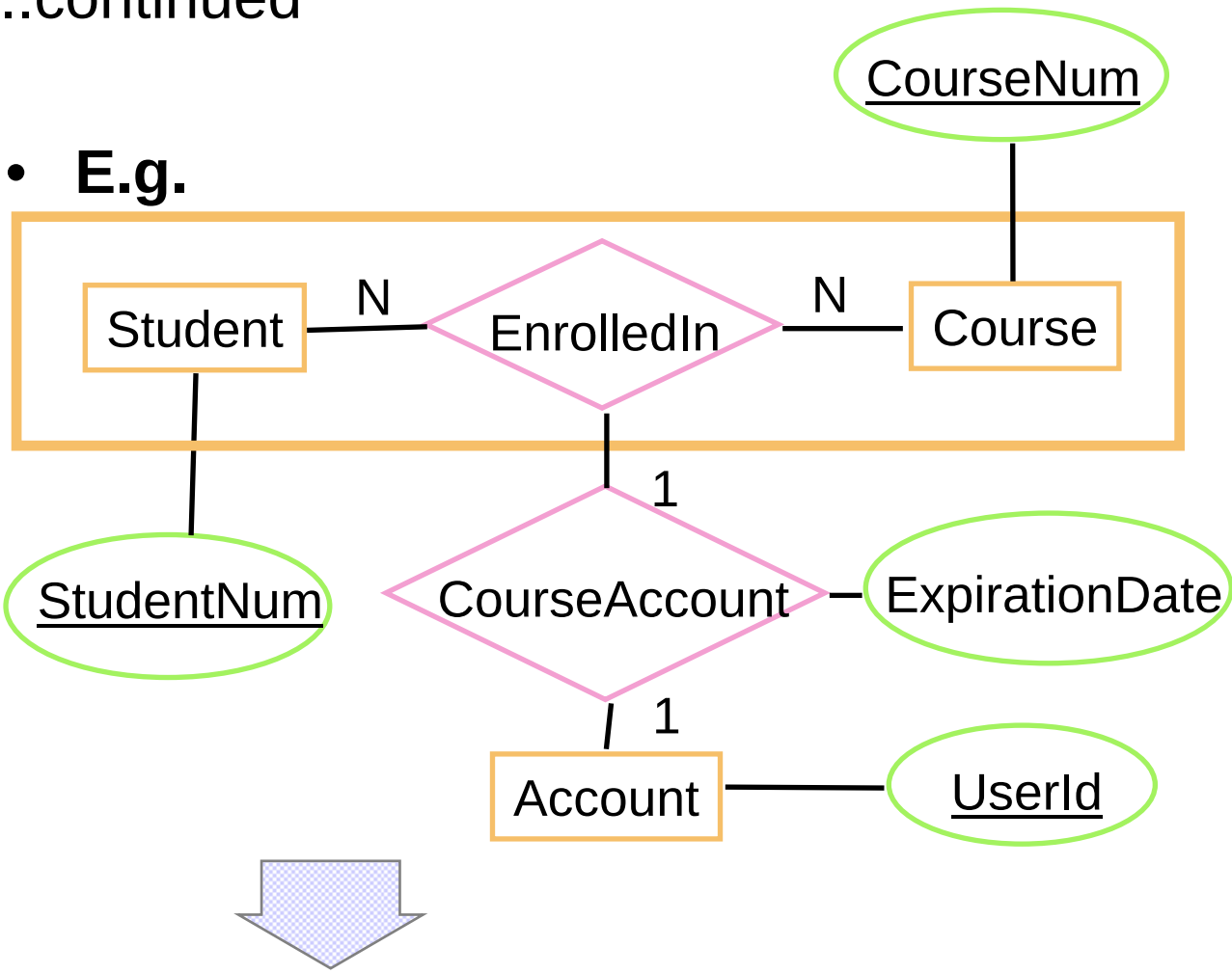
Representing aggregation

- Tabular representation for aggregation of relationship set *R* = tabular representation for relationship set *R*

- To represent relationship set involving aggregation of *R*, treat the aggregation like an entity set whose primary key = primary key of the table for *R*

...continued

- **E.g.**



Student

StudentNum

Course

CourseNum

Account

UserId

EnrolledIn

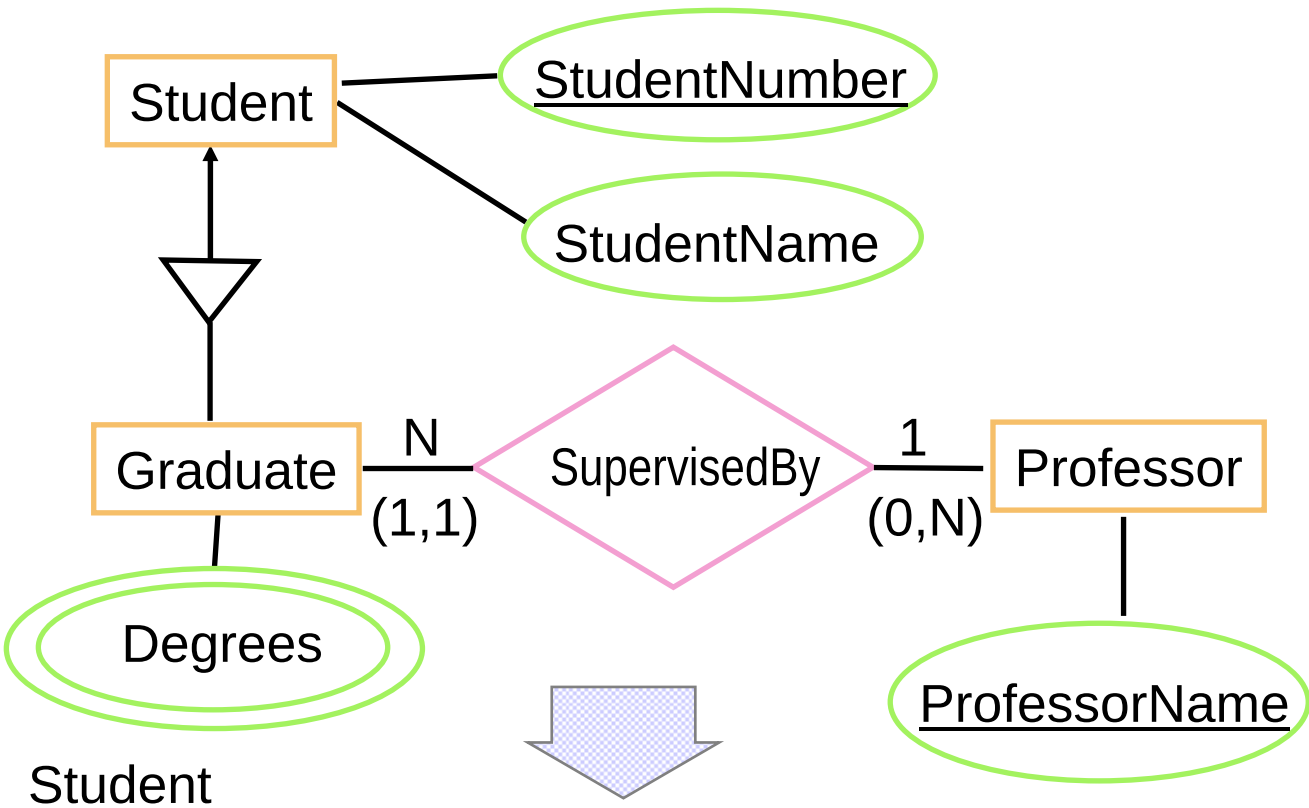
StudentNum	CourseNum

CourseAccount

UserId	StudentNum	CourseNum	ExpirationDate

Representing specialization

- Create specialized table with primary attribute of higher-level entity, plus attributes as usual



Student

StudentNumber	StudentName

Graduate

StudentNumber	ProfessorName

Professor

ProfessorName

Degree

StudentNumber	Degree

Representing generalization

- Create a table for each lower-level entity set only
- Columns of new tables should include:
  - Attributes of lower level entity set
  - Attributes of the superset
- The higher-level entity set can be defined as a view on the tables for the lower-level entity sets

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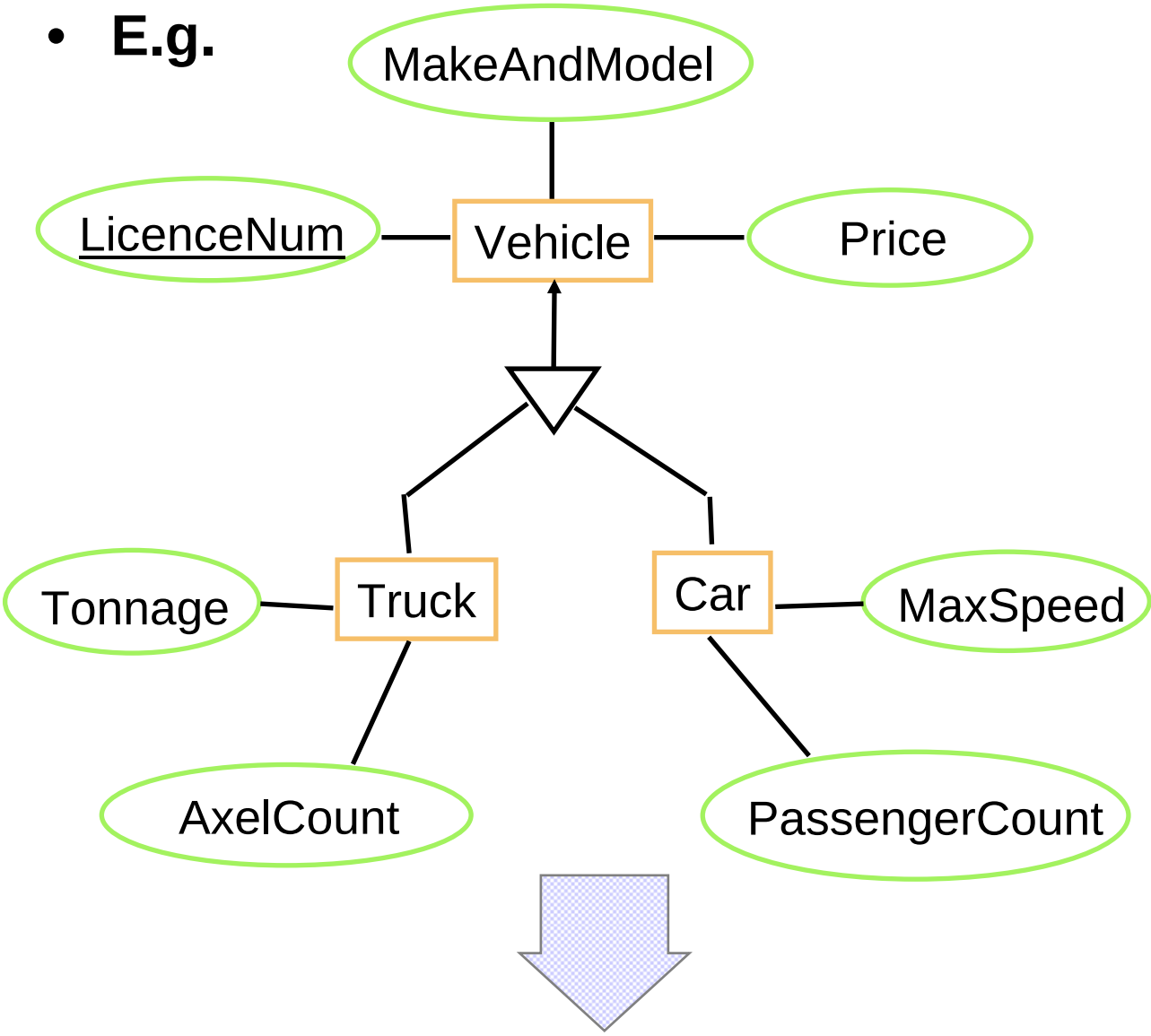
- **E.g.**



Truck

LicenceNum	MakeAndModel	Price	Tonnage	AxelCount

Car

LicenceNum	MakeAndModel	Price	MaxSpeed	P'gerCount