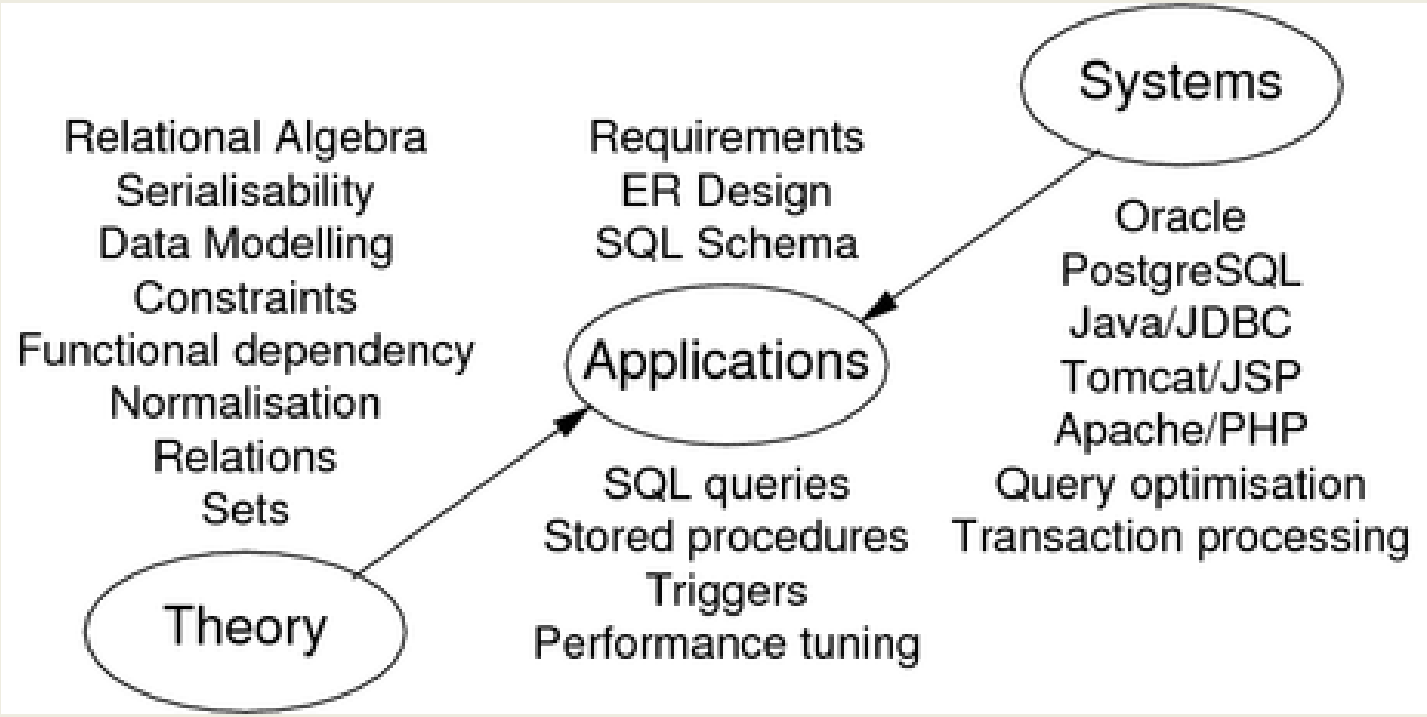
Conceptual Database Design

Textbook: chapter 3 & 4

Overview of the Databases Field



Database Application Development

A variation on standard software engineering process:

- analyse application requirements
- develop a data model to meet these requirements
- implement the data model as relational schema
- implement transactions via SQL and procedural programming languages
- construct an interface to these transactions
- At some point, populate the database (may be via interface)

Data Modelling

Aims of data modelling:

- describe what *information* is contained in the database

  (e.g., entities: students, courses, accounts, branches, patients, ...)

- describe *relationships* between data items

  (e.g., John is enrolled in COMP3311, Andrew's account is held at Commmonwealth Bank)

- describe *constraints* on data

  (e.g., 7-digit IDs)

Data modelling is a *design* process

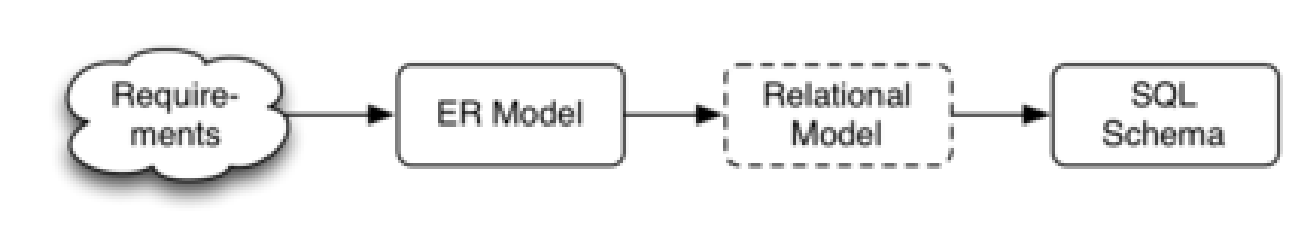
- converts requirements into a data model

Data Modelling

Kinds of data models:

- *logical*: abstract, for conceptual design, e.g., ER, ODL (object data language)
- *physical*: record-based, for implementation, e.g., relational

Strategy: design using abstract model; map to physical model



Some Design Ideas

Consider the following while we work through exercises:

- start simple ... evolve design as problem better understood
- identify objects (and their properties), then relationships
- *keywords in requirements suggest data/relationships*

  (rule-of-thumb: nouns → data, verbs → relationships)

Quality of Designs

There is no single "best" design for a given application.

Most important aspects of a design (data model):

- correctness (satisfies requirements accurately)
- completeness (all reqs covered, all assumptions explicit)
- consistency (no contradictory statements)

Potential inadequacies in a design:

- omits information that needs to be included
- contains redundant information ($\Rightarrow$ inconsistency)
- leads to an inefficient implementation
- violates syntactic or semantic rules of data model

Entity-Relationship (ER) Model

The world is viewed as a collection of inter-related entities.

ER has **three** major modelling **constructs**:

- *attribute*: data item describing a property of interest
- *entity*: collection of attributes describing object of interest
- *relationship*: association between entities (objects)

The ER model is not a standard, so many variations exist.

Lecture notes use simple notations. We can use this as 'COMP9311 standard'.

Entity-Relationship Model

The Entity-Relationship (ER) model is a high-level conceptual data model (Chen in 1966).

ER is used mainly as a design tool.

Entity and Attributes

Entities represent things in the real world.

Attributes describe properties of entities.

Attributes may be

- simple(atomic) e.g. sex = ’Female’, or
- composite e.g. name consists of title (Dr), Initials (C.C.), family name (Chen).

Entity and Attributes(cont)

Each entity has values for each attribute.

Attributes may be

- *single-valued* e.g. student number, name, or
- *multivalued* e.g. keywords = neural networks, computer graphics, databases.

Entity and Attributes(cont)

An attribute can have a null value if, for example:

- there is no suitable value e.g. a student may have no interests: keywords = NULL
- the true value is not known e.g. the marriage date of a person is not known: marriage date = NULL.

A derived attribute is one whose value can be derived from other attributes and entities. e.g. number of students.

Entity and Attributes(cont)

An *entity* type is a set of entities with the same attributes.

It is described by an *entity* schema: a name and a list of attributes.

The set of individual entity *instances* at a particular moment in time is called an extension of the entity type.

Entity and Attributes(cont)

Schema (Intension)	RESEACHER Name, Payroll_no, No_of_students, Keywords	DEPARTMENT Name
Instances (Extension)	(Dr C.C. Chen, 230-0013, 3, Neural Networks) (Dr R. Wilkinson, 231-0091, 1, Databases)	Computer Science Psychology Management

Entity and Attributes(cont)

An entity type usually has a *key*: a set of attributes that uniquely identifies an entity. For example:

- {payroll number} is a key of RESEARCHER,
- {name} is a key of DEPARTMENT.

There may be more than one possible key.

An important constraint is the key constraint: in any extension of the entity type, there cannot be two entities having the same values for their key attributes.

Key

Key (*superkey*): any set of attributes whose set of values are distinct over entity set

- natural (e.g., name+address+birthday) or artificial (e.g., SSN)

Candidate key = minimal superkey (no subset is a key)

Primary key = candidate key chosen by DB designer

Keys are indicated in ER diagrams by underlining

Entity and Attributes(cont)

Composite and mutli-valude attributes:

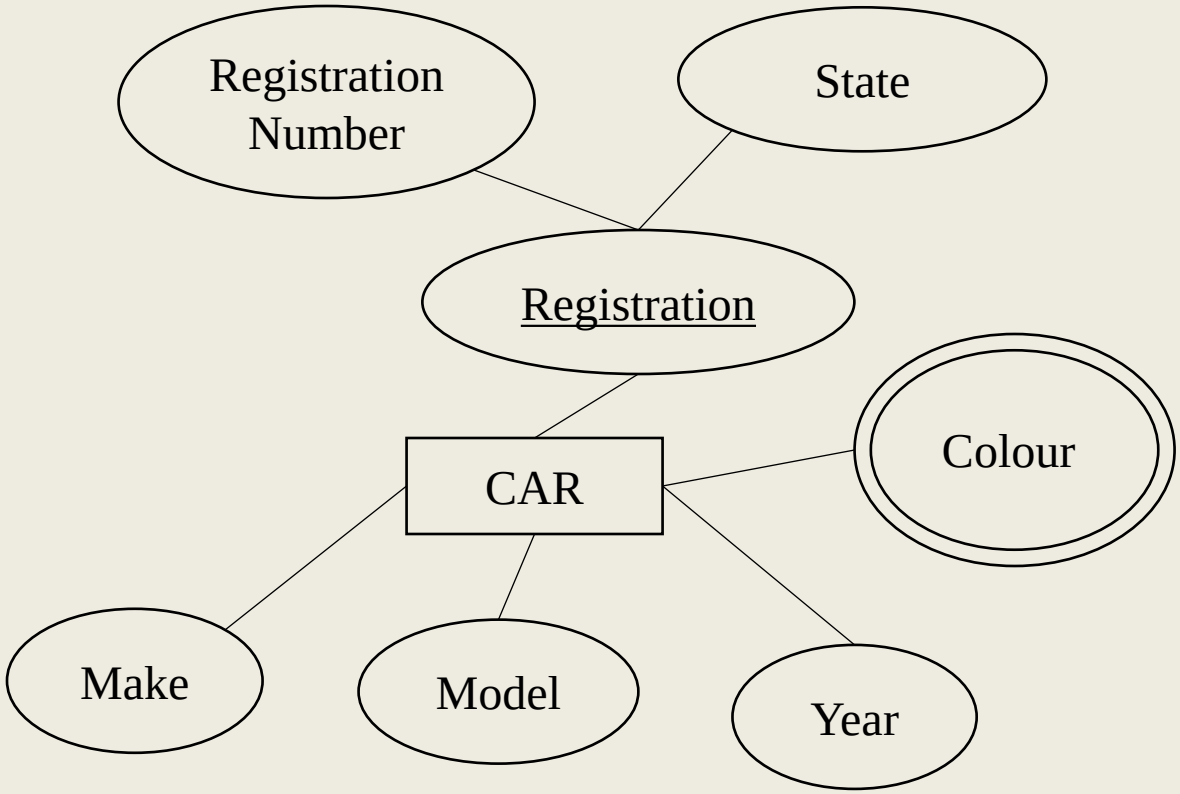
- We can describe schema with composite attributes using ()’s and with multi-valued attributes using {}’s. e.g.

Entity and Attributes(cont)

CAR Registration(Registration No, State), Make, Model, Year, {Colour}
((ARQ) 595, Vic), Datsun, 120Y, 1972, {green}) ((8HR) 696, WA), Mazda, 929, 1979, {grey, black})

Entity and Attributes(cont)

Entities and their attributes can also be described with Entity-Relationship Diagrams (ERDs). e.g.



Relationships

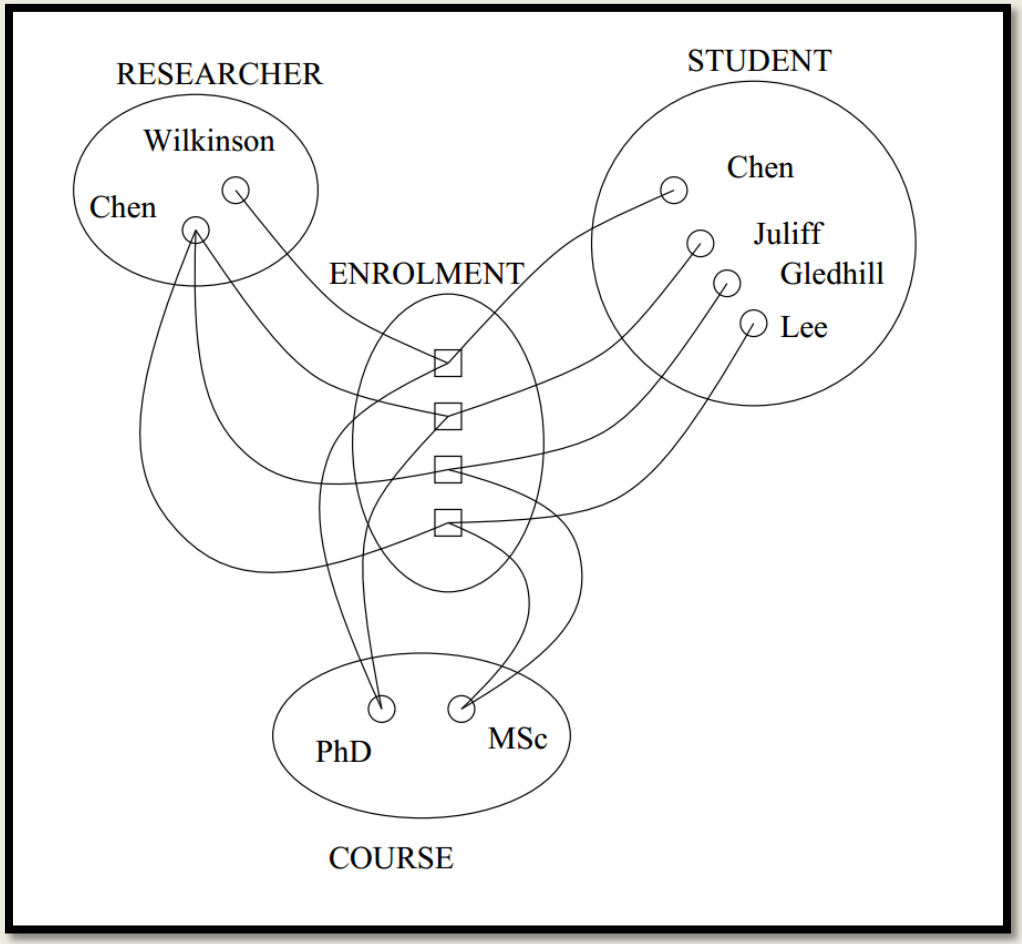
A *relationship* represents an association between things / entities.

The *degree* of a relationship is the number of participating entity types. For example,

- ENROLMENT could be a ternary (degree 3) relationship between RESEARCHER, STUDENT and COURSE.

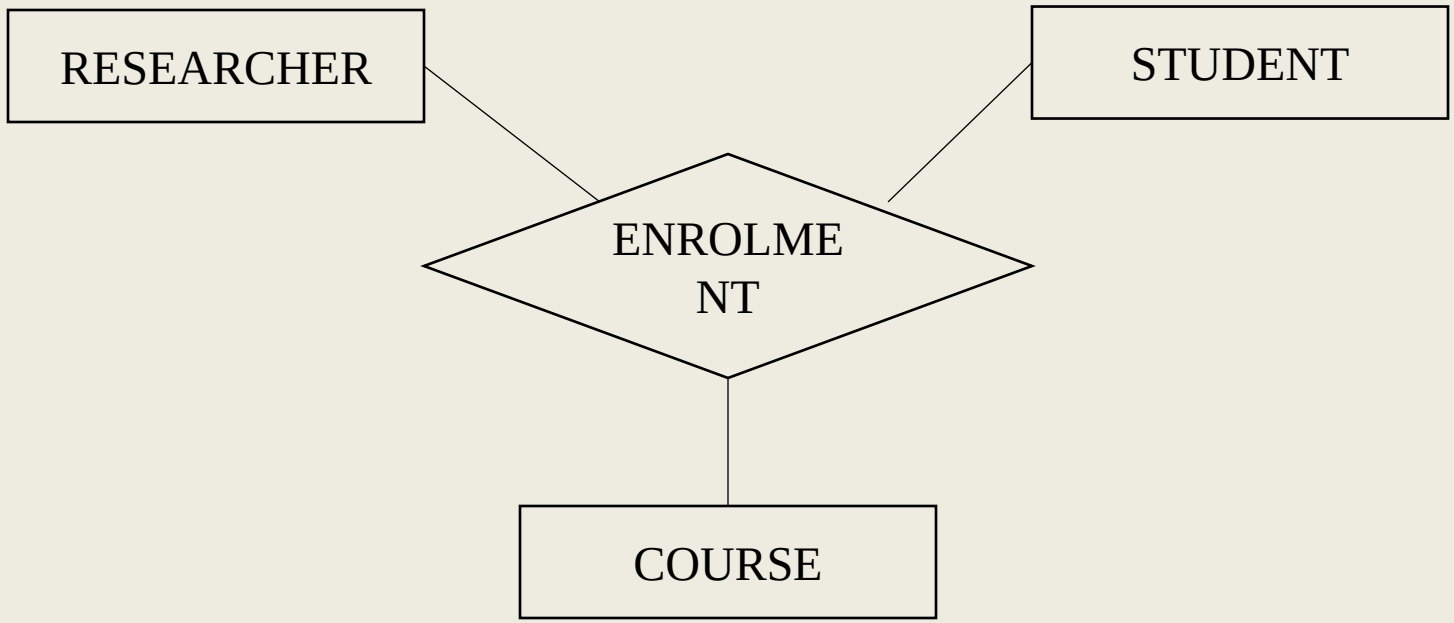
Relationships(cont)

We can illustrate this using an occurrence diagram:



Relationships(cont)

Entities and their relationships can also be represented using Entity-Relationship diagrams:



Relationships(cont)

Each entity type that participates in a relationship plays a particular *role* in the relationship.

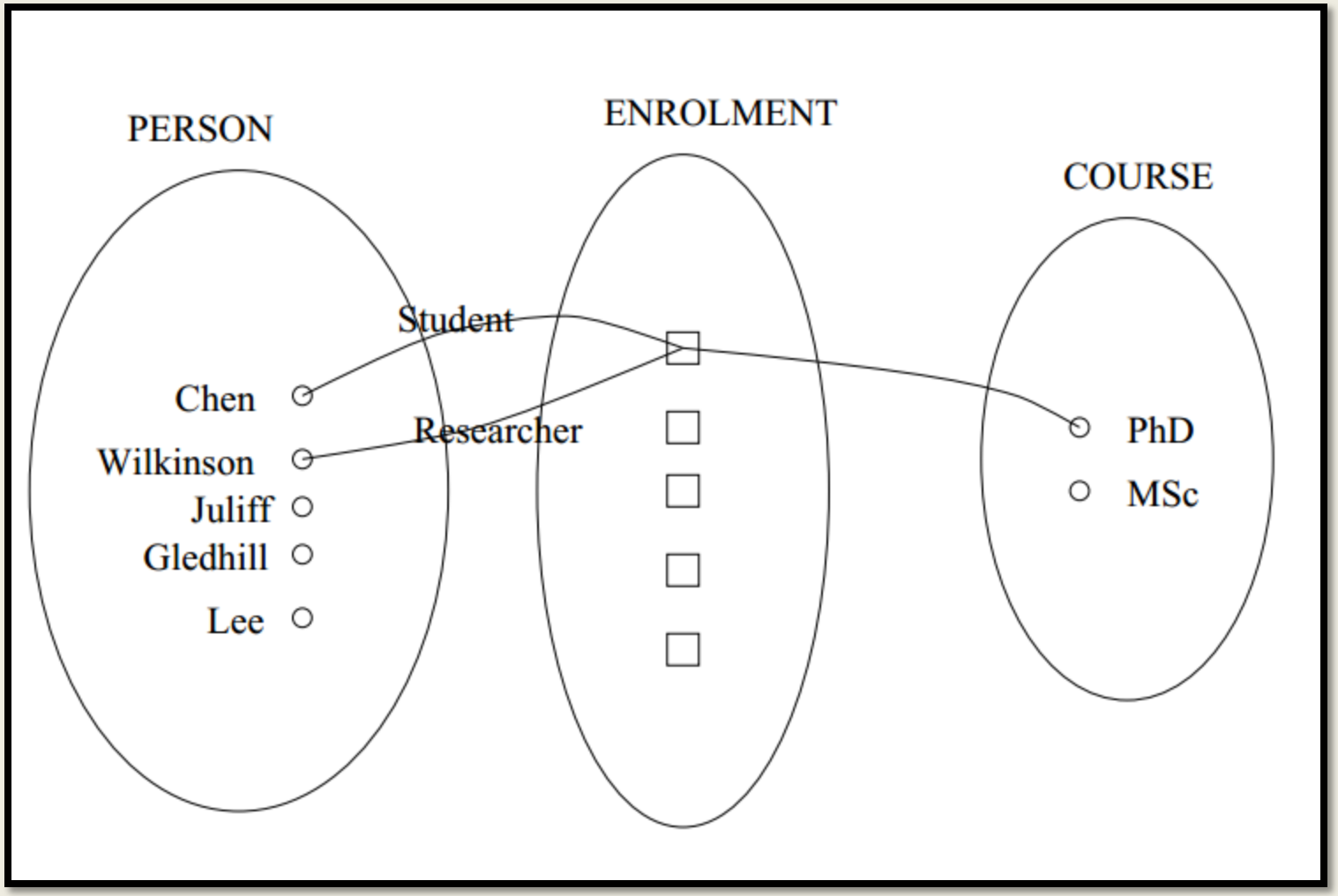
An entity type can play

- different roles in different relationships, or
- more than one role in a relationship.

A role name can be used to distinguish these.

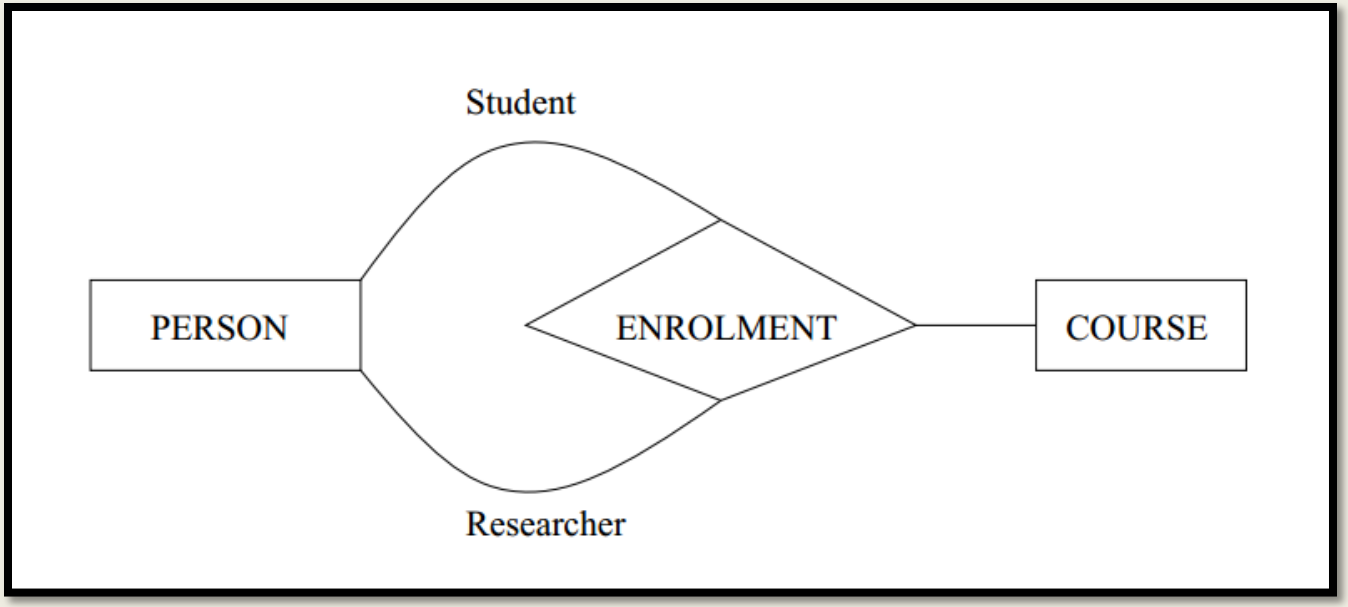
For example, ENROLMENT could be a relationship between PERSON(as researcher), PERSON(as student) and COURSE as in the diagram below:

Relationships(cont)



Relationships(cont)

Or, using an ERD:



This is called a recursive relationship.

Weak entity types

Some entity types do not have a key of their own.

Such entity types are called weak entity types.

Entities of a weak entity type can be identified by a partial key and by being related to another entity type - *owner*.

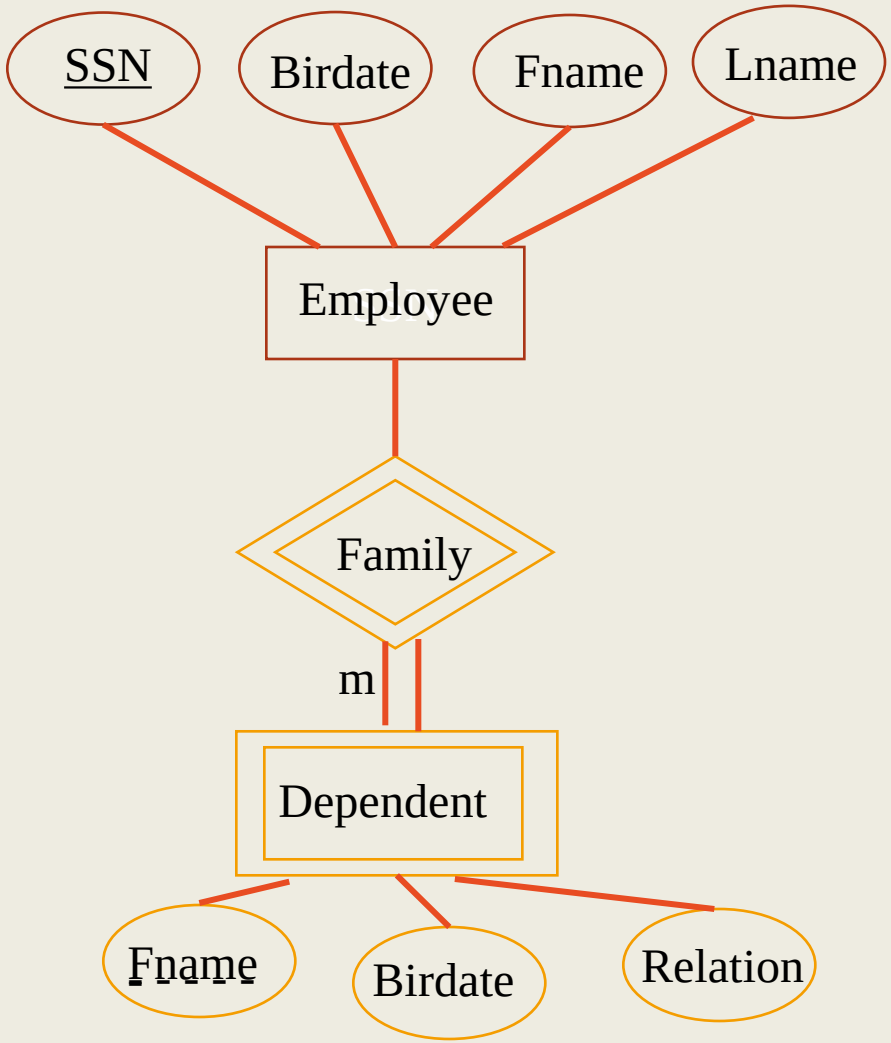
The relationship type between a weak entity type to its owner is the *identifying relationship* of the weak entity type.

Weak entity types(cont)

For example, a TAX PAYER entity may be related to several DEPENDENT, identified by their names.

In this example, DEPENDENT is called a weak entity, {Name} is a partial key for it. The identifying relationship between DEPENDENT and TAX PAYER is IS DEPENDENT OF. TAX PAYER is said to *own* DEPENDENT.

Weak entity types(cont)



Constraints on relationship types

Relationship types usually have certain constraints that limit the possible combinations of entities participating in relationship instances.

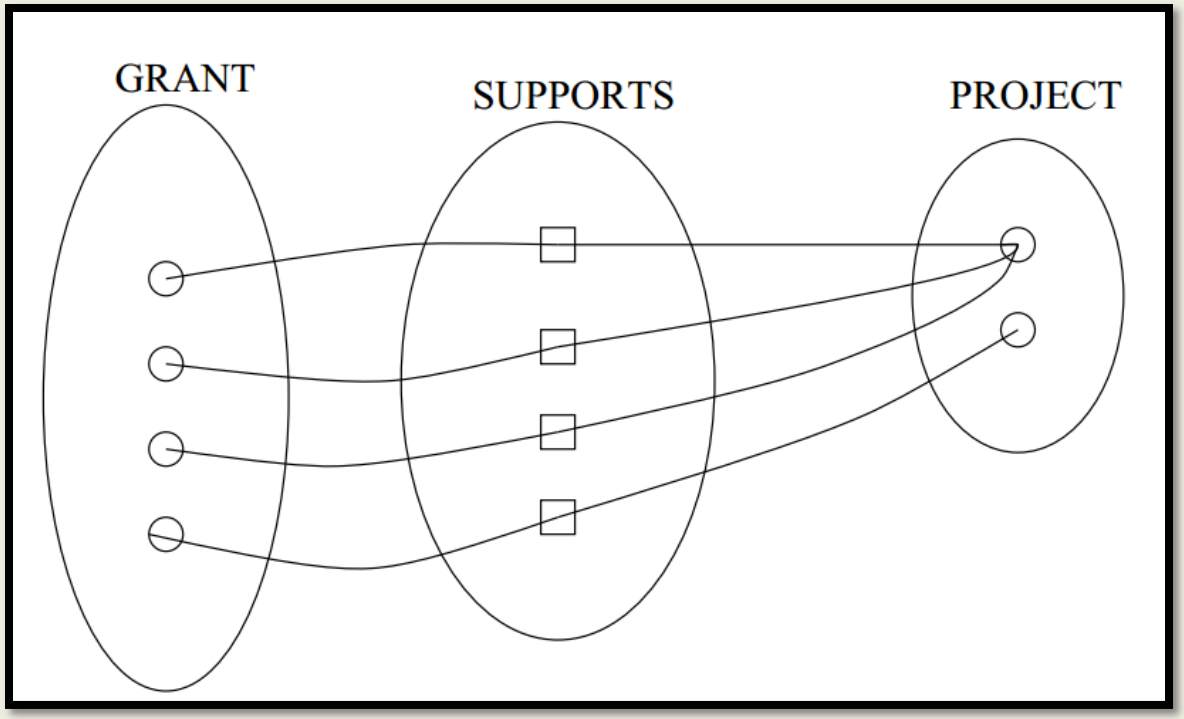
They should reflect the correct factors

Cardinality ratio constraint: specifies the number of relationship instances an entity can participate in.

Example: A research grant supports only one research project, but a research project may be supported by many grants. PROJECT:GRANT is a 1 : N relationship.

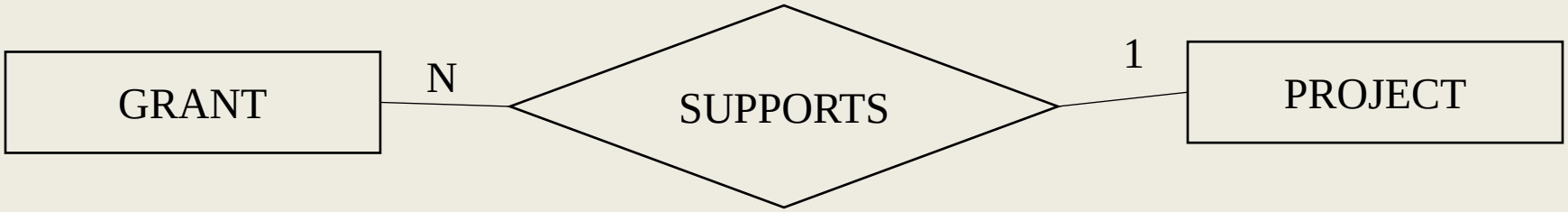
Constraints on relationship types(cont)

This is illustrated in the occurrence diagram below:



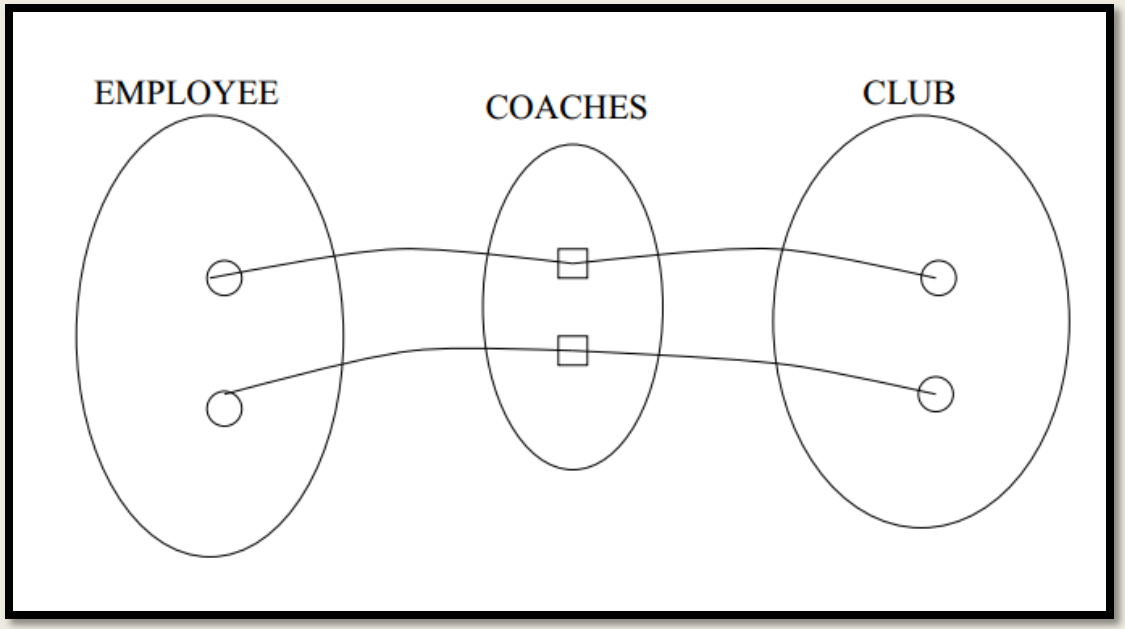
Constraints on relationship types(cont)

We can also show this in an ERD:



Constraints on relationship types(cont)

Example: Consider a database of AFL (here substitute your favourite team sport) statistics. The relationship of head coaches to clubs is an example of a 1 : 1 relationship.

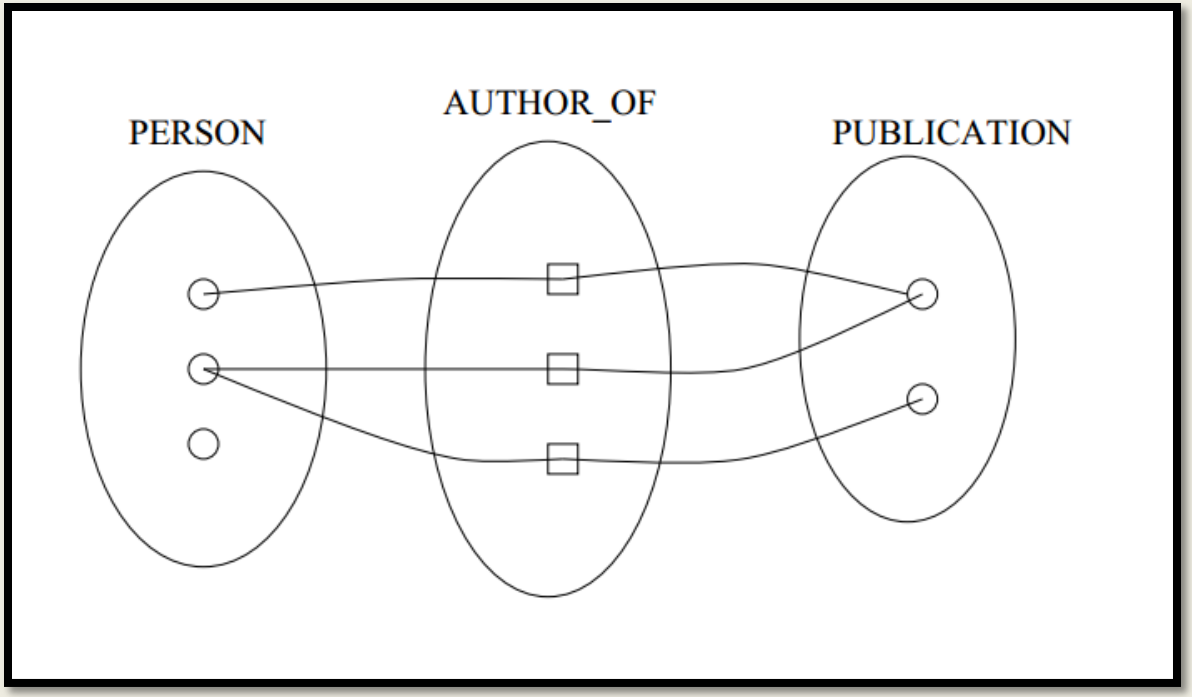


Constraints on relationship types(cont)

With an ERD:

Constraints on relationship types(cont)

Example: An example of an N : M relationship is authorship of publications:



Constraints on relationship types(cont)

The equivalent ERD:

Constraints on relationship types(cont)

Another kind of constraint that can be represented using the ER model is a

- *Participation constraint*: participation of an entity in a relationship can be:
  - *total*: every entity must participate e.g. every publication has an author.
  - *partial*: not necessarily total. e.g. not every person has publications.

Constraints on relationship types(cont)

This can be shown with an ERD like the one below:

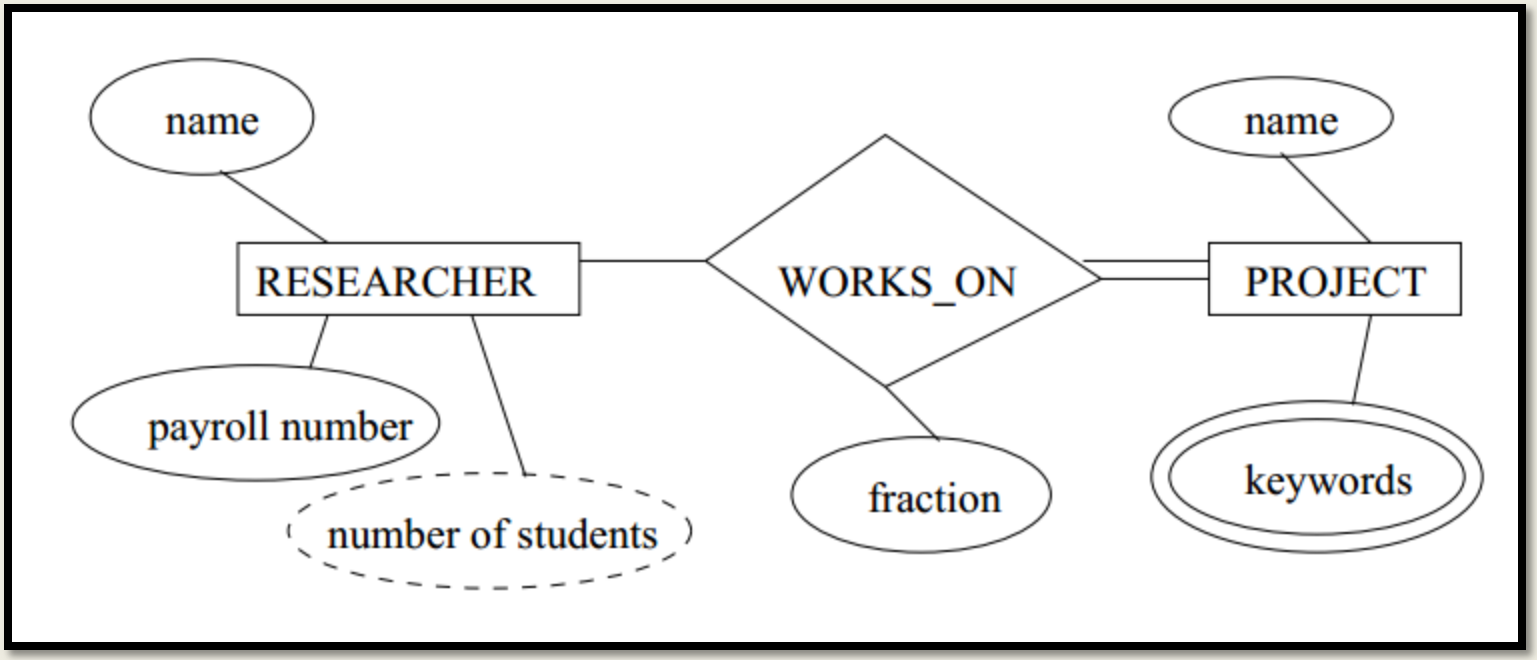
Attributes of relationship types

Relationship types can have attributes – for example,

- a researcher may work on several projects. The fraction of her time devoted to a particular project could be an attribute of the WORKS ON relationship type.

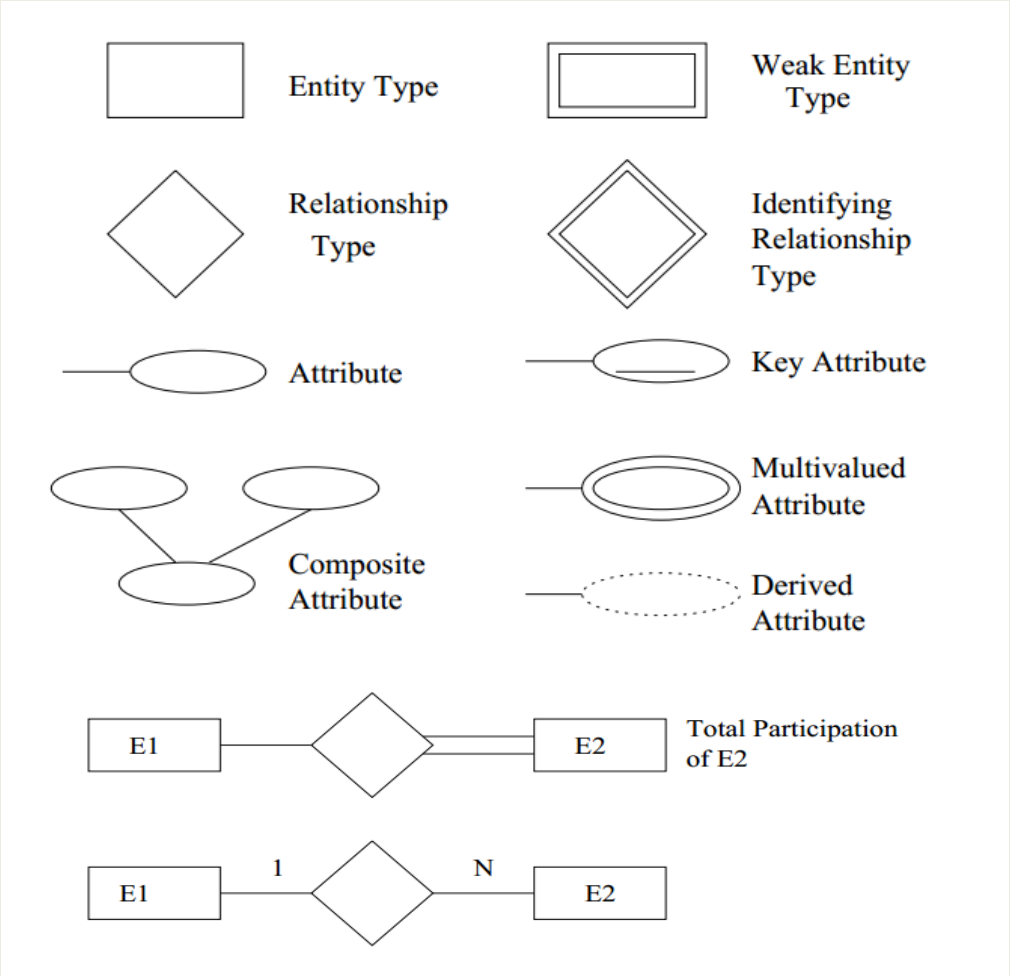
This can be shown in an ERD as below:

Attributes of relationship types(cont)



Attributes of relationship types(cont)

The notation used for ERDs is summarised in Elmasre/Navathe Figure 3.15.



Enhanced ER (EER) model

Designers must use additionally modelling concepts to

- represent the requirements from applications as accurately and explicitly as possible.

Enhanced ER (EER) model(cont)

There are many extensions to the ER model. We will look at one:

- *Specialisation*: the process of defining a set of subclasses of an entity type; this entity type is called the superclass of the specialization.
- *Generalisation*: a reverse process of specialisation.

A subclass inherits all the attributes of the superclasses.

Enhanced ER (EER) model(cont)

A specialisation involves the following aspects:

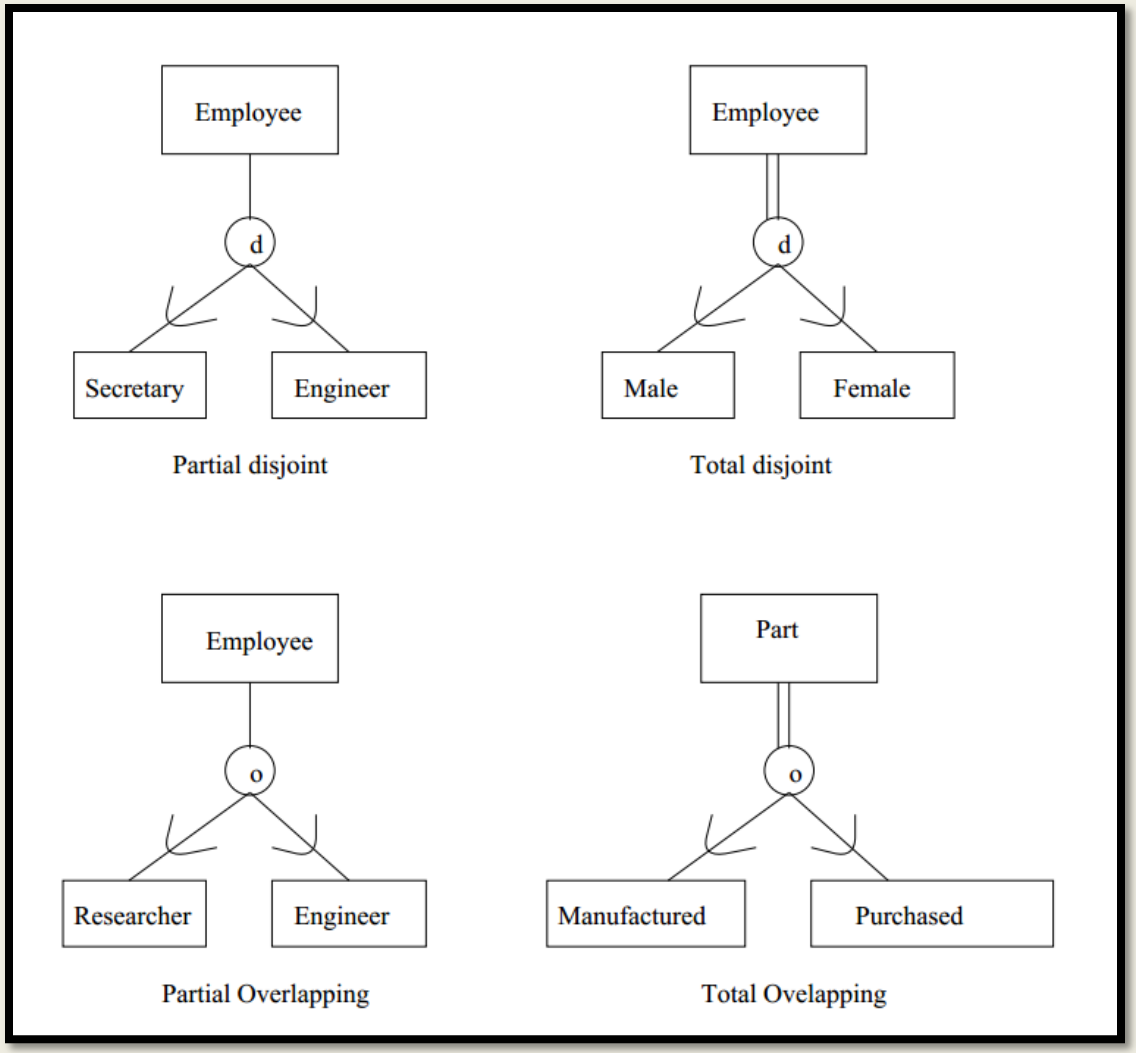
- Define a set of subclasses of an entity type.
- Associate additional specific attributes with each subclass.
- Establish additional specific relationship types between each subclass and other entity types, or other subclasses.

A subclass may have multiple superclasses.

A specialisation:

- may be either total or partial; and
- may be either disjoint or overlapping.

Enhanced ER (EER) model(cont)



Design Principles

Faithfulness: reflect reality.

Avoid redundancy.

Picking the right kind of element.

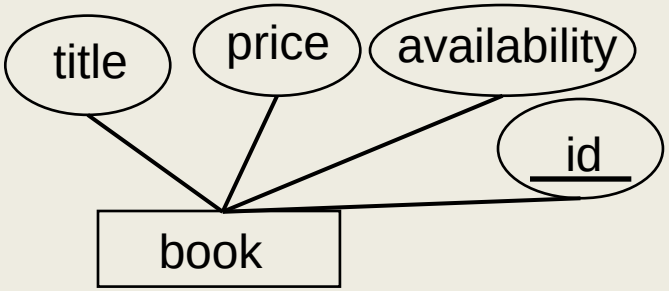
Exercise:

Please draw an ER diagram for UNSW library based on the following specifications.

- A book is uniquely identified by its book id. For each book, we also record its title, price, and availability.
- A reader is uniquely identified by his/her reader id and we also record his/her name, phone number, expire date and address. The address is composed of street and suburb.
- A publisher is uniquely identified by its publisher id. For each publisher, the name is also recorded.
- An author is uniquely identified by his/her author id. For each author, the name, phone number and birth date are also recorded.
- A reader can borrow zero or more books and a book can be borrowed by zero or more readers. Thus, we need to record the starting date and ending date for the borrowing relationship.
- A publisher can publish zero or more books and a book is published by exactly one publisher. We also need to record the date of publication.
- An author can write zero or more books and a book is written by one or more authors.

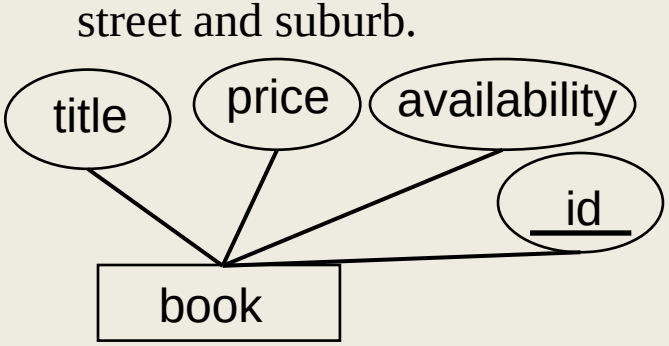
Exercise:

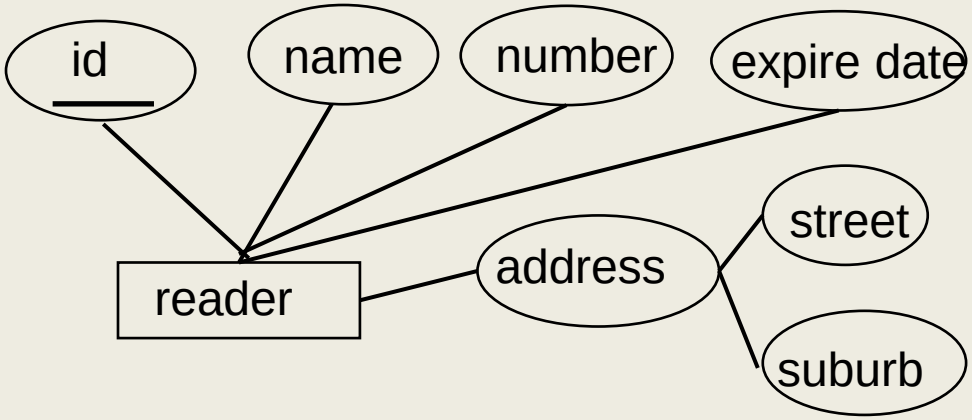
- A book is uniquely identified by its book id. For each book, we also record its title, price, and availability.



Exercise:

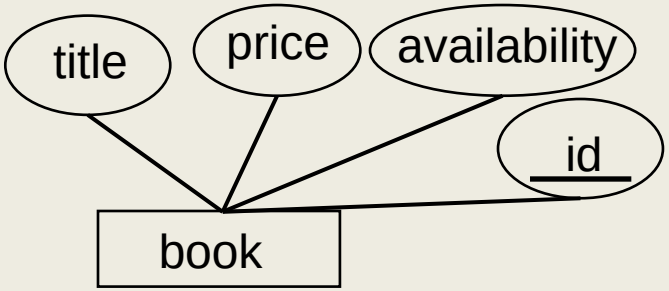
- A reader is uniquely identified by his/her reader id and we also record his/her name, phone number, expire date and address. The address is composed of street and suburb.

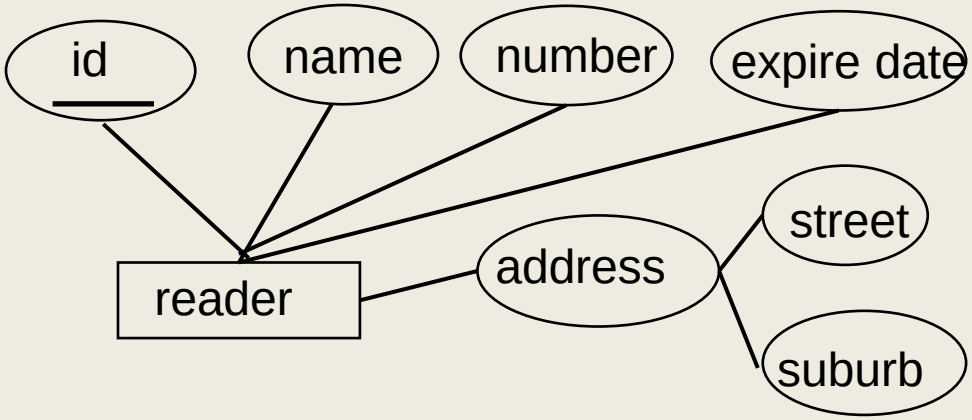


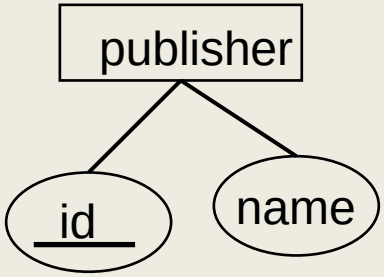


Exercise:

- A publisher is uniquely identified by its publisher id. For each publisher, the name is also recorded.

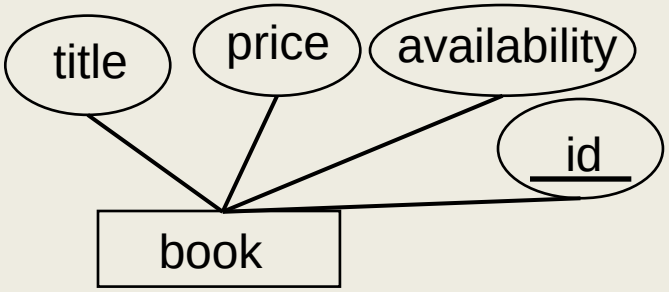


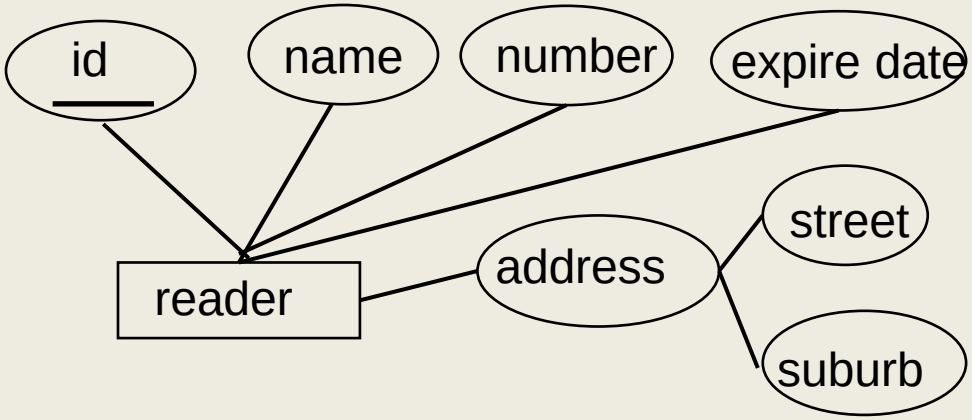


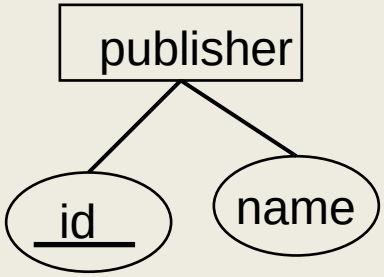


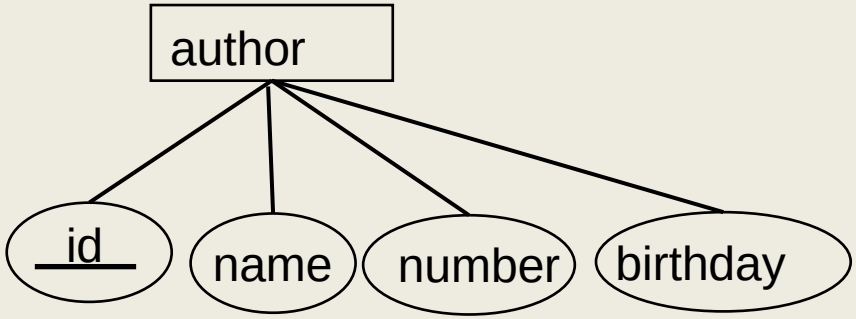
Exercise:

- An author is uniquely identified by his/her author id. For each author, the name, phone number and birth date are also recorded.



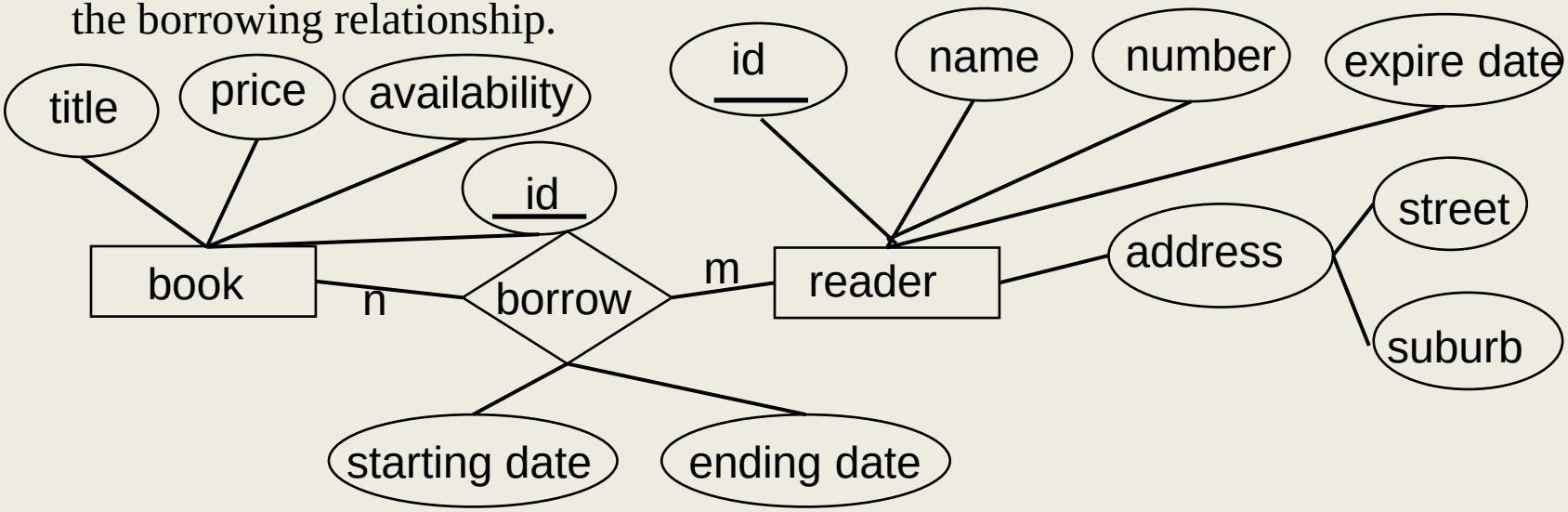


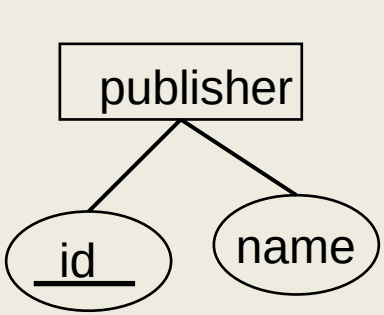


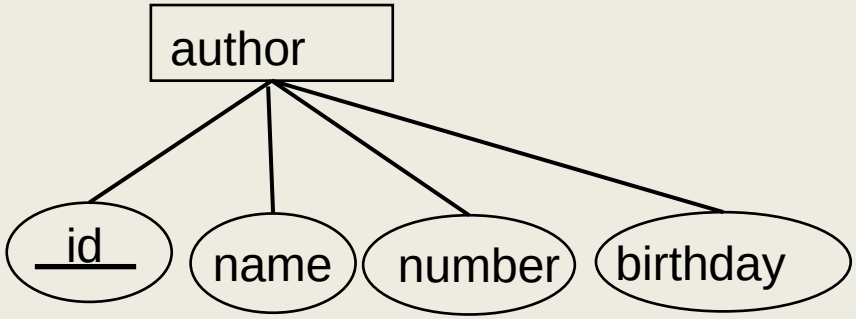


Exercise:

- A reader can borrow zero or more books and a book can be borrowed by zero or more readers. Thus, we need to record the starting date and ending date for the borrowing relationship.

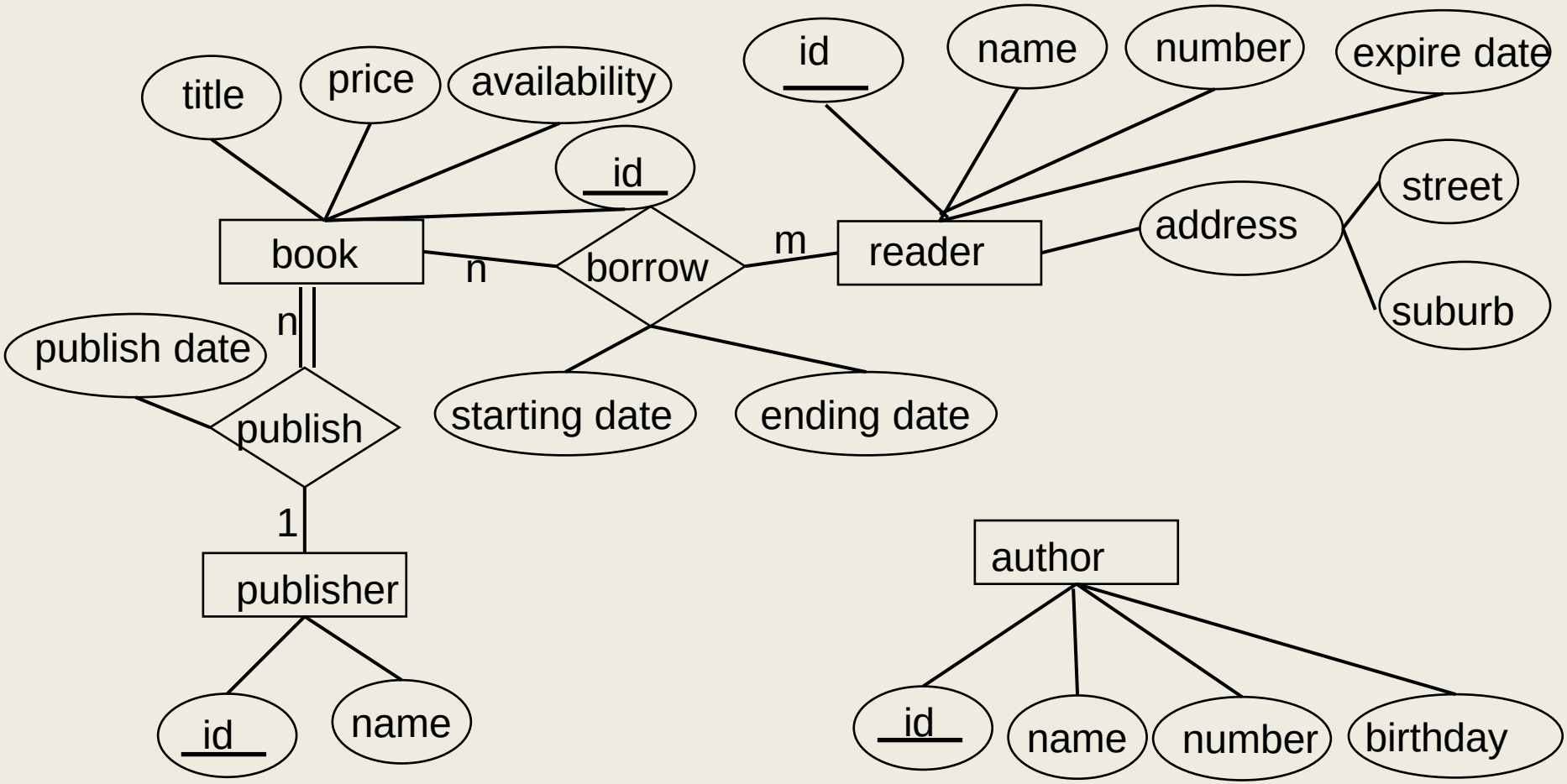






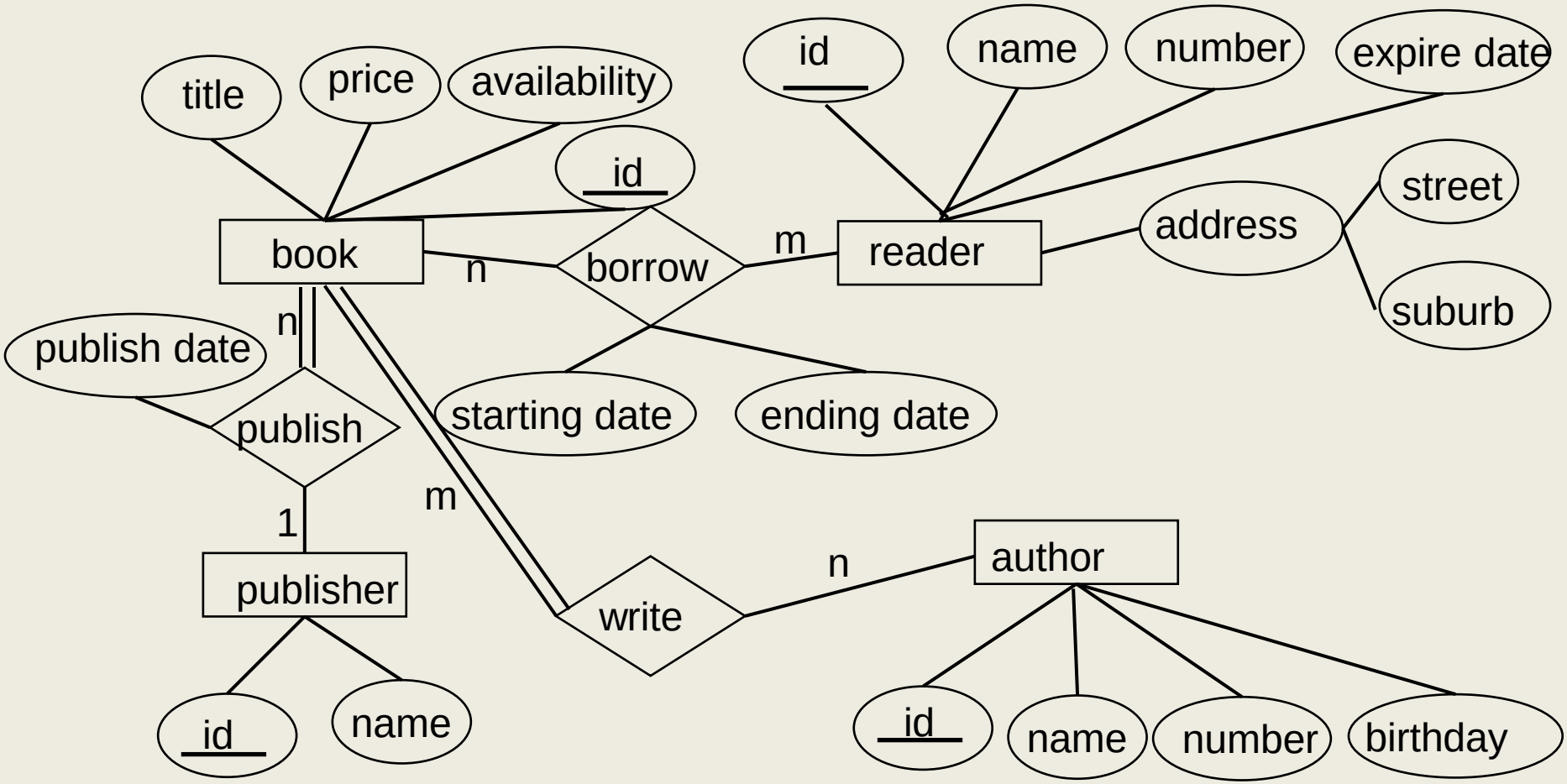
Exercise:

- A publisher can publish zero or more books and a book is published by exactly one publisher. We also need to record the date of publication.



Exercise:

- An author can write zero or more books and a book is written by one or more authors.



Learning Outcome:

- Given application requirements, design ER-diagram to accurately reflect the requirements