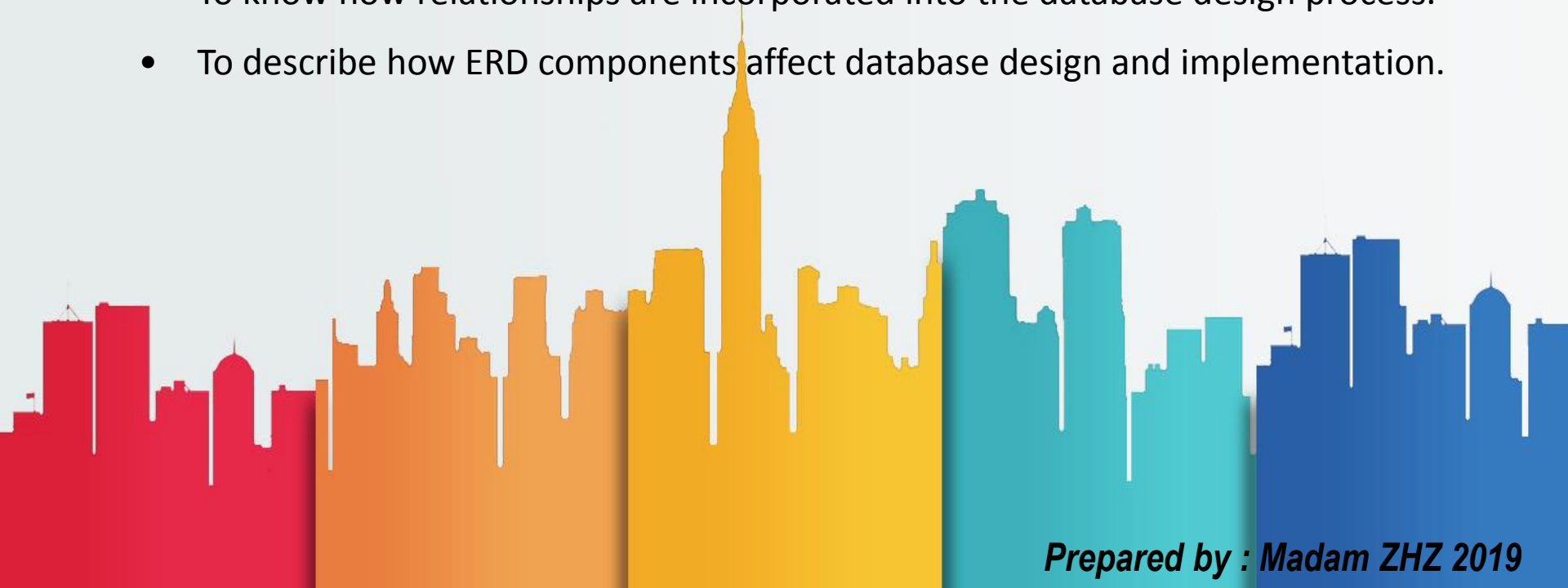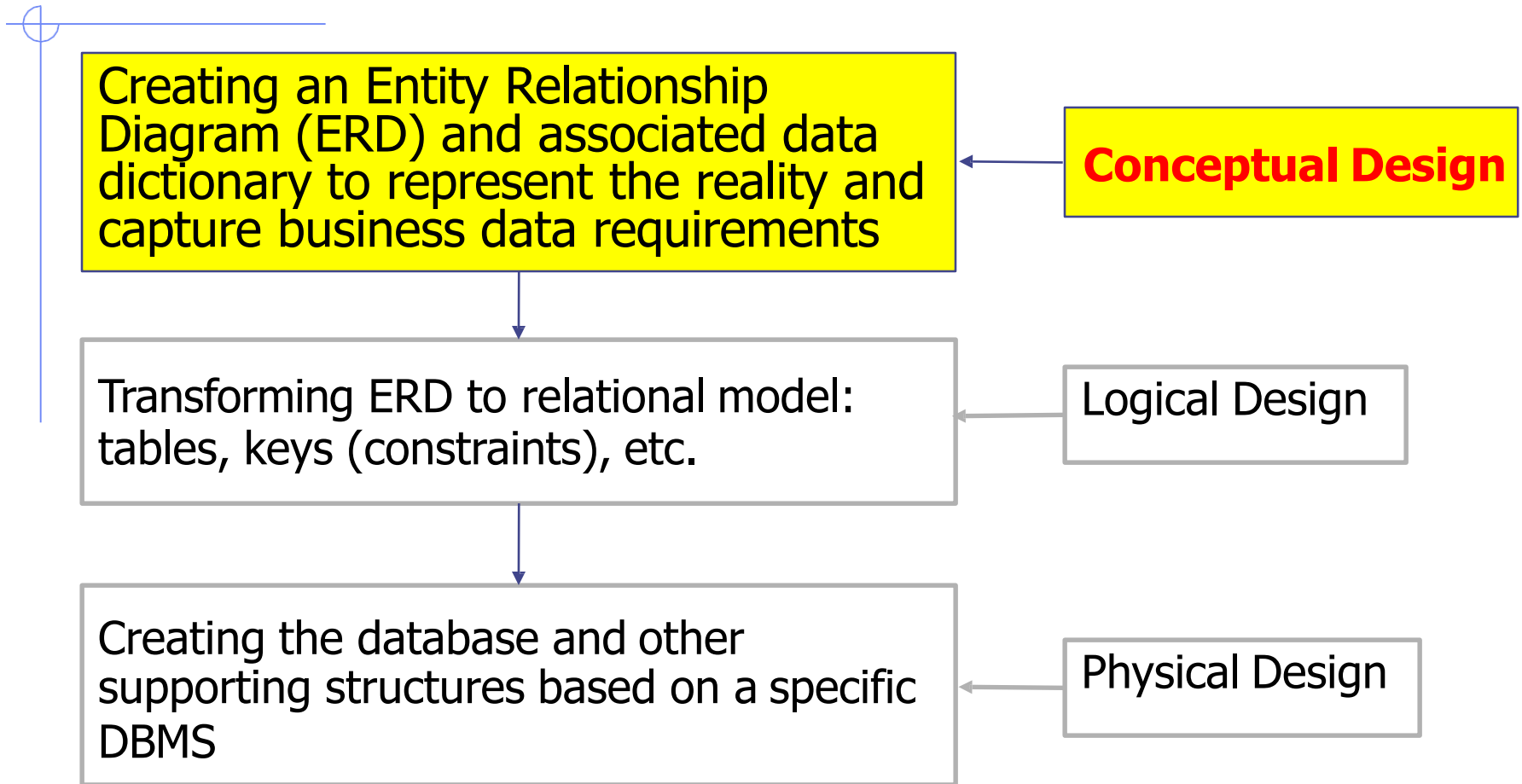# CHAPTER 3
ENTITY-RELATIONSHIP (E-R) MODEL & NORMALIZATION

Objectives:

- To illustrate how relationships between entities are defined and refined.

- To know how relationships are incorporated into the database design process.

- To describe how ERD components affect database design and implementation.

Level Database Design

| Creating an Entity Relationship Diagram (ERD) and associated data dictionary to represent the reality and capture business data requirements | ← | **Conceptual Design** |

↓

| Transforming ERD to relational model: tables, keys (constraints), etc. | ← | Logical Design |

↓

| Creating the database and other supporting structures based on a specific DBMS | ← | Physical Design |

What is Conceptual Database Design?

- Process of describing the data, relationships between the data, relationships between the data, and the constraints on the data.

- After analysis - Gather all the essential data required and understand how the data are related

- The focus is on the _data_, rather than on the processes.

- The output of the conceptual database design is a **Conceptual Data Model** (_+ Data Dictionary_)

Gathering Information for
Conceptual Data Modeling

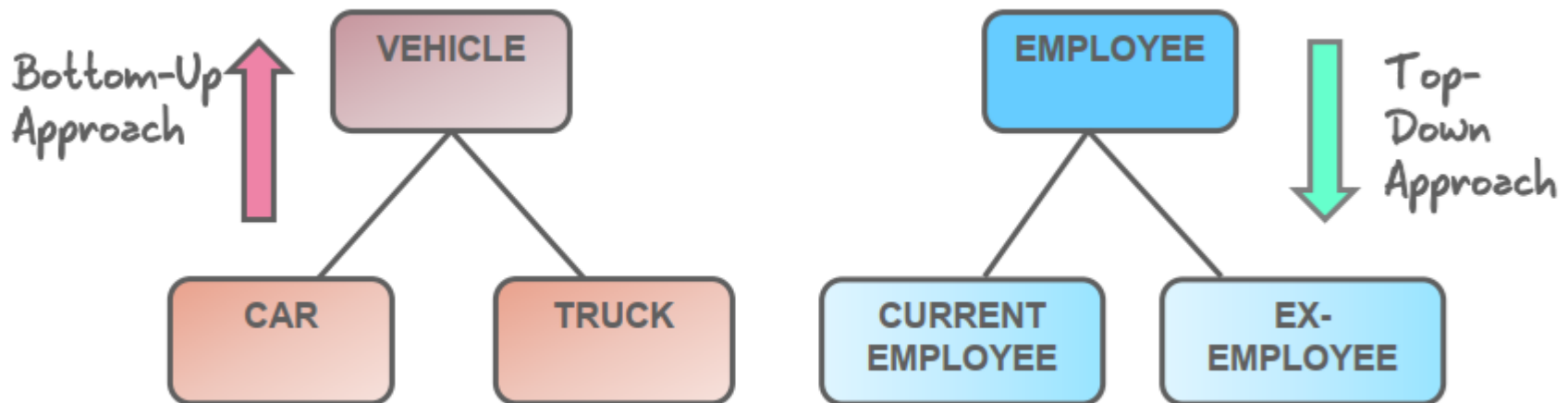## Two perspectives

01 **Top-down**

Data model is derived from an intimate understanding of the business.

02 **Bottom-up**

Data model is derived by reviewing specifications and business documents.

Entity-Relationship (ER) Modeling

ER Modeling is a *top-down* approach to database design.

An **Entity–relationship model (ER model)** describes the structure of a database with the help of a diagram, which is known as **Entity Relationship Diagram (ER Diagram)**.
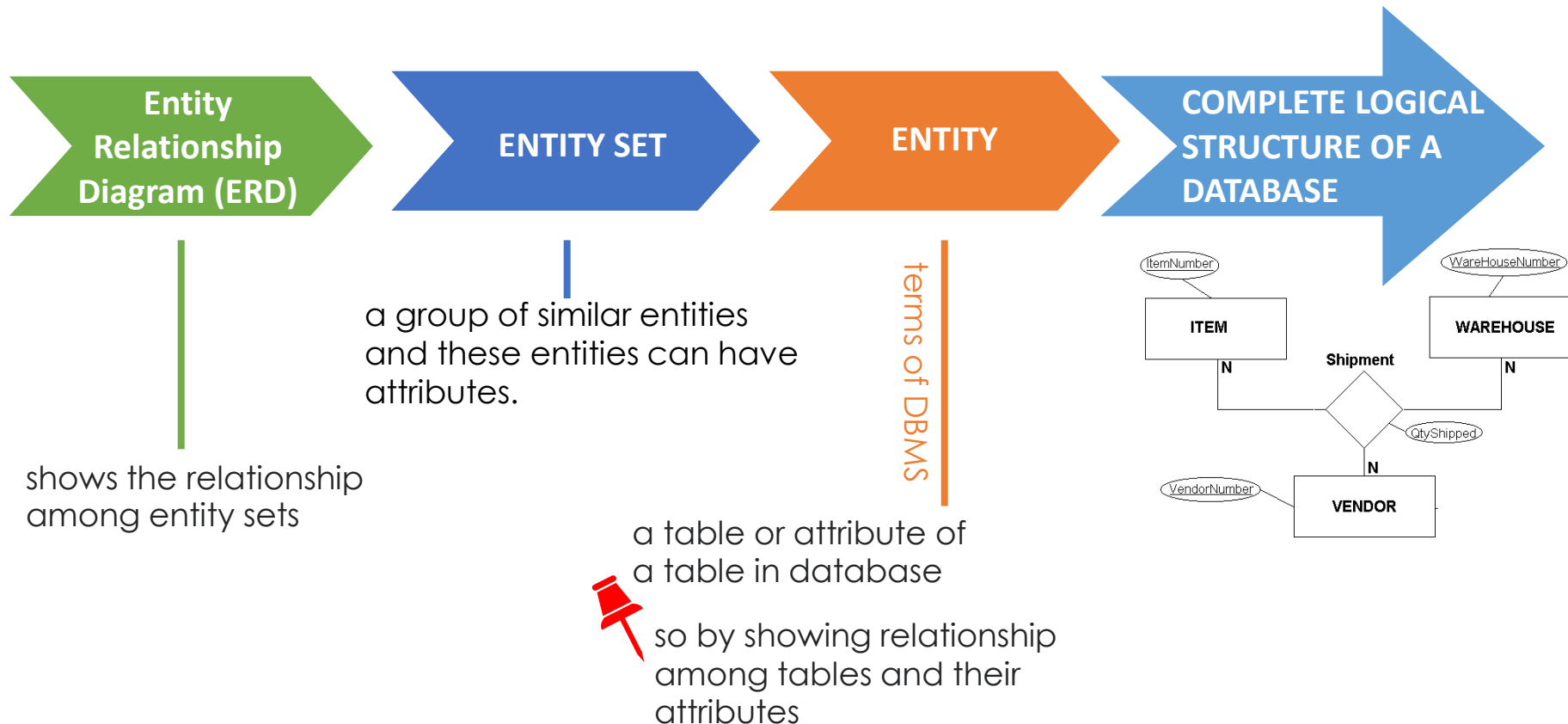
An ER model is a <u>design</u> or <u>blueprint</u> of a database that can later be implemented as a database.

The main components of E-R model are:

ENTITY SET

RELATIONSHIP SET

Entity-Relationship (ER) Modeling 🖨

What is an
Entity Relationship Diagram (ER Diagram)?

Entity Relationship Diagram (ERD)	ENTITY SET	ENTITY	COMPLETE LOGICAL STRUCTURE OF A DATABASE

a group of similar entities and these entities can have attributes.

terms of DBMS

shows the relationship among entity sets

a table or attribute of a table in database

so by showing relationship among tables and their attributes

Entity-Relationship (ER) Modeling

An ER diagram shows the relationship among entity sets.
An entity set is a group of similar entities and these entities can have attributes.
In,

ER diagram shows the complete logical structure of a database.

Entity-Relationship (ER) Modeling

Notation uses **THREE** main constructs:

1 Data Entities

2 Relationship

3 Attributes

1. Chen Model
2. Crow's Foot Model

ENTITY

- An entity is an object or component of data.

- An entity is represented as rectangle in an ER diagram.

- In the following ER diagram we have two entities Student and College and these two entities have many to one relationship as many students study in a single college.

| Student | —— M —— Study —— 1 —— | College |

- Entities are typically nouns such as :
    product, customer, location, or promotion

ENTITY
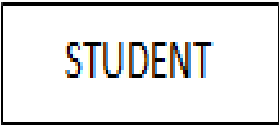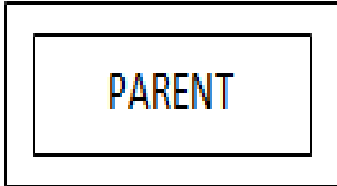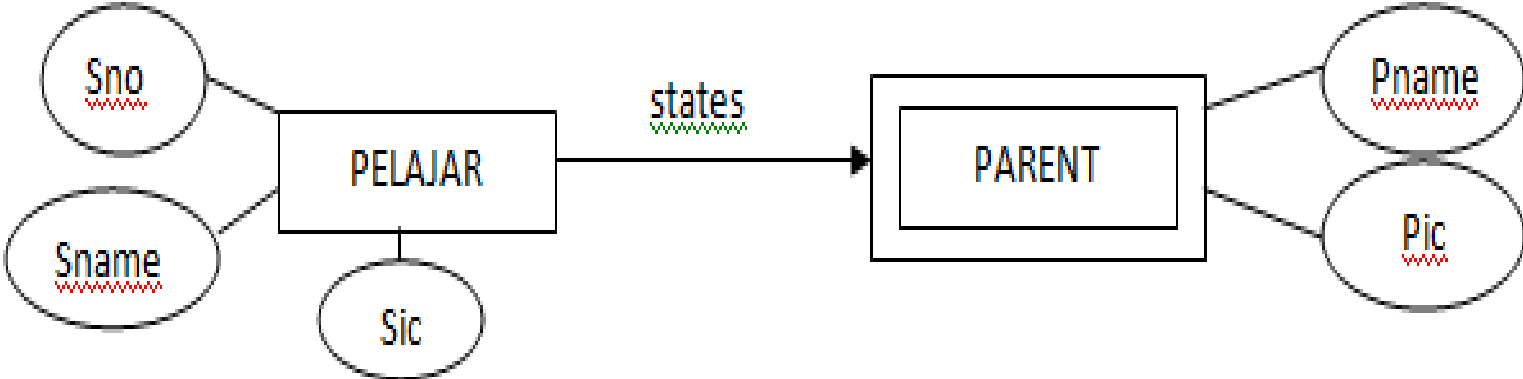
- Examples of entities:
  - Person: EMPLOYEE, STUDENT, PATIENT
  - Place: STORE, WAREHOUSE
  - Object: MACHINE, PRODUCT, CAR
  - Event: SALE, REGISTRATION, RENEWAL
  - Concept: ACCOUNT, COURSE

- Guidelines for naming and defining entity types:
  - An entity type name is a singular noun
  - An entity type should be descriptive and specific
  - An entity name should be concise
  - Event entity types should be named for the result of the event, not the activity or process of the event.

Weak ENTITY

- A weak entity is an entity that **depends on the existence of another entity.**

- In more technical terms it can be defined as an entity that *cannot be identified by its own attributes*.

- An entity that cannot be uniquely identified by its own attributes and relies on the relationship with other entity.

- The weak entity is represented by a **double rectangle**.

Strong ENTITY VS Weak ENTITY

Strong entity	Weak entity
An entity type that is not existence-dependent on some other entity type	An entity type that is existence-dependent on some other entity type
STUDENT	PARENT

Associative Entity

Associative Entity
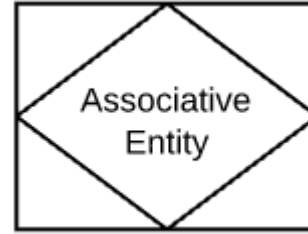
- Associative entities relate the instances of several entity types. They also contain attributes specific to the relationship between those entity instances

- Associative entities are implemented in a **database structure using associative tables, which are tables that can contain references to columns from the same or different database tables.**

student — registers — course

Associative Entity

- An associative (or junction) table maps two or more tables together by referencing the primary keys of each data table.

  → it contains a number of foreign keys, each in a many-to-one relationship from the junction table to the individual data tables.
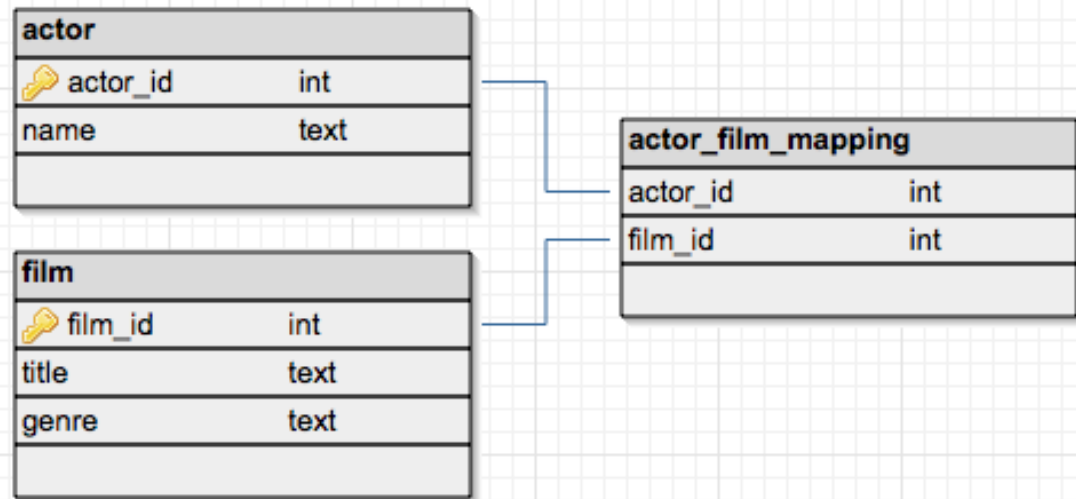
ATTRIBUTES

- Attribute – a property of an entity or a relationship type.
- Attribute - oval, with a line to the rectangle representing its entity set.
- Example :

Sno   Sname   StaffNo
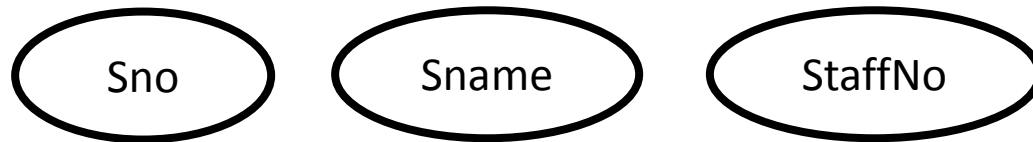
- Attribute domain – the set of allowable values for one or more attributes.
- *Example*:

> Attribute domain for attribute Sname is the value of the character between 1 and 24

ATTRIBUTES

- An attribute is a property, trait, or characteristic of an entity, relationship, or another attribute.

- Attributes describe entities and are the specific information that must be known.

For example, the attribute Inventory Item Name is an attribute of the entity Inventory Item.
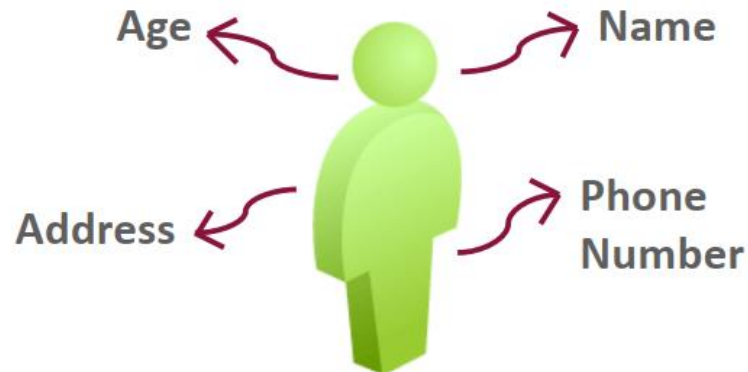
Characteristic of ATTRIBUTES

- It is a single-valued property detail of an entity.

- Attributes are shown within the entity box on the ERD.

- Attribute names are singular and mixed case or lowercase.
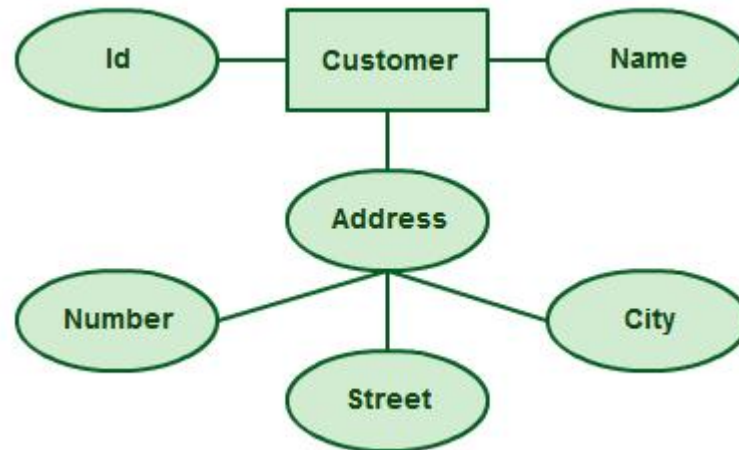
Types of ATTRIBUTES

There are four types of attributes:

1) Key attribute
2) Composite attribute
3) Multivalued attribute
4) Derived attribute

Key ATTRIBUTES

- **Simple attribute/Key Attribute** – an attribute composed of a single component with an independent existence.

- EXAMPLE:

StudentName   Gender

Composite ATTRIBUTES

- **Composite attribute** – an attribute composed of multiple components, each with an independent existence.

- Attributes can also have their own specific attributes.

- For example, the attribute "name" can have the attributes *FirstName* and *LastName*.
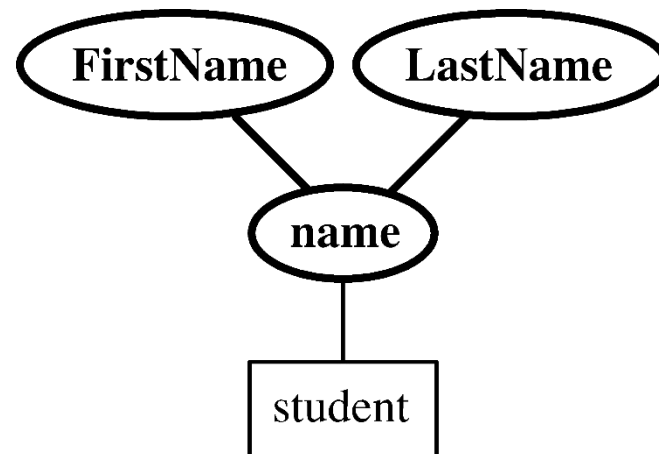
Composite ATTRIBUTES

- A combination of other attributes is known as composite attribute.

- For example, In student entity, the student address is a composite attribute as an address is composed of other attributes such as pin code, state, country.

Address is a composite attribute
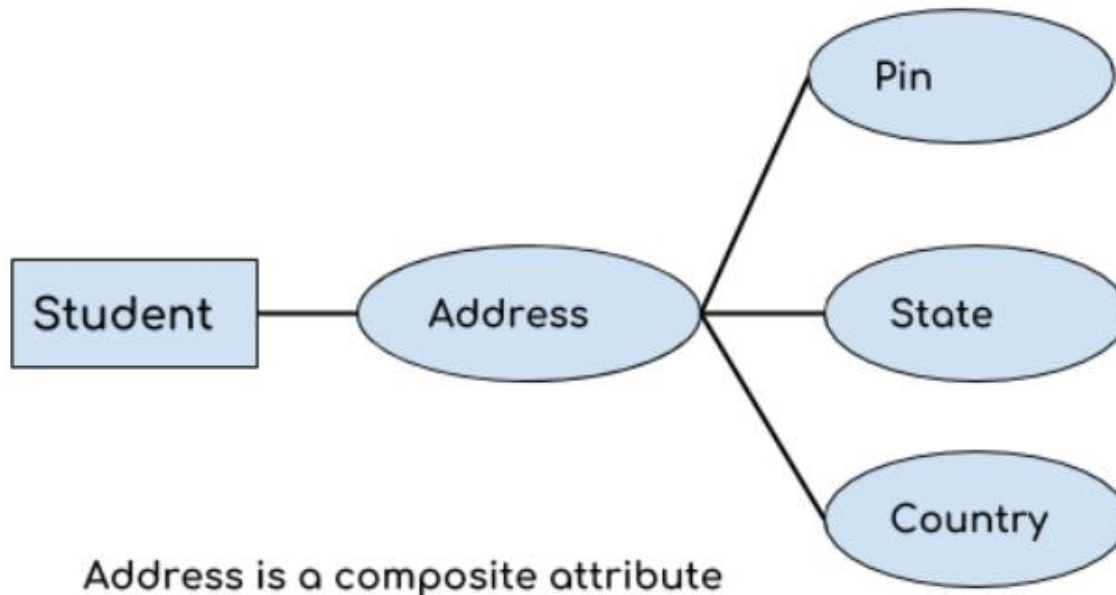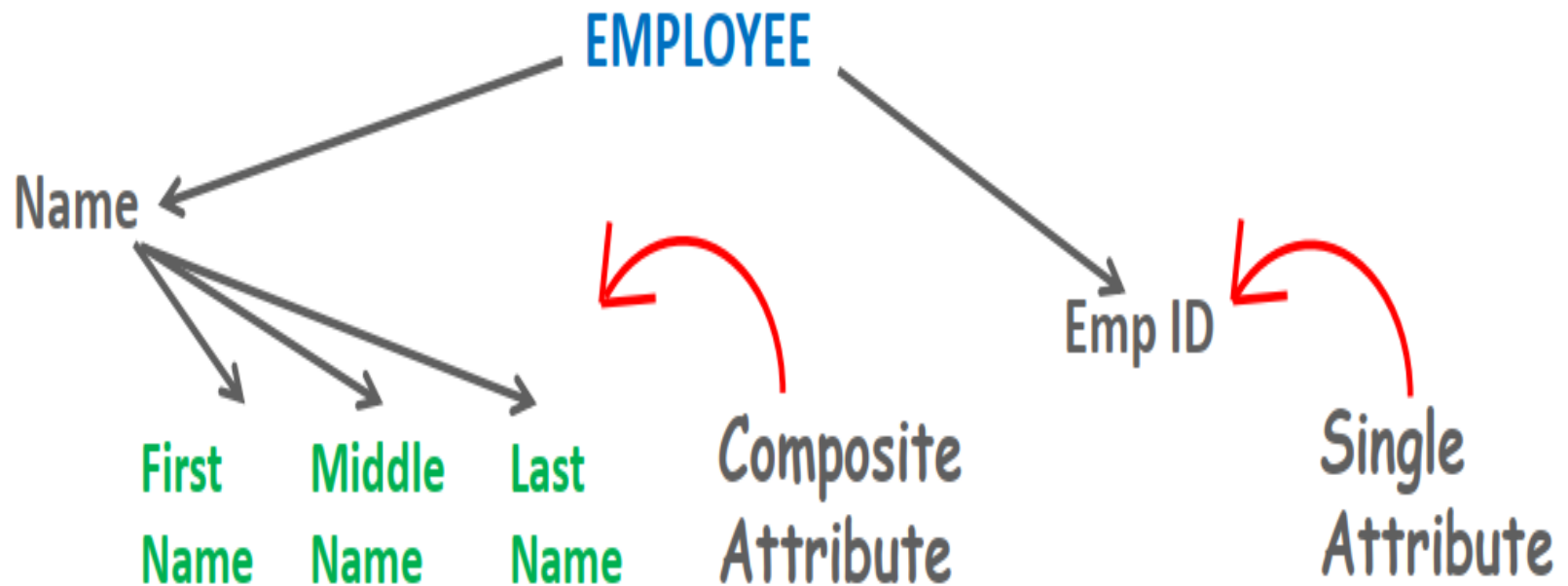
Multi-valued ATTRIBUTES

- Multi-valued attribute – an attributes that holds multiple values for each occurrence of an entity type.

- It is represented with **double ovals** in an ER Diagram

Sskill

Teacher —— Subjects

A teacher entity can have multiple subject values.

A person can have more than one phone numbers so the phone number attribute is multivalued.

telNo
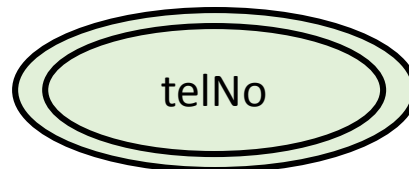
Derived ATTRIBUTES

- Derived attribute – an attribute that represents a value that is derivable from the value of a related attribute or set of attributes, not necessarily in the same entity type.

- one whose value is dynamic and derived from another attribute. It is represented by **dashed oval** in an ER Diagram.

- An attribute based on another attribute.

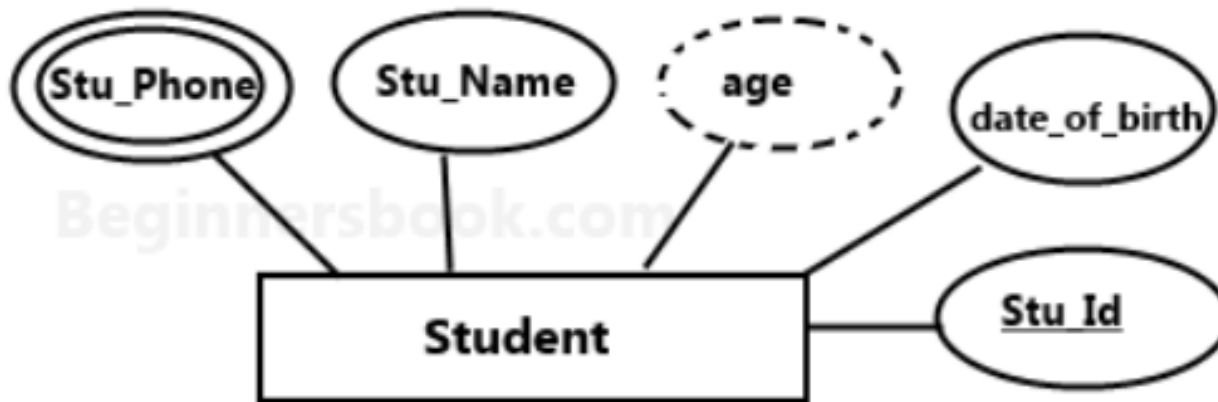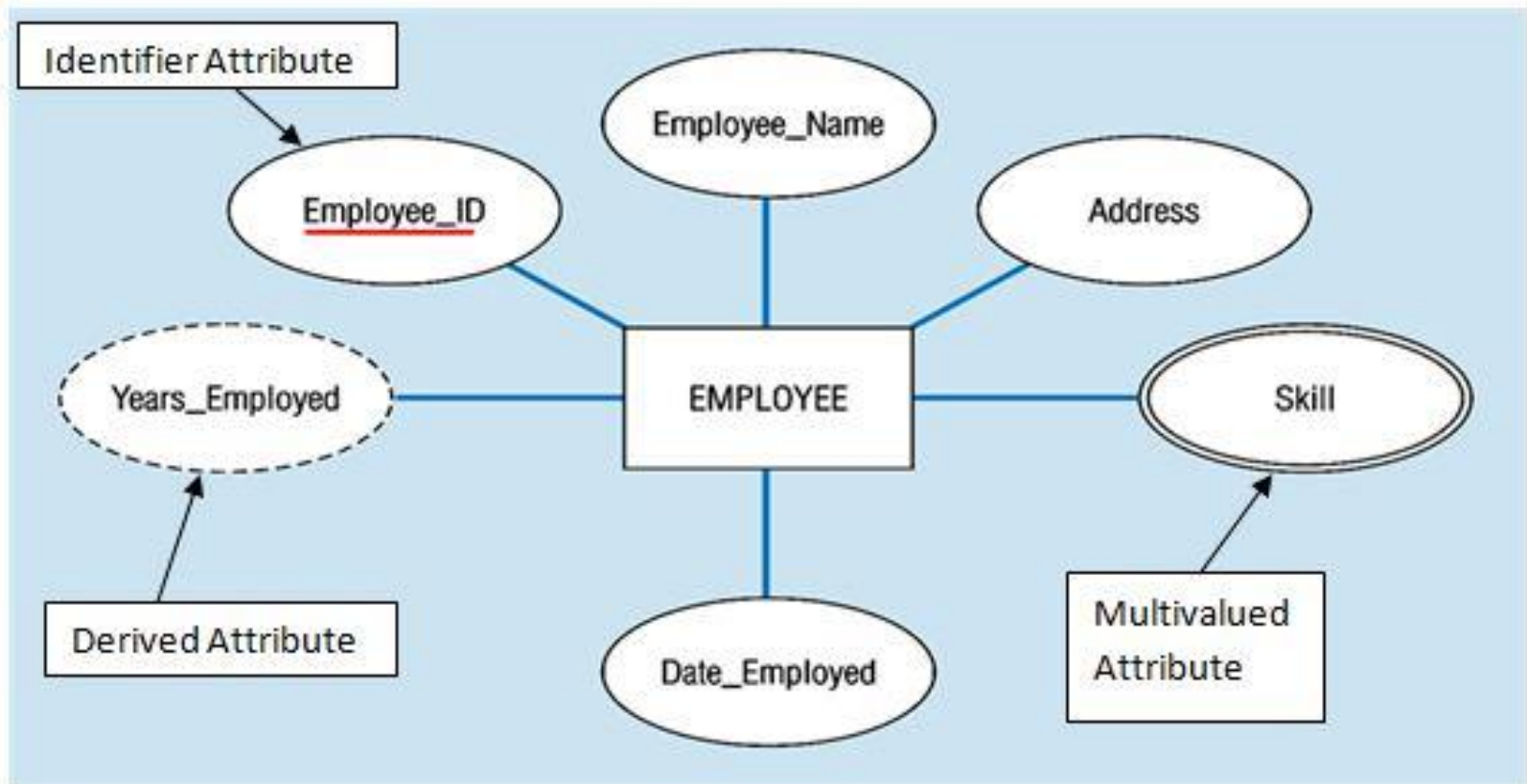For example, for a circle, the area can be derived from the radius.
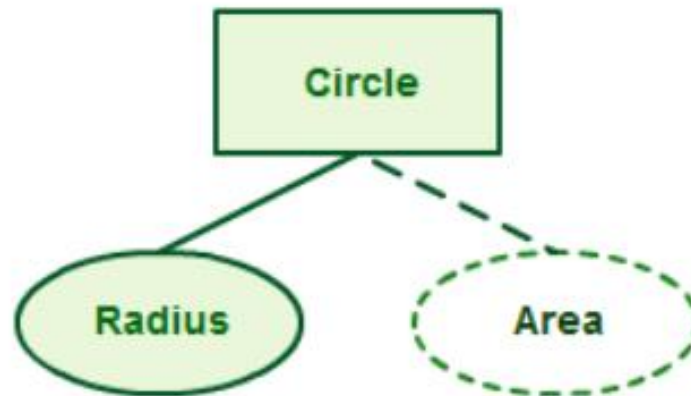
Derived ATTRIBUTES

Example :   **age**

Person age is a derived attribute as it changes over time

and can be derived from another attribute (Date of birth).

Types of ATTRIBUTES

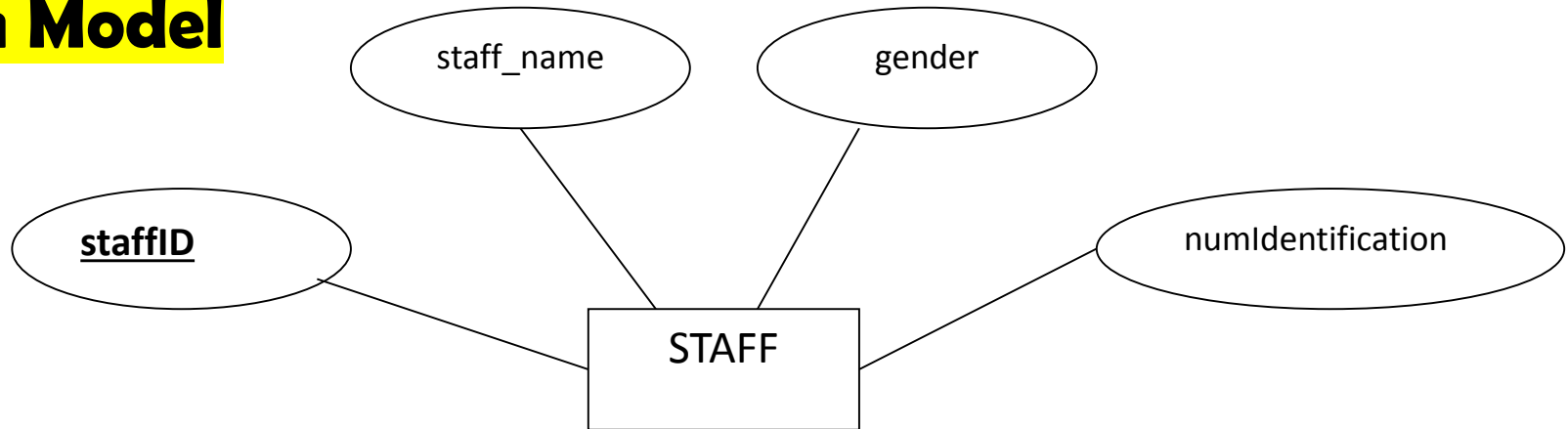| Attribute Symbol	Name	Description
Attribute	Attribute	Attributes are characteristics of an entity, a many-to-many relationship, or a one-to-one relationship.
Multivalued Attribute	Multivalued attribute	Multivalued attributes are those that are can take on more than one value.
Derived Attribute	Derived attribute	Derived attributes are attributes whose value can be calculated from related attribute values.
Relationship	Relationship	Relationships are associations between or among entities.

Chen Model


```
          staff_name          gender

staffID                    STAFF                    numIdentification
```

STAFF	
PK	**staffID**
	staff_name gender numIdentification

Crow's Foot Model

CHEN NOTATION

Association between the instances of one or more entity types

Entity Name	Verb Phrase	Attribute Name
Entity	**Relationship**	**Attribute**

Person, place, object, event or concept about which data is to be maintained

named property or characteristic of an entity
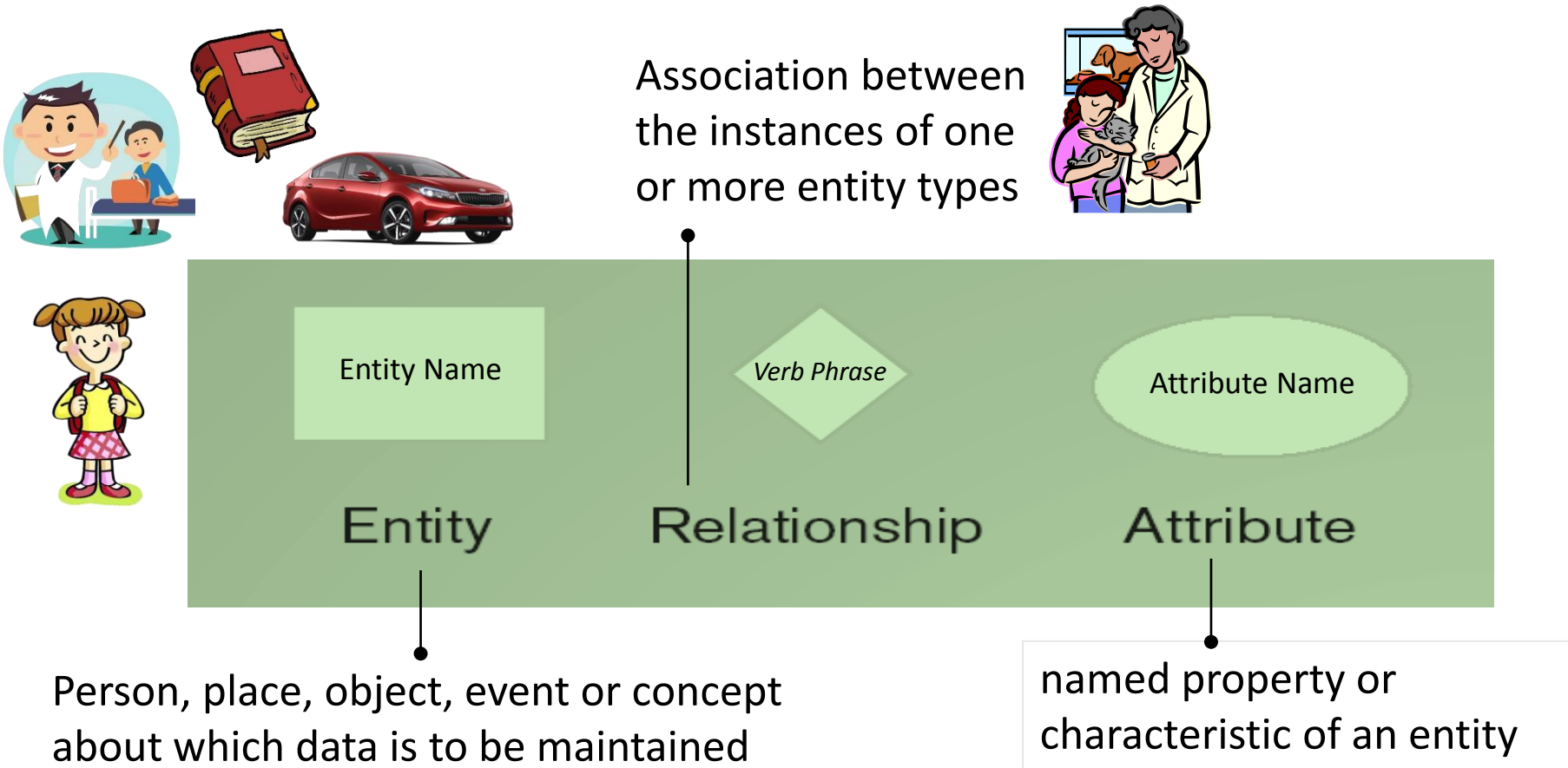
Represents a set or collection of objects in the real world that share the same properties

CHEN NOTATION

attribute

WRITTEN BY

DIRECTOR

DURATION

TITLE

MOVIE

RELEASE DATE
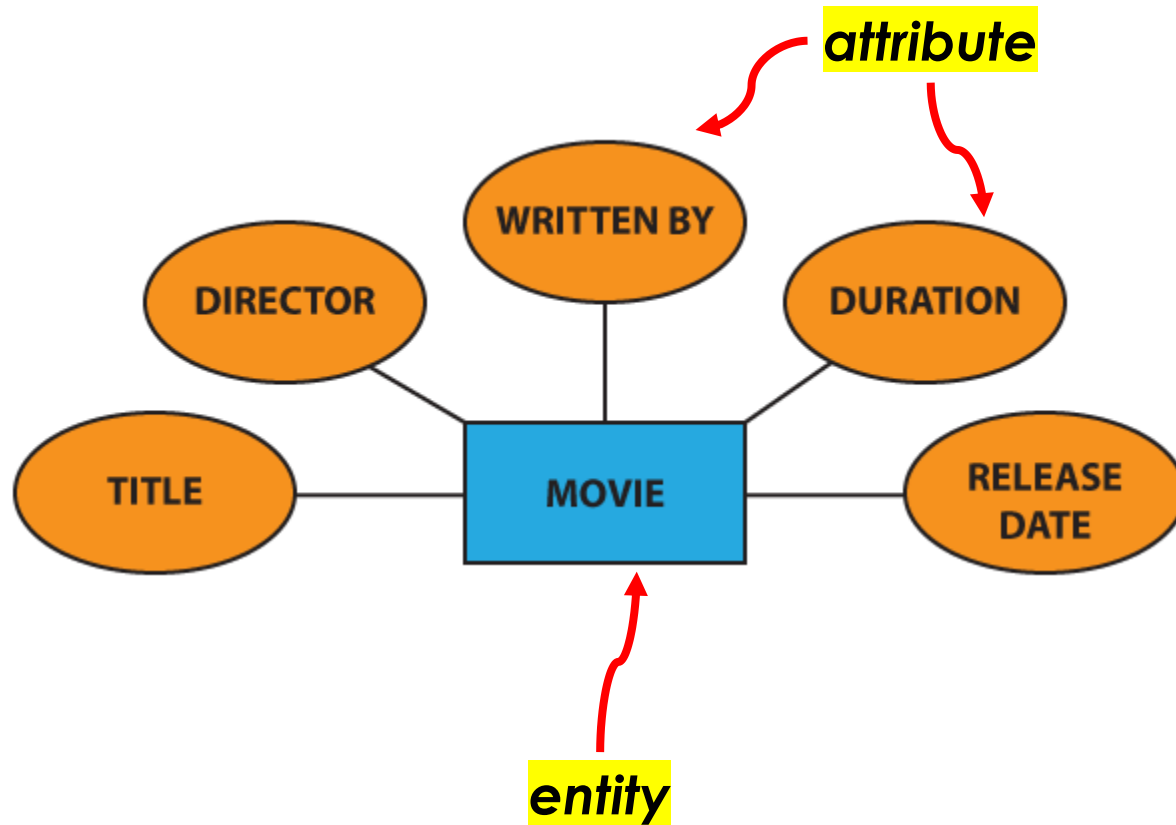
entity

CROW'S FOOT NOTATION

ENTITY

entity

An entity is a representation of a class of object.

Entities usually have attributes that describe them

ATTRIBUTE

student
* student_id first_name last_name date_of_birth major

An attribute is a property that describes a particular entity.

RELATIONSHIP
Verb phrase

Relationships illustrate the association between two entities.

Presented as a straight line.
Each relationship has a name, expressed as a verb, written on the relationship line.

This describes what kind of relationship connects the objects.

CASE STUDY

Faculty: Matt, I want to know the specifications for all tables and columns required in the simplified library database.

Matt: Sure. I will convert the entities and their attributes into tables and columns.
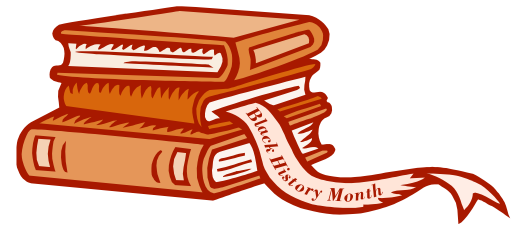
Learn about Relationship

→ Associations between instances of one or more entity types that is of interest

→ A relationship describes how entities interact.

→ Given a name that describes its function.

→ relationship name is an <u>active</u> or a <u>passive</u> verb.

Relationship name:
writes

Author

Book

An author writes one or more books
A book can be written by one or more authors.

Learn about Relationship

Relationships are represented by **diamond shapes** and *are labeled using verbs*.
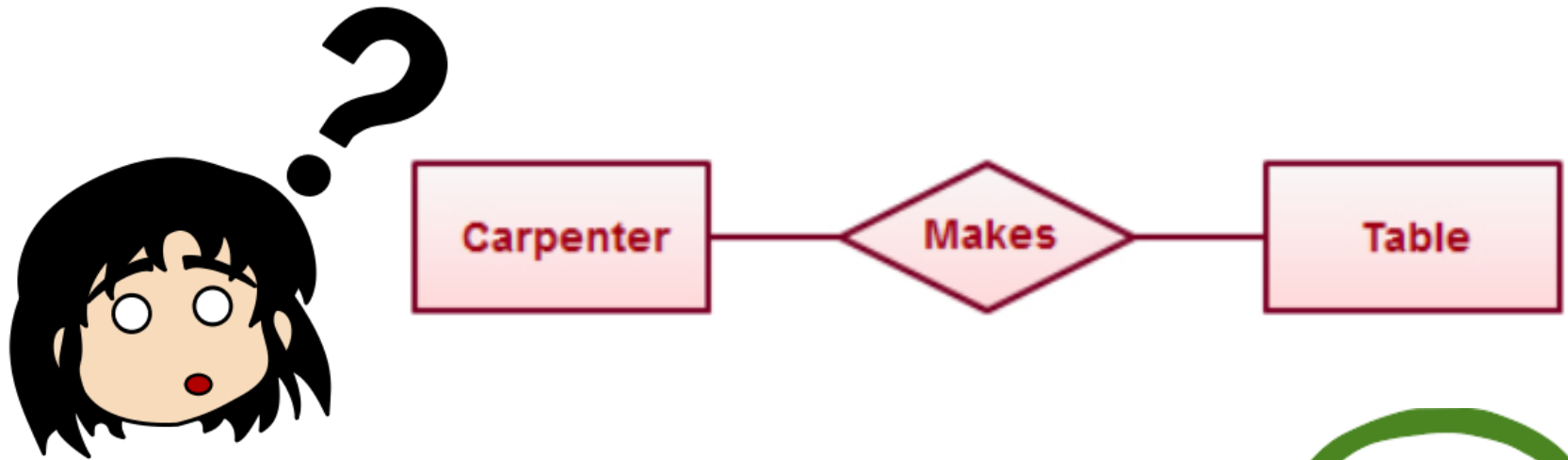
- *Relationships illustrate the association between two entities.*
- *They are presented as a straight line.*
- *Usually, each relationship has a name, expressed as a verb, written on the relationship line.* → *describes what kind of relationship connects the objects.*
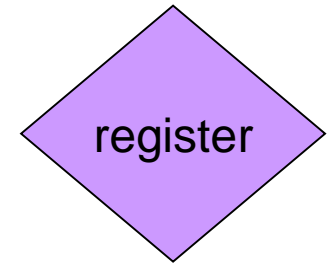
Degree of **Relationship**

- Degree: number of entity types that participate in a relationship

- **THREE CASES**

  - **Unary:** between two instances of one entity type

  - **Binary:** between the instances of two entity types

  - **Ternary:** among the instances of three entity types

Unary   Binary   Ternary
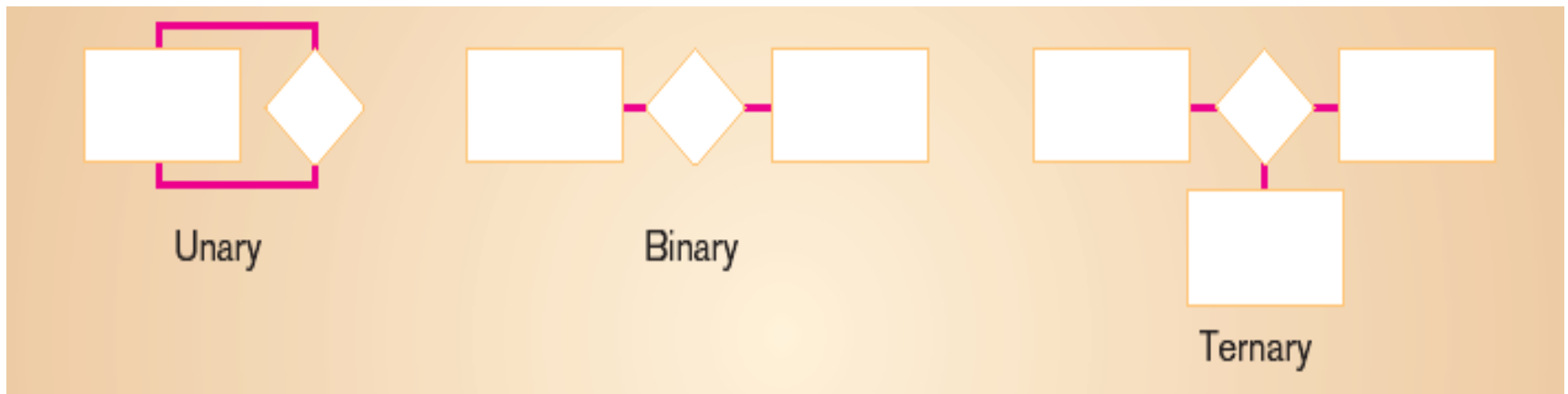
2.4 Cardinality and Connectivity

register

- A relationship is represented by diamond shape in ER diagram, it shows the relationship among entities. There are four types of relationships:

    1. One to One
    2. One to Many
    3. Many to One
    4. Many to Many

    Connectivity

- *Cardinality* : minimum and maximum number of instances of Entity B that can (or must be) associated with each instance of entity A.

One to One Relationship

- In a *one-one* relationship, each entity of either entity set is related to at most one entity of the other set

One to One Relationship

Table name: PROFESSOR
Primary key: EMP_NUM
Foreign key: DEPT_CODE

Database name: Ch03_TinyCollege

EMP_NUM	DEPT_CODE	PROF_OFFICE	PROF_EXTENSION	PROF_HIGH_DEGREE
103	HIST	DRE 156	6783	Ph.D.
104	ENG	DRE 102	5561	MA
105	ACCT	KLR 229D	8665	Ph.D.
106	MKT/MGT	KLR 126	3899	Ph.D.
110	BIOL	AAK 160	3412	Ph.D.
114	ACCT	KLR 211	4436	Ph.D.
155	MATH	AAK 201	4440	Ph.D.
160	ENG	DRE 102	2248	Ph.D.
162	CIS	KLR 203E	2359	Ph.D.
191	MKT/MGT	KLR 409B	4016	DBA
195	PSYCH	AAK 297	3550	Ph.D.
209	CIS	KLR 333	3421	Ph.D.
228	CIS	KLR 300	3000	Ph.D.
297	MATH	AAK 194	1145	Ph.D.
299	ECON/FIN	KLR 284	2851	Ph.D.
301	ACCT	KLR 244	4683	Ph.D.
335	ENG	DRE 208	2000	Ph.D.
342	SOC	BBG 208	5514	Ph.D.
387	BIOL	AAK 230	8665	Ph.D.
401	HIST	DRE 156	6783	MA
425	ECON/FIN	KLR 284	2851	MBA
435	ART	BBG 185	2278	Ph.D.

Table name: DEPARTMENT
Primary key: DEPT_CODE
Foreign key: EMP_NUM

DEPT_CODE	DEPT_NAME	SCHOOL_CODE	EMP_NUM	DEPT_ADDRESS	DEPT_EXTENSION
+ ACCT	Accounting	BUS	114	KLR 211, Box 52	3119
+ ART	Fine Arts	A&SCI	435	BBG 185, Box 128	2278
+ BIOL	Biology	A&SCI	387	AAK 230, Box 415	4117
+ CIS	Computer Info. Systems	BUS	209	KLR 333, Box 56	3245
+ ECON/FIN	Economics/Finance	BUS	299	KLR 284, Box 63	3126
+ ENG	English	A&SCI	160	DRE 102, Box 223	1004
+ HIST	History	A&SCI	103	DRE 156, Box 284	1867
+ MATH	Mathematics	A&SCI	297	AAK 194, Box 422	4234
+ MKT/MGT	Marketing/Management	BUS	106	KLR 126, Box 55	3342
+ PSYCH	Psychology	A&SCI	195	AAK 297, Box 438	4110
+ SOC	Sociology	A&SCI	342	BBG 208, Box 132	2008

One to Many Relationships

- When a single instance of an entity is associated with more than one instances of another entity

Customer —1— placed —M— Order

One to Many Relationships

• When a single instance of an entity is associated with more than one instances of another entity

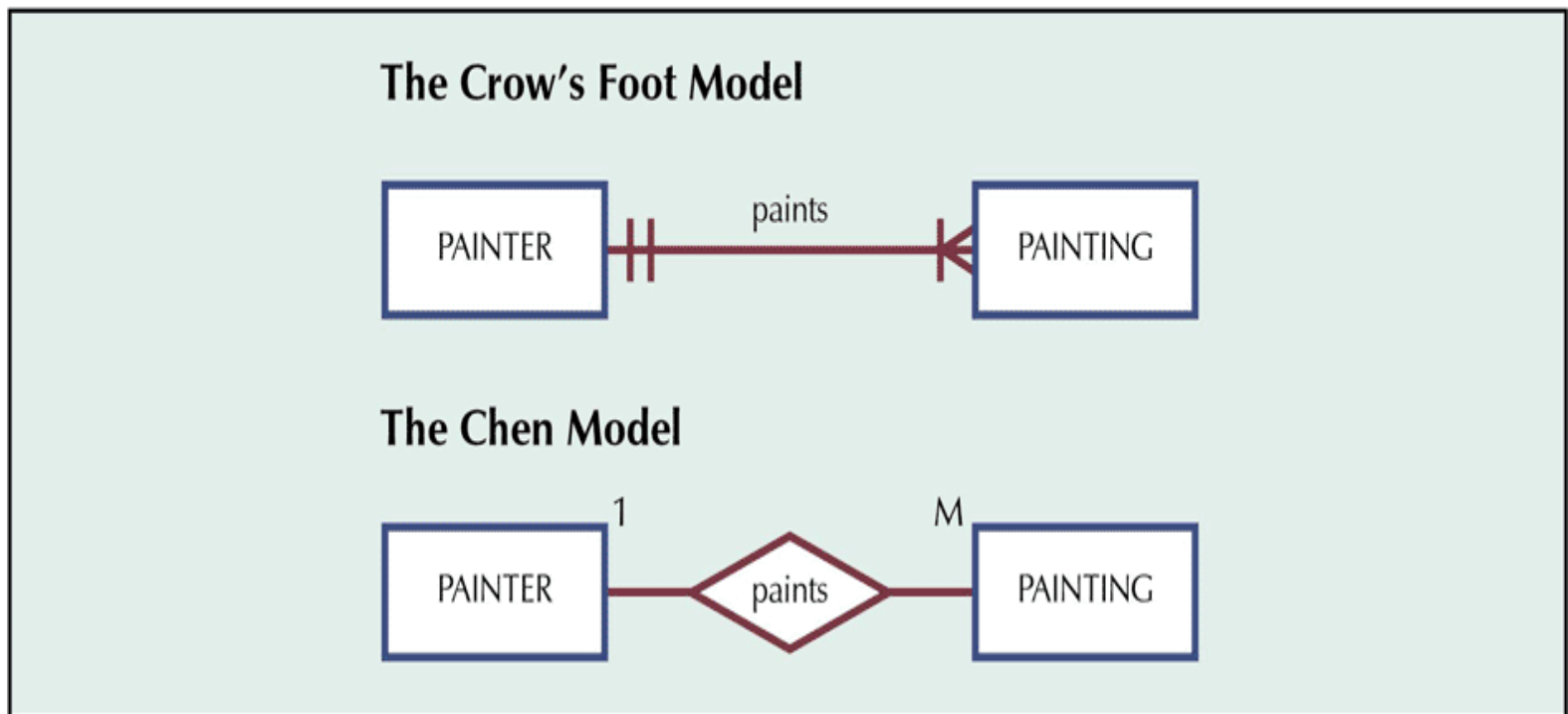**The Crow's Foot Model**

PAINTER ⫢—paints—⟨ PAINTING

The Chen Model

PAINTER —1— ⟨paints⟩ —M— PAINTING

The Implemented 1:M relationship between PAINTER and PAINTING

Many-One Relationships

- Some binary relationships are *many -one* from one entity set to another.

- Each entity of the first set is connected to at most one entity of the second set.

- But an entity of the second set can be connected to zero, one, or many entities of the first set.

Many-One Relationships

EXAMPLE :

Many students can study in a single college but a student cannot study in many colleges at the same time.

Many-One Relationships

STUDENT — 1 M M — register — 1 1 1 — CO-CURICULUM

One student can register only one co-curriculum unit

One co-curriculum unit can register by many students
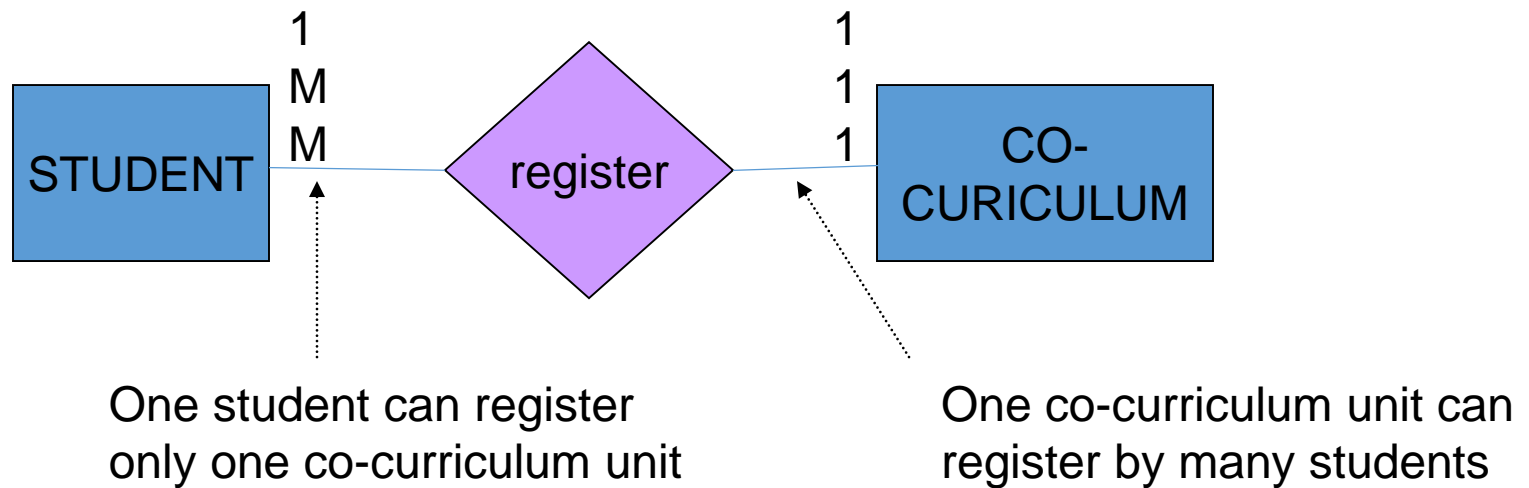
Many To Many (M:N) Relationships

- When more than one instances of an entity is associated with more than one instances of another entity
- **Must be avoided because they lead to *data redundancies*.**
- Can be implemented by breaking it up to produce a set of 1:M relationships
- Can avoid problems inherent to M:N relationship by creating a ***composite entity or bridge entity***
  - This will be used to link the tables that were originally related in a M:N relationship
  - The composite entity structure includes-as f**oreign keys-at least the primary keys of the tables that are to be linked.**

Many To Many (M:N) Relationships

A student can be assigned to many projects

A project can be assigned to many students.

Many To Many (M:N) Relationships
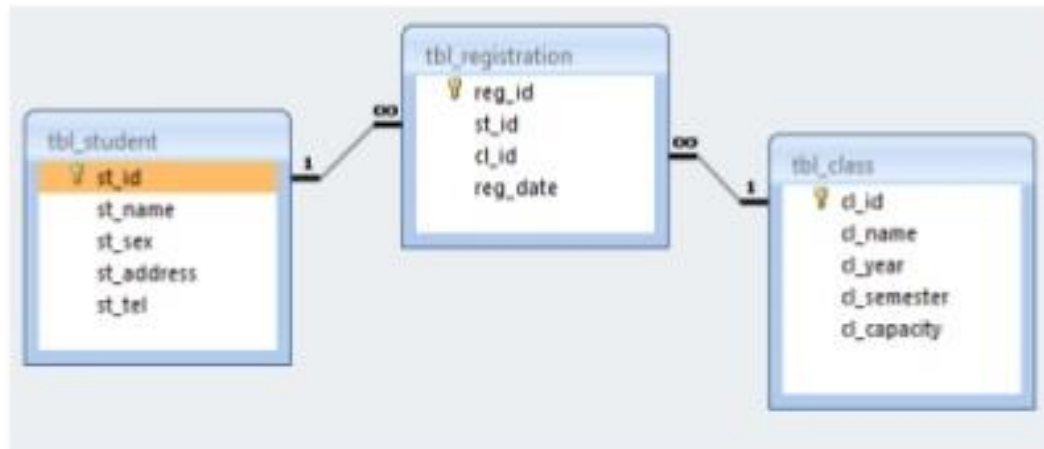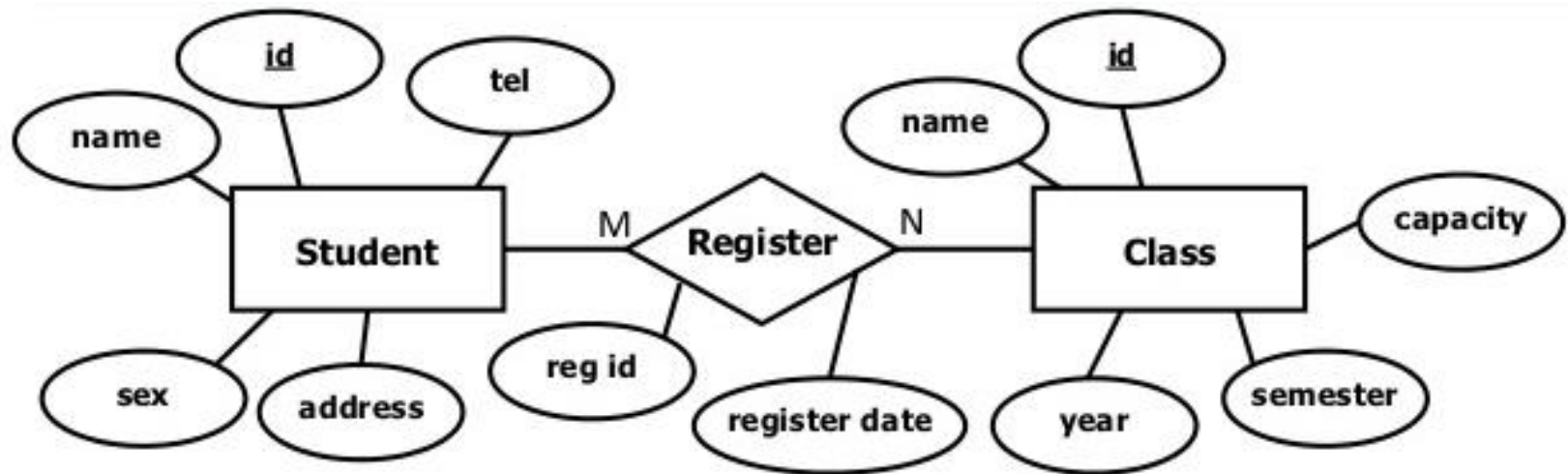
Many To Many (M:N) Relationships
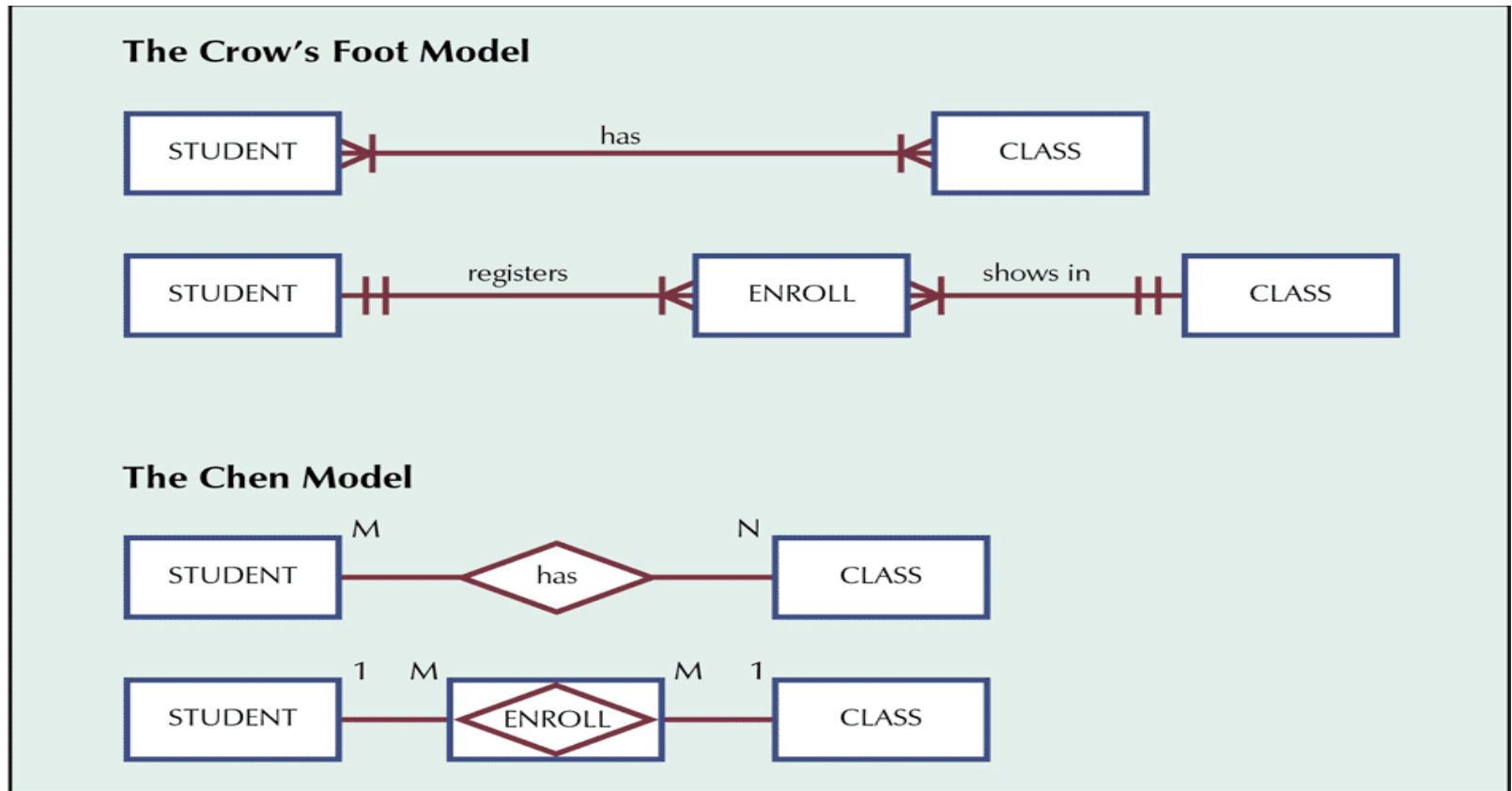
Changing the M:N relationship to TWO 1:M relationships

Many To Many (M:N) Relationships
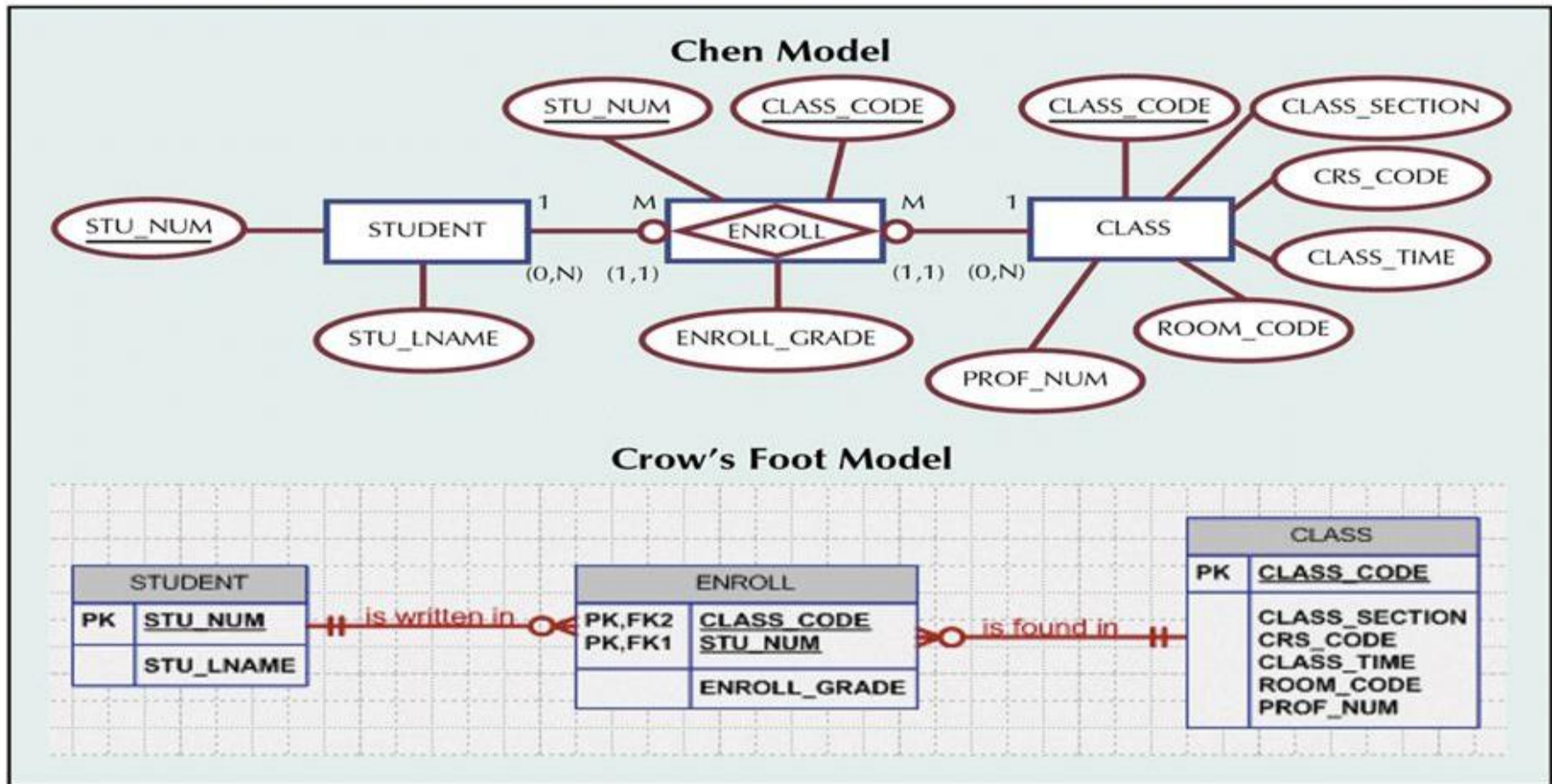
Changing the M:N relationship to TWO 1:M relationships

Minimum Cardinality

- Minimum cardinality describes the minimum number of instances that must participate in a relationship for any one instance

- Minimums are generally stated as either zero or one:
  - 0 (optional): participation in the relationship by the entity is optional.
  - 1 (mandatory): participation in the relationship by the entity is mandatory.

One to many maximum cardinality: a programmer can have many certificates; a certificate is issued to only one programmer.

- ERD Notation (Crow's foot)

Certificates ⊃○── Has / Issued to ──│┼── Programmers
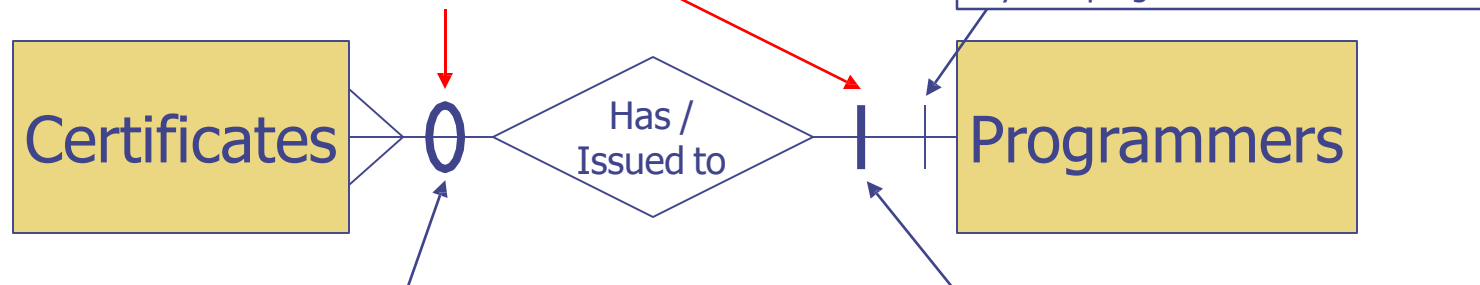
A certificate is optional in the relationship (optional for a programmer); or a programmer may not have any certificates.

A programmer instance is required in the relationship (a programmer is mandatory for a certificate); or a certificate has to be issued to someone.

MADAM ZHZ 2019

2.6 Mandatory vs. Optional Cardinalities

Specifies whether an instance must exist or can be absent in the relationship

- **Cardinality Constraints - the number of instances of one entity that can or must be associated with each instance of another entity.**
- **Minimum Cardinality**
  - ✓ If zero, then optional
  - ✓ If one or more, then mandatory
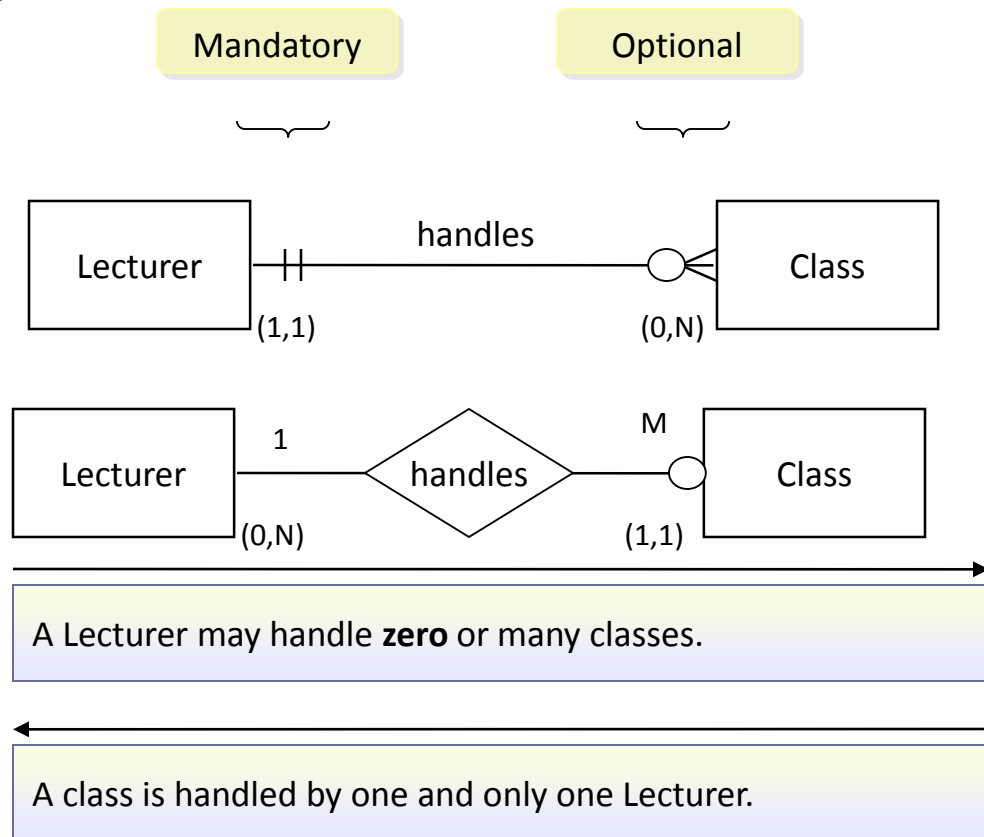- **Maximum Cardinality**
  - ✓ The maximum number

2.6 Mandatory vs. Optional Cardinalities

Symbol	Meaning
—————┤├—	One — Mandatory
—————┤<	Many — Mandatory
—————O┤—	One — Optional
—————O<	Many — Optional

Cardinality of the relationship

2.6 Mandatory vs. Optional Cardinalities

- Specifies whether an instance must exist or can be absent in the relationship

Mandatory   Optional

Lecturer ╫── handles ──O< Class
(1,1)   (0,N)

Lecturer ─1─ ◇handles◇ ─M─ O Class
(0,N)   (1,1)

A Lecturer may handle **zero** or many classes.

A class is handled by one and only one Lecturer.

Business rules
Customer can rent many tapes
Tapes can be rented by many customers
Some customers do not rent tape
Some tapes are never rented
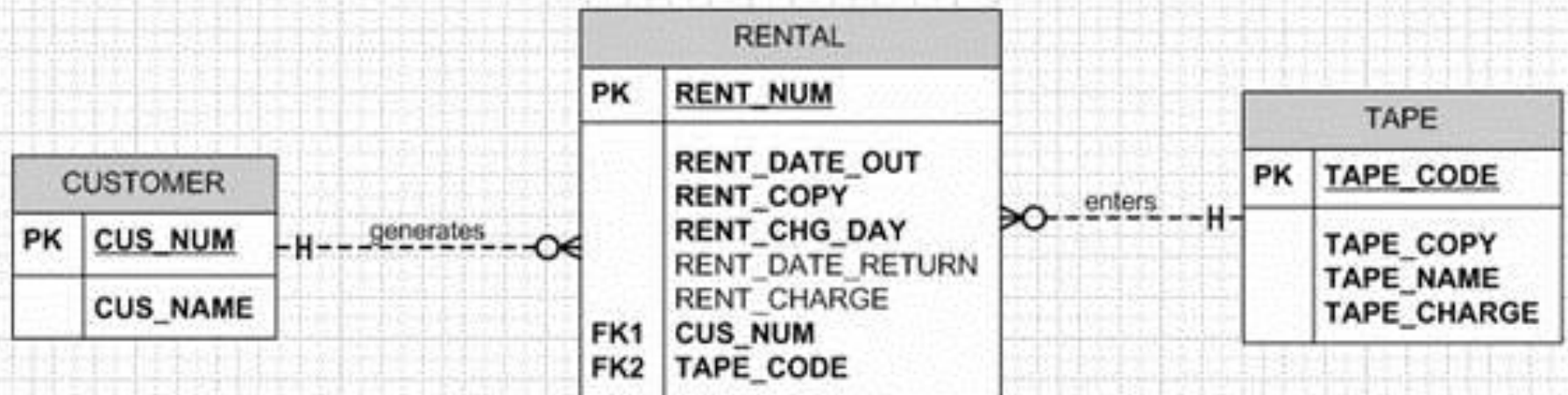
CHEN'S MODEL

- Developed by [Peter Chen](#) and published in a 1976.
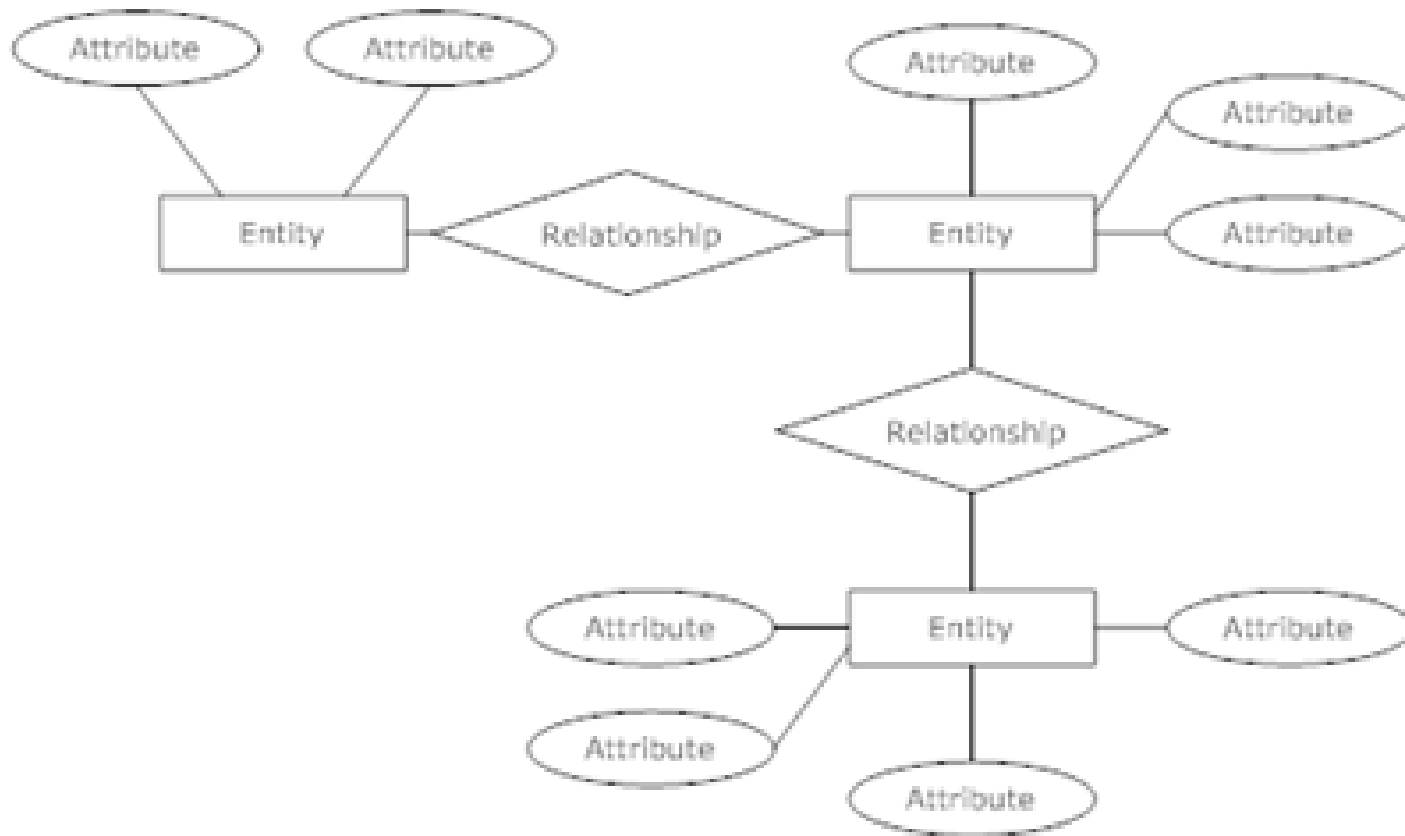
CHEN'S MODEL
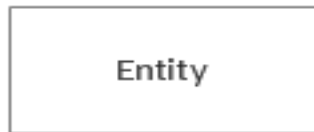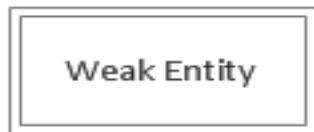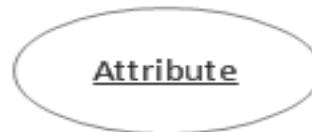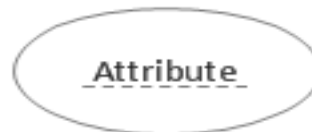
Entity	Entity
Weak Entity	Weak Entity
Relationship	Relationship
Relationship	Identifying Relationship
Associative Entity	Associative Entity
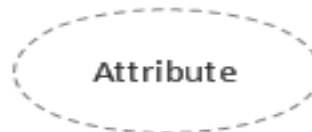
Attribute	Attribute
Attribute	Key attribute
Attribute	Weak key attribute
Attribute	Derived attribute
Attribute	Multivalue attribute

Notations used in Chen's Model

CHEN'S MODEL

1   1   (1:1)

1   M   (1: M)

M   N   (M: N)

Relationship / Cardinality in Chen's Model

CROW'S FOOT NOTATION

- Crow's foot diagrams represent entities as boxes, and relationships as lines between the boxes.

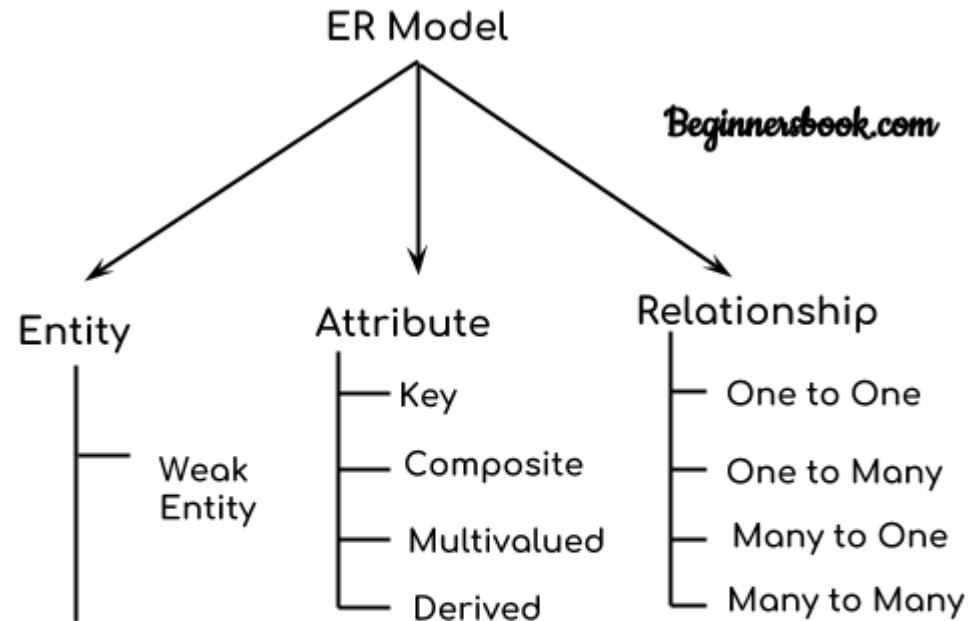- Different shapes at the ends of these lines represent the cardinality of the relationship.

ENTITY   *ENTITY*

lecturer
PK   attribute1
attribute2
attributeN

RELATIONSHIP

course
PK   attribute1
attribute2
attributeN

CROW'S FOOT NOTATION

One or Zero

One and only One

Zero or Many
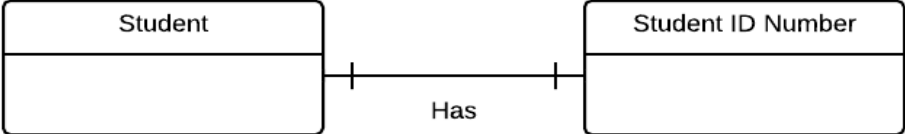
One or Many
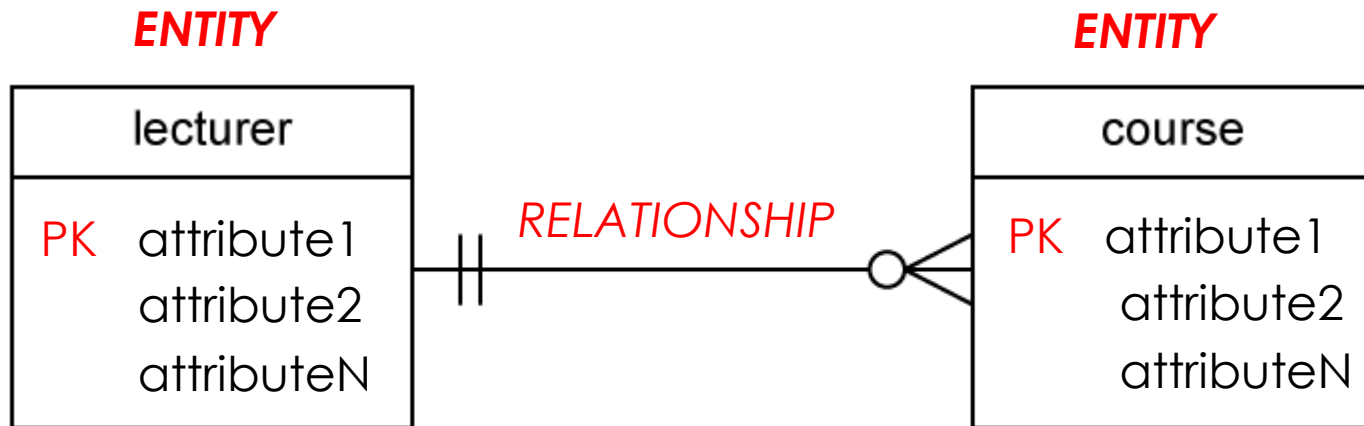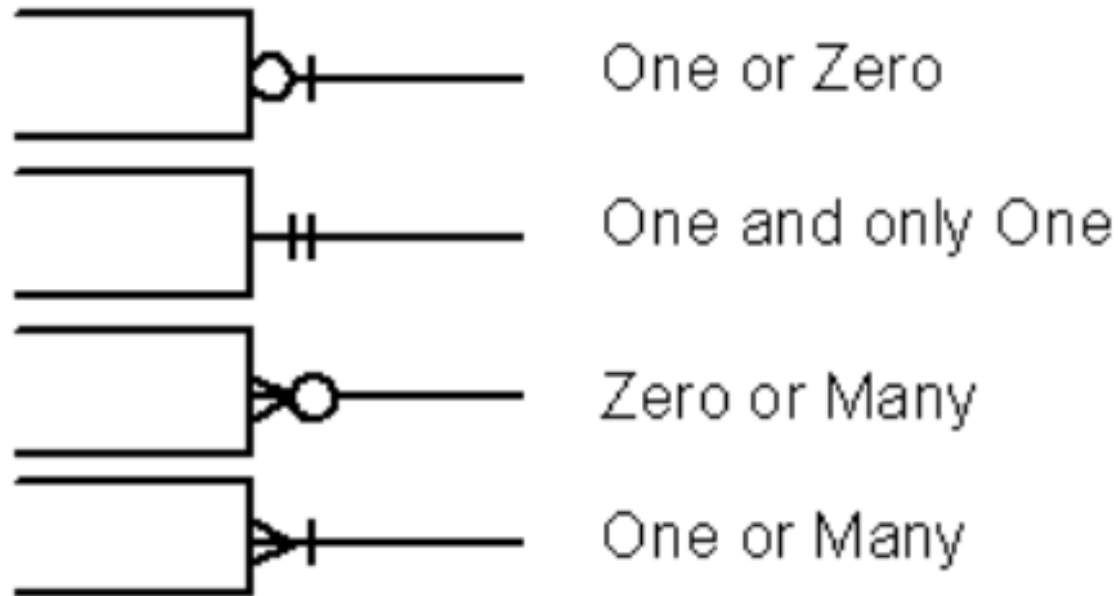
Cardinality of the relationship

Example: Crow's Foot
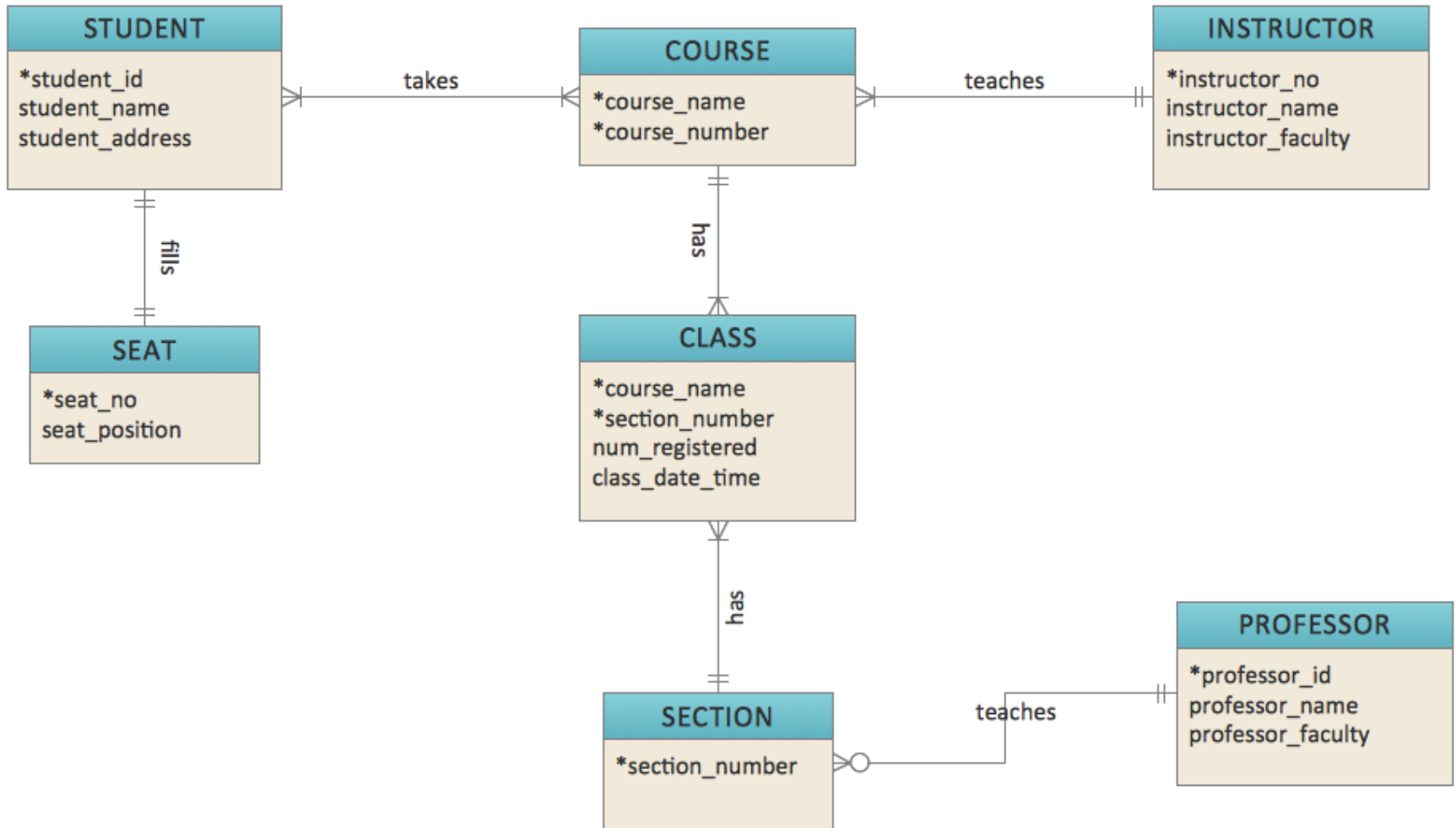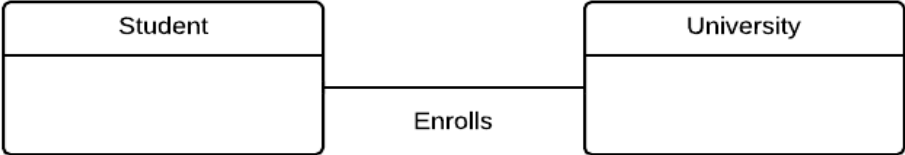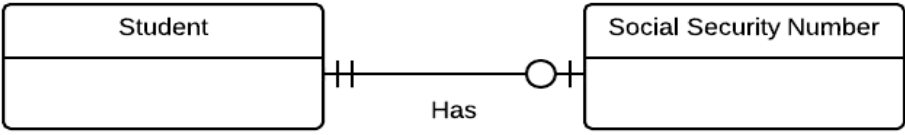
Components of a ER Diagram

ER Model

Beginnersbook.com

Entity | Weak Entity

Attribute
— Key
— Composite
— Multivalued
— Derived

Relationship
— One to One
— One to Many
— Many to One
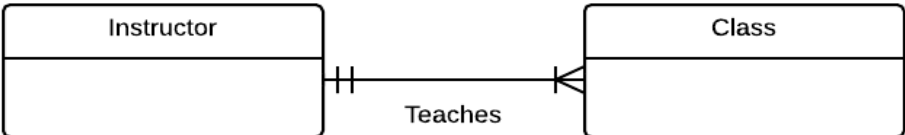— Many to Many

Components of ER Diagram

As shown in the above diagram, an ER diagram has three main components:
1. Entity
2. Attribute
3. Relationship

Notation	Meaning	Example
——	Relationship	Student — University (Enrolls)
——⊦	One	Student —⊦——⊦ Student ID Number (Has)
——<	Many	Student >——< Class (Attends)
——⊦⊦	One and ONLY One	Student ⊦⊦——⊦⊦ Chair (Uses)
——○⊦	Zero or One	Student ⊦⊦——○⊦ Social Security Number (Has)
——⟨<	One or Many	Instructor ⊦⊦——⟨< Class (Teaches)
——○<	Zero or Many	Classroom ⊦⊦——○< Chair (Has)

MADAM ZHZ 2019

ERD "Crow's Foot" Relationship Symbols [Quick Reference]

Created by Vivek M. Chawla | @VivekMChawla | April 7, 2013

SAMPLE ERD

SSN — Has — Student
Student ID — Has
Chair — Uses
Student — Attends — Class — Teaches — Instructor
University — Enrolls / Employs
Class — Has — Classroom
Chair — Has — Classroom