Relational Database Design by ER-to-Relational Mapping

Outline

- **Schema Mapping (Logical Database Design) step of Database Design**
- **ER-to-Relational Mapping Algorithm**
  - Step 1: Mapping of Regular Entity Types
  - Step 2: Mapping of Weak Entity Types
  - Step 3: Mapping of Binary 1:1 Relation Types
  - Step 4: Mapping of Binary 1:N Relationship Types.
  - Step 5: Mapping of Binary M:N Relationship Types.
  - Step 6: Mapping of Multivalued attributes.
  - Step 7: Mapping of N-ary Relationship Types.

Data Model Mapping Phase of Relational DB Design

- DB designers use ER/EER or other conceptual data model to produce a conceptual schema design (*independent* from any specific DBMS) during the *Conceptual Database Design* phase
- In *Logical Database Design* Phase (see Figure 7.1, next slide) conceptual schema design is converted (Mapped) to the data model of the DBMS
  - Typically relational model (see Chapters 3-6), or object/object-relational models (see Chapter 11)
  - Data model mapping is usually automated or semi-automated in many database design tools
- In this chapter, we study the various options for mapping ER/EER model constructs to relational model constructs
  - Object and object-relational mapping discussed in Chapter 11

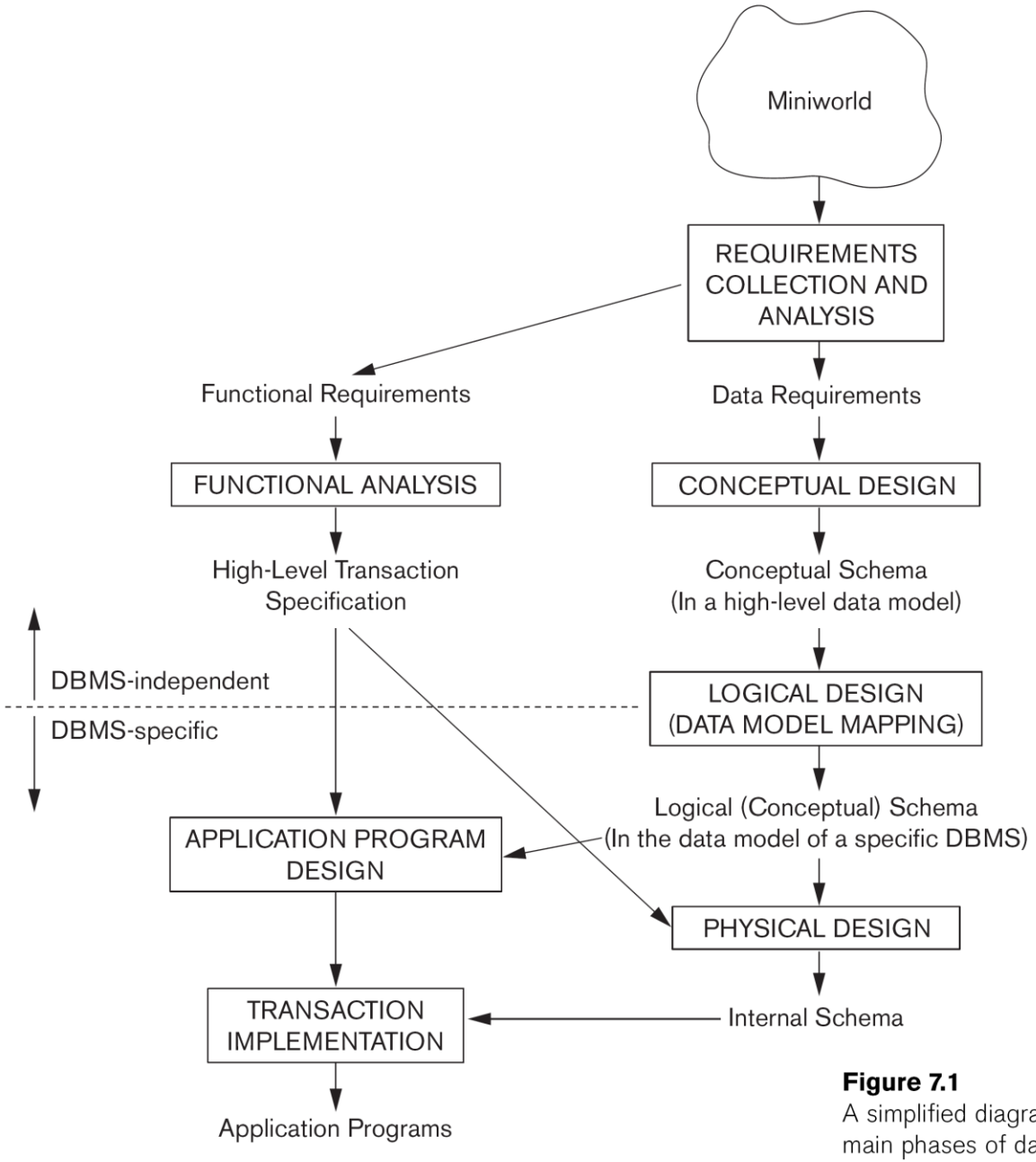
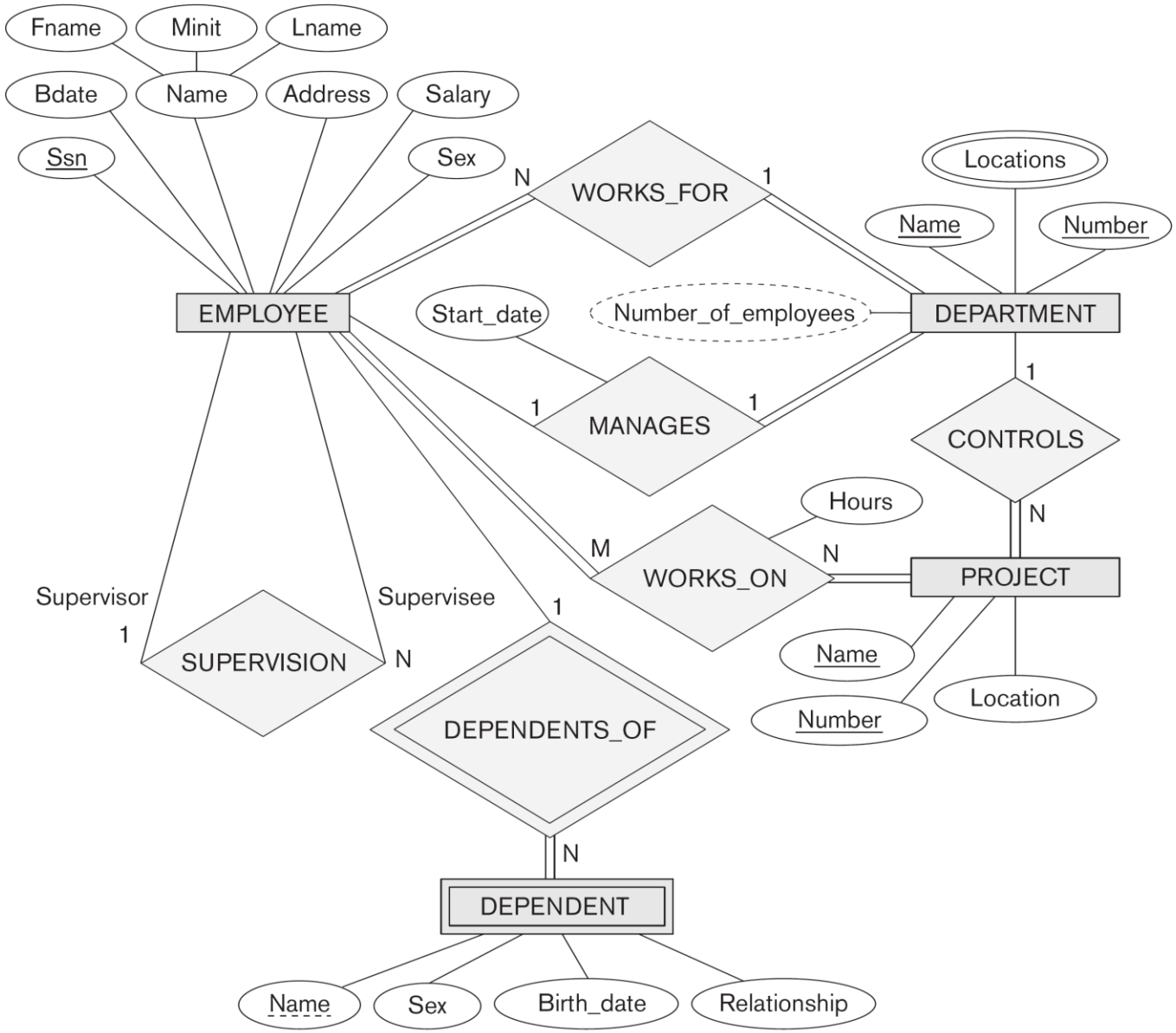


Figure 7.1
A simplified diagram to illustrate the main phases of database design.

Overview of ER-to-Relational Mapping Algorithm

- We present the concepts of a general mapping algorithm
- Algorithm has 7 steps:
  - Step 1: Mapping of regular (strong) entity types
  - Step 2: Mapping of weak (dependent) entity types
  - Steps 3, 4, 5: Mapping of binary relationship types of different ca rdinality ratios (1:1, 1:N, M:N)
  - Step 6: Mapping of multi-valued attributes
  - Step 7: Mapping of n-ary relationship types, n > 2
- Example: We use the COMPANY ER schema diagram (Figure 9.1, next slide) to illustrate the mapping steps
- Additional steps (Steps 8, 9) for mapping EER model construct s (specialization/generalization, UNION types) presented later

Figure 9.1
The ER conceptual schema diagram for the COMPANY database.



ER-to-Relational Mapping Algorithm

- **Step 1: Mapping of Regular Entity Types**
  - For each regular (strong) entity type E in the ER schema, create a relation R that includes all the *simple* attributes (or simple compo nents of composite attributes) of E.
  - Choose one of the key attributes of E as primary key for R.
  - If the chosen key of E is *composite*, the set of simple attributes th at form it will together form the primary key of R.
- Example: We create the relations EMPLOYEE, DEPARTMEN T, and PROJECT in the relational schema corresponding to the regular entity types in Figure 9.1
  - SSN, DNUMBER, and PNUMBER are chosen as primary keys f or the relations EMPLOYEE, DEPARTMENT, and PROJECT (F igure 9.3(a), next slide).
  - Note: Additional attributes will be added to these tables in later m apping steps

Figure 9.3
Illustration of some mapping steps.
a. *Entity* relations after step 1.
b. Additional *weak entity* relation after step 2.
c. *Relationship* relation after step 5.
d. Relation representing multivalued attribute after step 6.

(a) **EMPLOYEE**

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary

DEPARTMENT

Dname	Dnumber

PROJECT

Pname	Pnumber	Plocation

(b) **DEPENDENT**

Essn	Dependent_name	Sex	Bdate	Relationship

(c) **WORKS_ON**

Essn	Pno	Hours

(d) **DEPT_LOCATIONS**

Dnumber	Dlocation

ER-to-Relational Mapping Algorithm (cont.)

- **Step 2: Mapping of Weak Entity Types**
  - For each weak entity type W with owner entity type E, create a relation R that includes all simple attributes (or simple components of composit e attributes) of W as attributes of R.
  - Include as foreign key attribute(s) in R the primary key attribute(s) of th e relation(s) that corresponds to the *owner* entity type(s).
  - The primary key of R is the *combination of* the primary key(s) of the o wner(s) and the partial key of the weak entity type W, if any.
- Example: Create the relation DEPENDENT in this step to corr espond to the weak entity type DEPENDENT.
  - see Figure 9.3(b)
  - Include the primary key SSN of the EMPLOYEE relation as a foreign k ey attribute of DEPENDENT (renamed to ESSN in Fig.).
  - The primary key of DEPENDENT is the combination {ESSN, DEPEN DENT_NAME} because DEPENDENT_NAME is the partial key of D EPENDENT.

ER-to-Relational Mapping Algorithm (cont.)

- **Step 3: Mapping of Binary 1:1 Relationship Types**
  - For each binary 1:1 relationship type R in the ER schema, identify the r elations S and T that correspond to the entity types participating in R.
- Three possible approaches:
  - **Foreign Key approach:** Choose one of the relations (say S) and includ e as *foreign key* in S the primary key of T (it is better to choose an entit y type *with total participation in R* in the role of S).
    - Example (see Figure 9.2): 1:1 relationship MANAGES (Fig. 9.1) is mappe d by choosing DEPARTMENT to serve in the role of S (because its partici pation in the MANAGES relationship type is total)
    - Mgr_SSN of DEPARTMENT is foreign key referencing EMPLOYEE
    - Attributes of MANAGES become attributes of DEPARTMENT
  - **Merged relation option:** Merge the two entity types and the relationshi p into a single relation (possible when *both participations are total*).
  - **Cross-reference or *relationship relation* option:** Set up a third relation R for cross-referencing the primary keys of the two relations S and T re presenting the entity types.

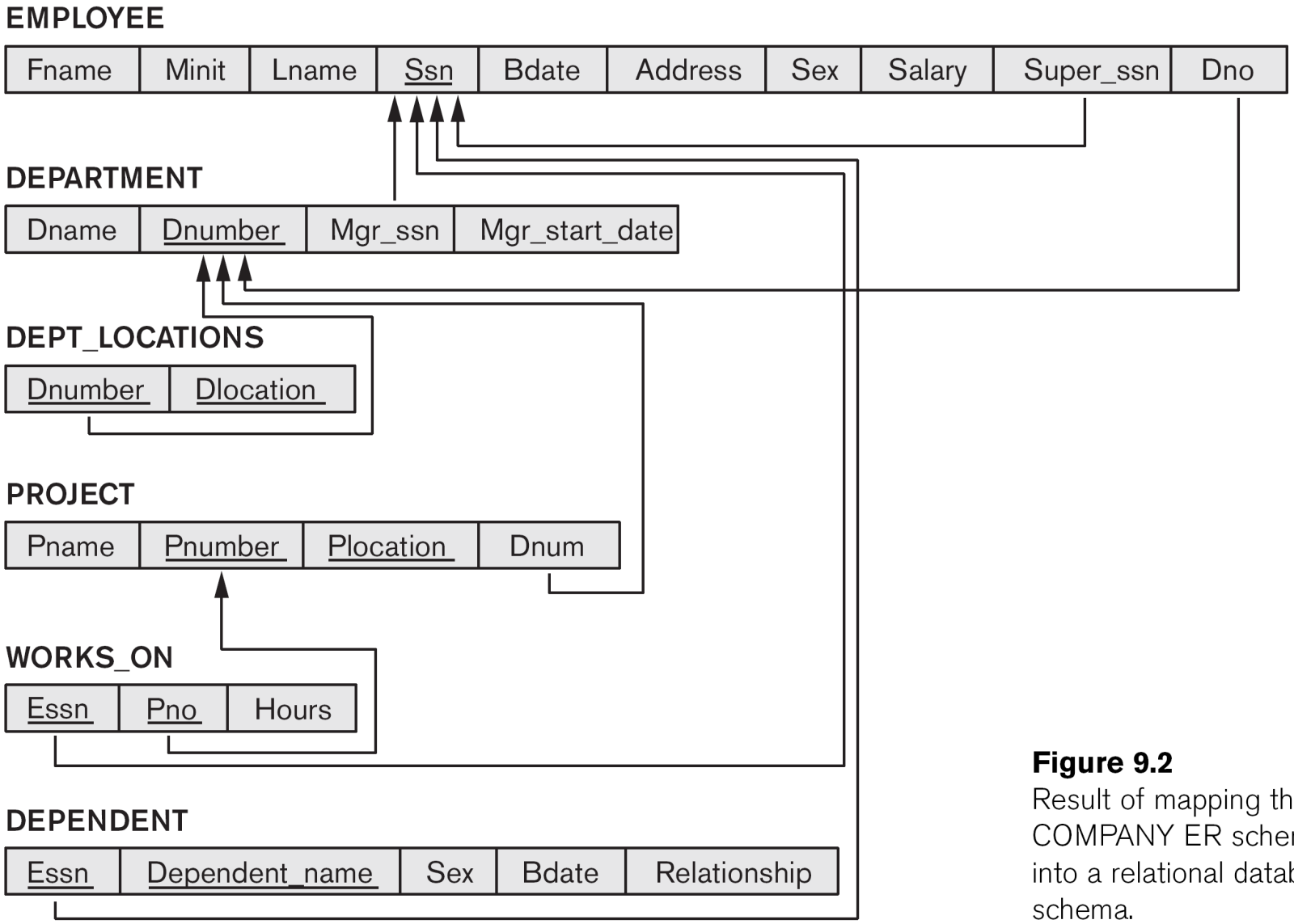


Figure 9.2
Result of mapping the COMPANY ER schema into a relational database schema.

ER-to-Relational Mapping Algorithm (cont.)

- **Step 4: Mapping of Binary 1:N Relationship Types**
  - For each regular binary 1:N relationship type R, identify the relation S that represent the participating entity type *at the N-side* of the relationship type.
  - Include as foreign key in S the primary key of the relation T that represents the other entity type participating in R.
  - Include any simple attributes of the 1:N relation type as attributes of S.
- Examples (Figures 9.1, 9.2): 1:N relationship types are WORKS_FOR, CONTROLS, and SUPERVISION.
  - For WORKS_FOR we include the primary key DNUMBER of the DEPARTMENT relation as foreign key in the EMPLOYEE relation and call it DNO
  - (cont. on next slide)

ER-to-Relational Mapping Algorithm (cont.)

- Examples (cont.):
  - For CONTROLS, we include the primary key DNUMBER of DE PARTMENT as foreign key in PROJECT and call it DNUM.
  - For SUPERVISION, we include the primary key SSN of EMPLO YEE as foreign key in EMPLOYEE itself and call it SuperSSN (t his is a recursive relationship)
- All three 1:N relationship examples (Figures 9.1, WORKS_FO R, CONTROLS, and SUPERVISION) are mapped using the **fo reign key** option in Figure 9.2
  - Can also use the **cross-reference** option (create a separate relatio n that has the primary keys of both relations as foreign keys).

ER-to-Relational Mapping Algorithm (cont.)

- **Step 5: Mapping of Binary M:N Relationship Types**
  - For each regular binary M:N relationship type R, *create a new relation* S to represent R.
  - Include as foreign key attributes in S the primary keys of the relations that represent the participating entity types; *their combination will form the pri mary key* of S.
  - Also include any simple attributes of the M:N relationship type (or simple components of composite attributes) as attributes of S.
- Example: The M:N relationship type WORKS_ON (Figure 9.1) is mapped by creating a relation WORKS_ON in the relational data base schema (Figure 9.3(c), Figure 9.2).
  - The primary keys of PROJECT and EMPLOYEE are foreign keys in WO RKS_ON and renamed PNO and ESSN, respectively.
  - Attribute HOURS in WORKS_ON represents the HOURS attribute of the relation type.
  - The primary key of WORKS_ON is the combination {ESSN, PNO}.

ER-to-Relational Mapping Algorithm (cont.)

- **Discussion of Mapping of Binary Relationship Types (steps 3, 4, an d 5):**
  - Foreign key option is preferred for 1:1 and 1:N relationships, but cannot be used for M:N relationships.
  - Relationship relation option can be used for any cardinality ratio, but the *pr imary key* will be different:
    - Combination of both foreign keys for M:N
    - Either foreign key for 1:1
    - Foreign key in the N-side relation for 1:N
  - Attributes of relationship type are included in the relationship relation (for cross-referencing option), or in the relation that includes the foreign key (f or foreign key option).

ER-to-Relational Mapping Algorithm (cont.)

- **Step 6: Mapping of Multivalued attributes.**
  - For each multivalued attribute A, create a new relation R.
  - This relation R will include an attribute corresponding to A, plus the prima ry key attribute K (as a foreign key in R) of the relation that represents the entity type that has A as an attribute.
  - The primary key of R is the combination of A and K. If the multivalued att ribute is composite, we include its simple components.
- Example (Figure 9.3(d)): The relation DEPT_LOCATIONS is cr eated.
  - The attribute DLOCATION represents the multivalued attribute Locations of DEPARTMENT (Figure 9.1), while DNUMBER is foreign key to the D EPARTMENT relation (Figure 9.2).
  - The primary key of DEPT_LOCATIONS is the combination of {DNUMB ER, DLOCATION}.

ER-to-Relational Mapping Algorithm (cont.)

- **Step 7: Mapping of N-ary Relationship Types.**
  - For each n-ary relationship type R, where n>2, create a new *relati onship relation* S to represent R.
  - Include as foreign key attributes in S the primary keys of the relati ons that represent the participating entity types.
  - Also include any simple attributes of the n-ary relationship type (or simple components of composite attributes) as attributes of S.
- Example: The relationship type SUPPLY (Figure 7.17(a), next slide)
  - This can be mapped to the relation SUPPLY (Figure 9.4, following slide), whose primary key is the combination of the three foreign keys {SNA ME, PARTNO, PROJNAME}

Figure 9.4
Mapping the *n*-ary relationship type SUPPLY from Figure 7.17(a).

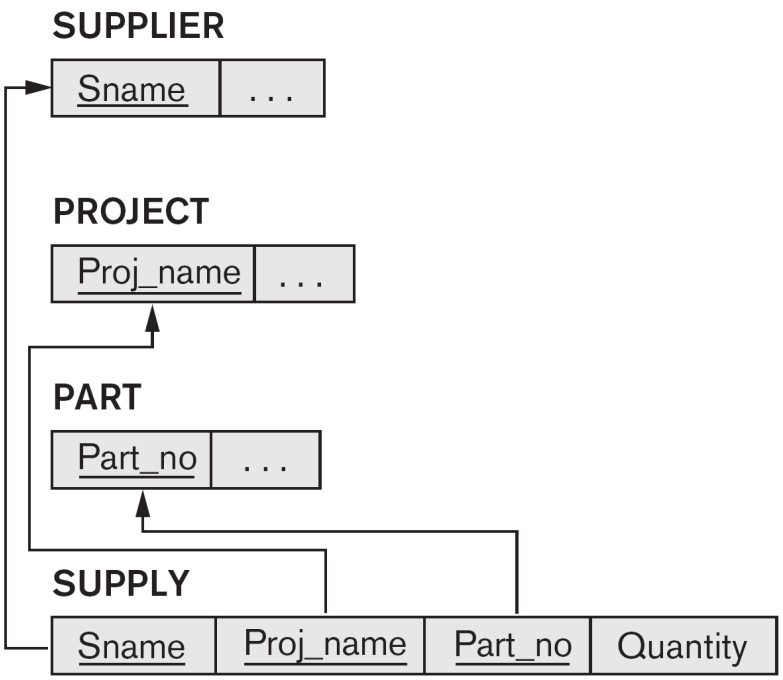


Table 9.1 Correspondence between ER and Relational Models

ER MODEL	RELATIONAL MODEL
Entity type	*Entity* relation
1:1 or 1:N relationship type	Foreign key (or *relationship* relation)
M:N relationship type	*Relationship* relation and *two* foreign keys
n-ary relationship type	*Relationship* relation and *n* foreign keys
Simple attribute	Attribute
Composite attribute	Set of simple component attributes
Multivalued attribute	Relation and foreign key
Value set	Domain
Key attribute	Primary (or secondary) key

Chapter Summary

- **ER-to-Relational Mapping Algorithm**
  - Step 1: Mapping of Regular Entity Types
  - Step 2: Mapping of Weak Entity Types
  - Step 3: Mapping of Binary 1:1 Relation Types
  - Step 4: Mapping of Binary 1:N Relationship Types.
  - Step 5: Mapping of Binary M:N Relationship Types.
  - Step 6: Mapping of Multivalued attributes.
  - Step 7: Mapping of N-ary Relationship Types.

Possible In-Class Exercises

- **Apply the ER-to-Relational Mapping Algorithm to the SHIP_TRACKING ER Schema in Figure 9.8 (next slide)**

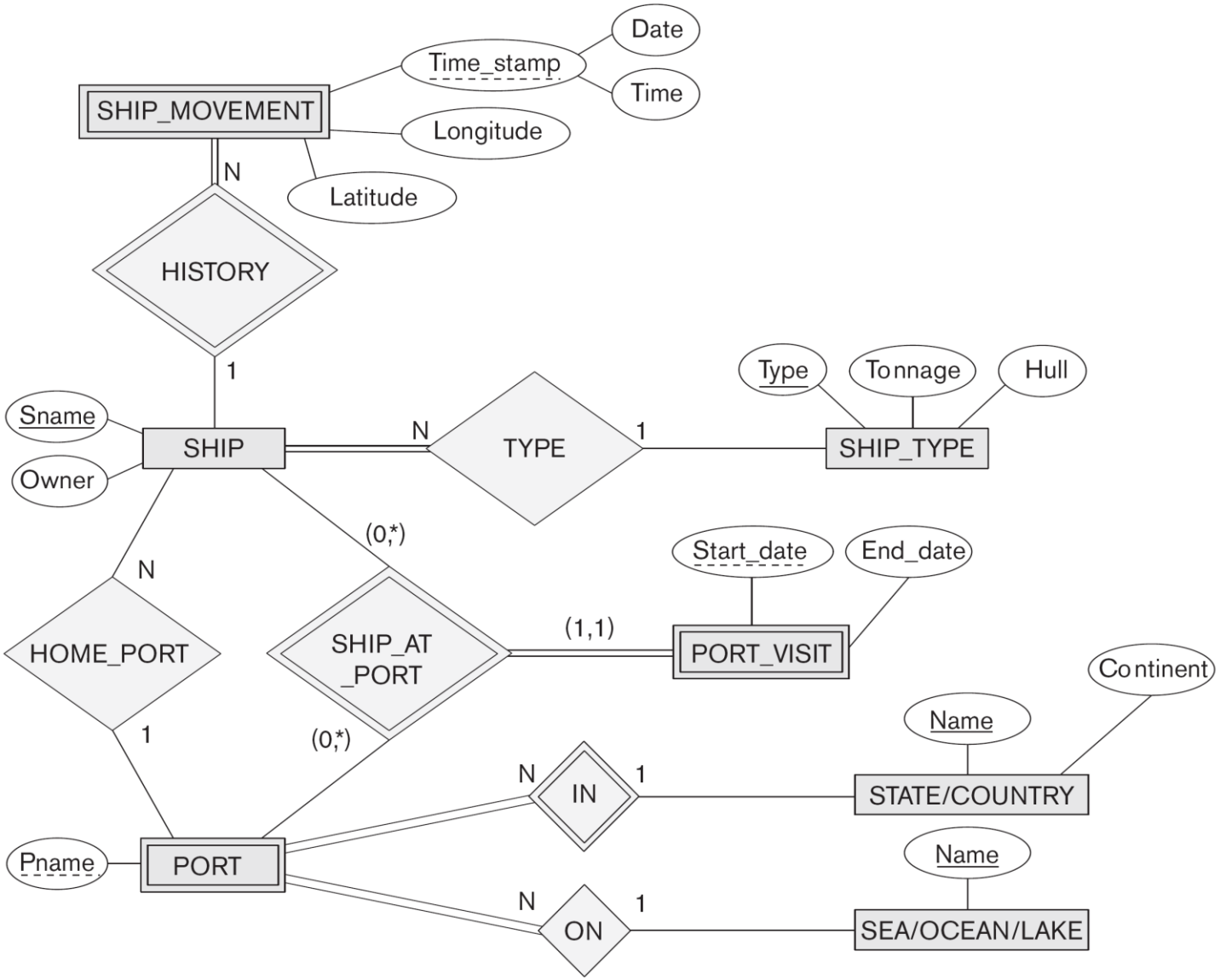


Figure 9.8
An ER schema for a SHIP_TRACKING database.

Thanks to all