The Relational Data Model

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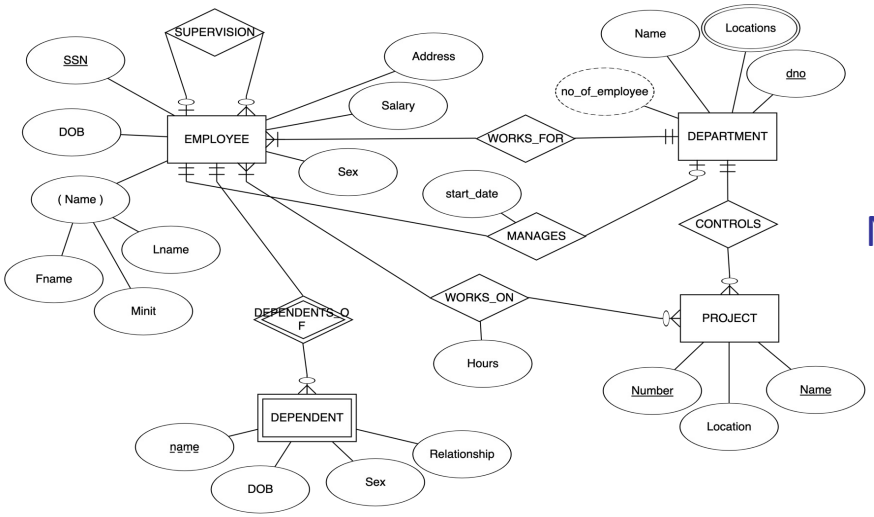
Converting ER to DBMS Tables



ER/EER
(Conceptual data models)

Not equivalent

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

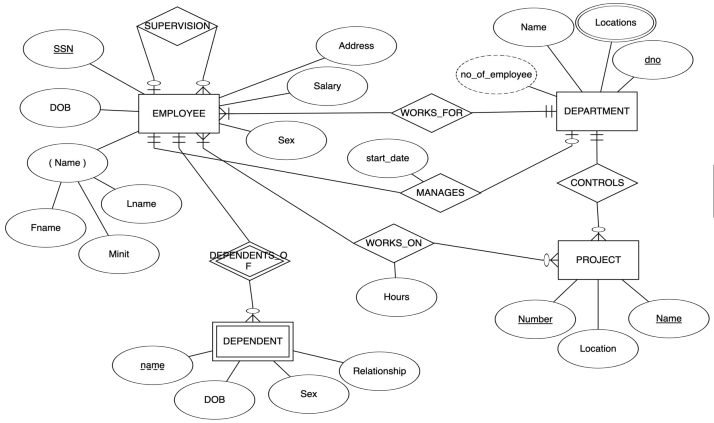
Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

DBMS Tables

ER => Relational Model => DBMS Tables



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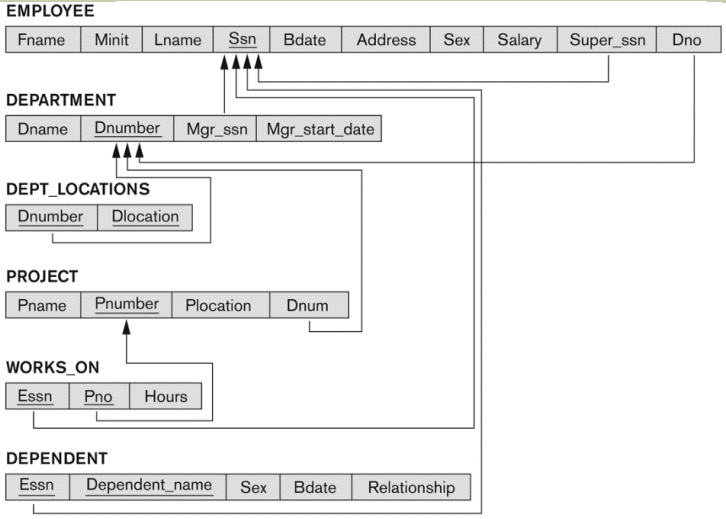
(Conceptual data models)



Relational Model
Close to DB Tables

Figure 5.6
One possible database state for the COMPANY relational database schema.

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987654321	20	15.0
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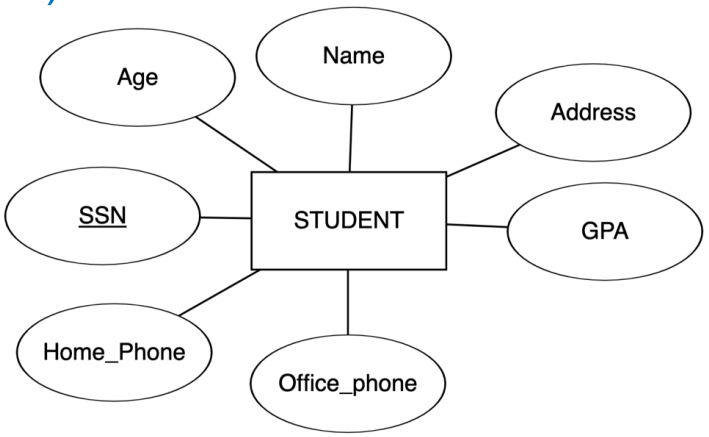
DBMS Tables

A Relation

- Relation ≠ Relationship (of Entity-Relationship Model)
- Relation = Entity / DBMS Table
- Attributes Name = DBMS Columns
- Tuples = DBMS rows



Relation Name → **STUDENT**

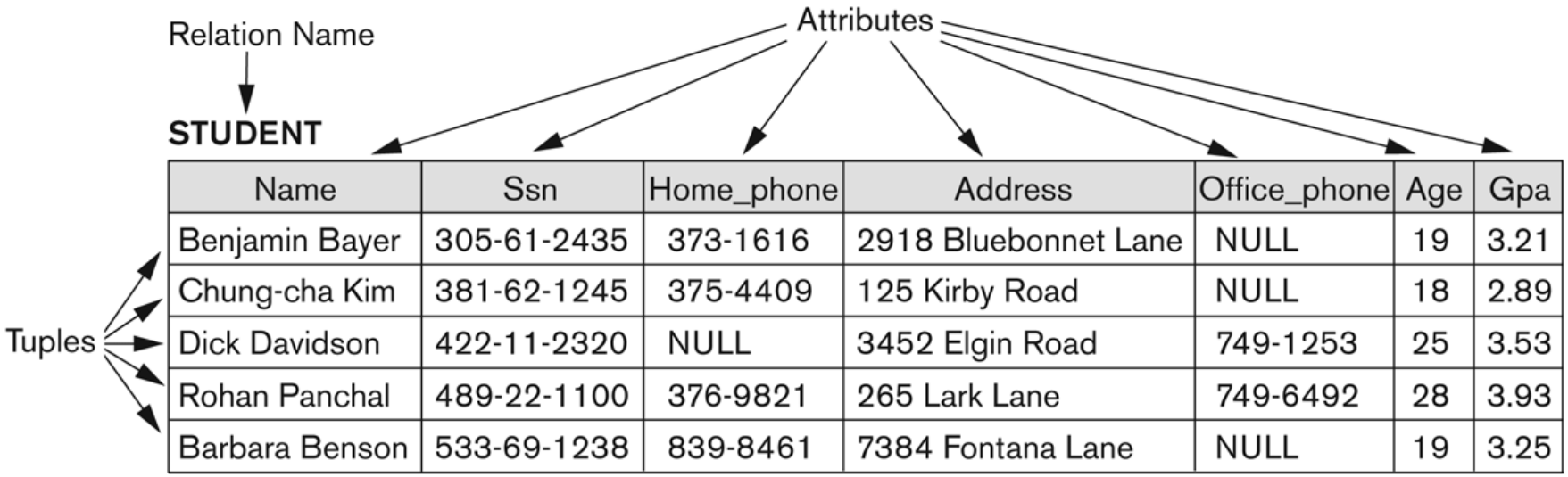
Attributes

Tuples

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	NULL	19	3.21
Chung-cha Kim	381-62-1245	375-4409	125 Kirby Road	NULL	18	2.89
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	749-1253	25	3.53
Rohan Panchal	489-22-1100	376-9821	265 Lark Lane	749-6492	28	3.93
Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25

A Relation

- A **relation** looks like a **table** filled with values
- Each **column** has a ***column header*** similar to **attribute** name
- The data elements in each **row** is the value of **attributes**
- Relational Model is proposed by Dr. E.F. Codd 1970.
  - He got Turing Award later



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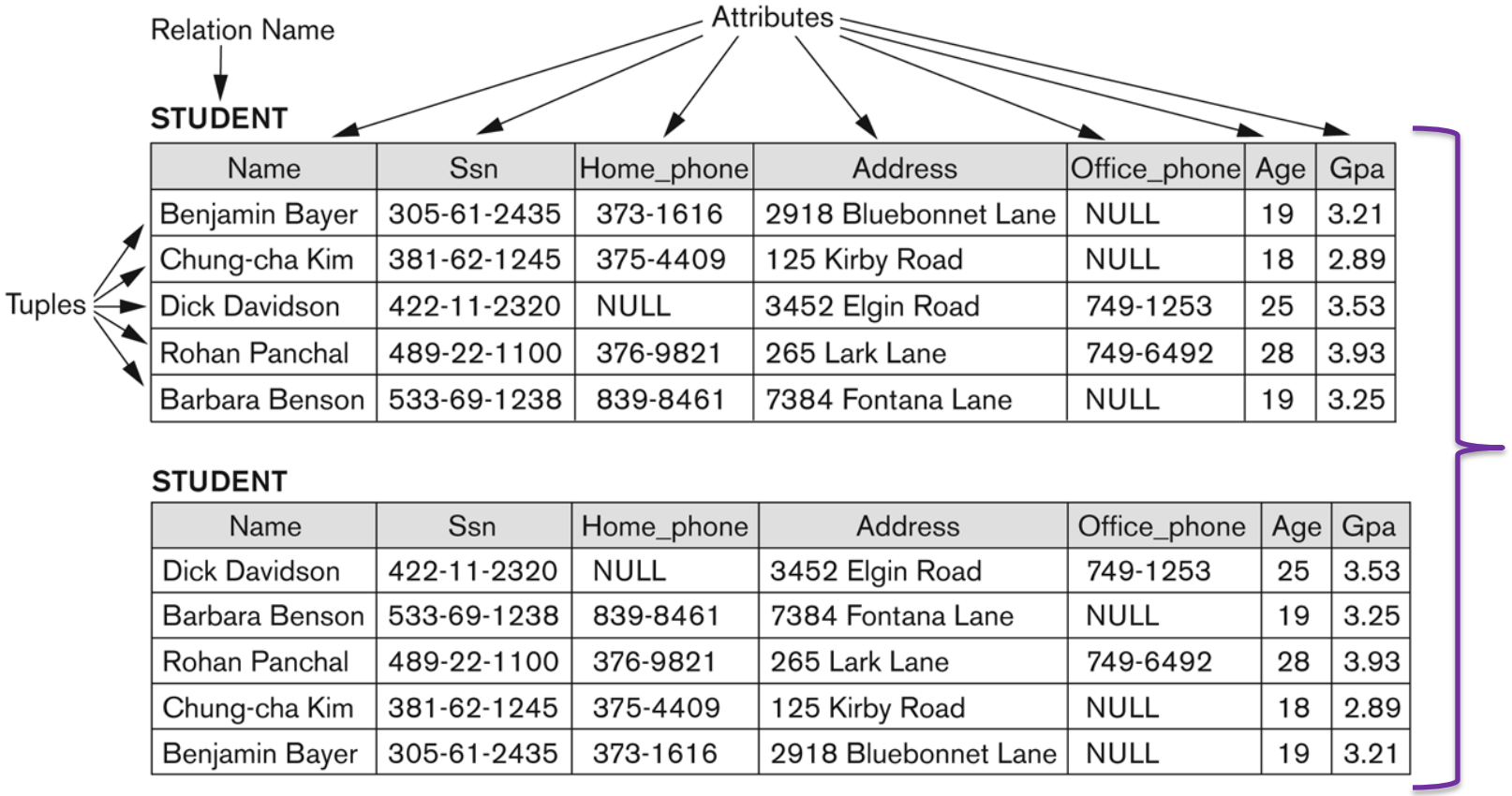
Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25

A Relation

- A relation looks like **set of rows (tuples)**
  - ***Unordered rows*** (Note: Set is a unordered list)



STUDENT

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STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
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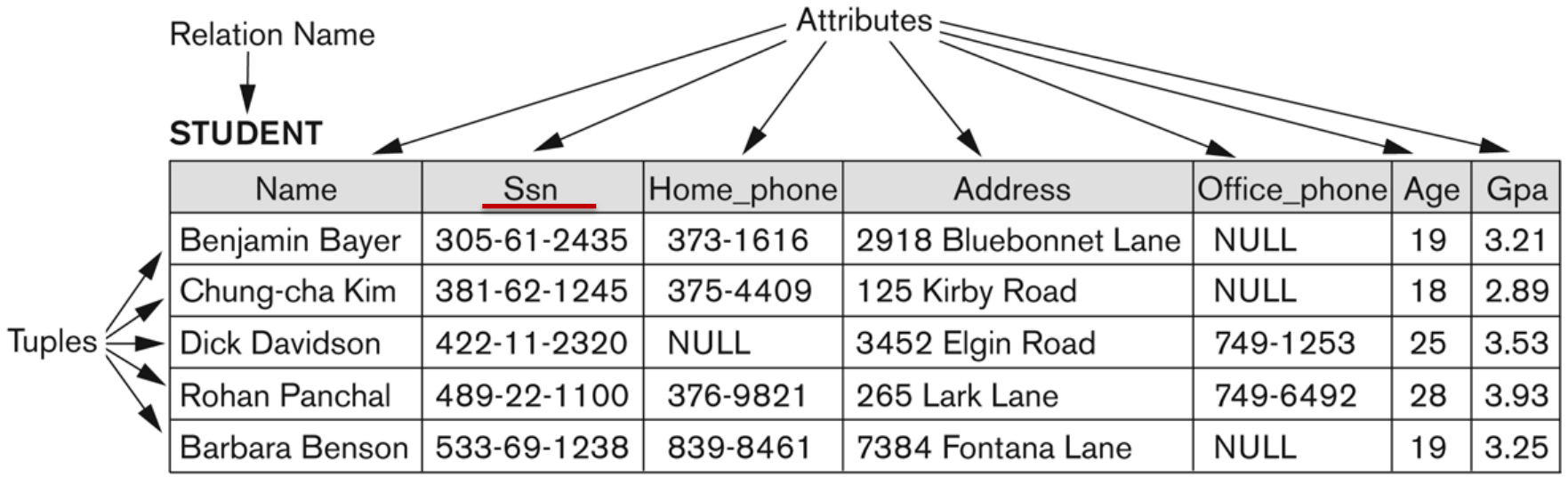
Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25
Rohan Panchal	489-22-1100	376-9821	265 Lark Lane	749-6492	28	3.93
Chung-cha Kim	381-62-1245	375-4409	125 Kirby Road	NULL	18	2.89
Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	NULL	19	3.21

A Relation

- **Key** of a Relation: an **attribute** which ***uniquely*** identifies that particular row in the table. E.g., *SSN*
- Sometimes we create keys ***artificially*** (e.g., if no key exists)
- **Primary key**, ***Pk***: A chosen key, example: *SSN*
  - If there are multiple keys, choose one



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
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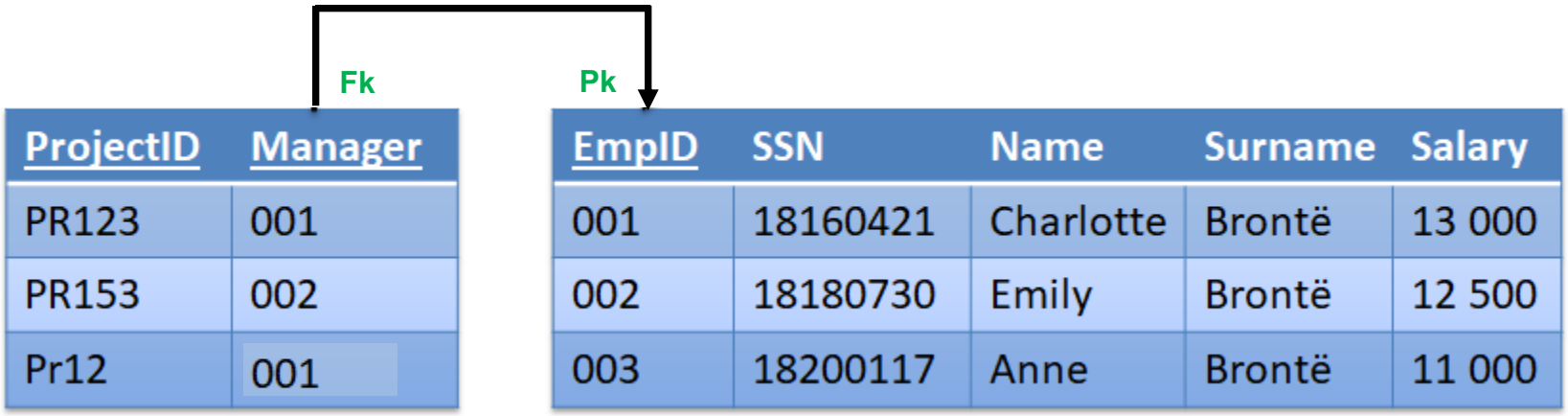
Characteristics of Relations

- Values in a tuple:
  - Are atomic (indivisible/single-value).
  - No *multivalued data*
  - Each value in a tuple must be from the ***domain*** of the attribute
  - Value can be **null**
    - to represent: unknown/not available/inapplicable

A Relation

- **Foreign Key, *Fk*:** A relation uses another relation's **primary key** as an **attribute**.



ProjectID	Manager
PR123	001
PR153	002
Pr12	001

EmpID	SSN	Name	Surname	Salary
001	18160421	Charlotte	Brontë	13 000
002	18180730	Emily	Brontë	12 500
003	18200117	Anne	Brontë	11 000

Formal Definitions

- **The Schema:** description of a Relation
  - `R(A1, A2, .....An)`
  - `R` name of a relation,
  - `A1, A2, .....An` are the attributes of the relation
- Example: STUDENT(Name, SSN, Home_phone…, Gpa)
  - Relation name *STUDENT*, attributes: *Name, SSN…. Gpa*
- **Domain**: each attribute has a set-of-values/data-type
  - Example: integer, date, varchar(256), etc.

STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	NULL	19	3.21
Chung-cha Kim	381-62-1245	375-4409	125 Kirby Road	NULL	18	2.89
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Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25

Formal Definitions

- A **tuple** is an **ordered** set of values of attributes
  - written inside <…>
- Example:
  - <“Benjamin Bayer”, “305-61-2435”, “373-1616”, 2918 Bluebonnet Lane”, ….>
- Order of attribute values matter

STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	NULL	19	3.21
Chung-cha Kim	381-62-1245	375-4409	125 Kirby Road	NULL	18	2.89
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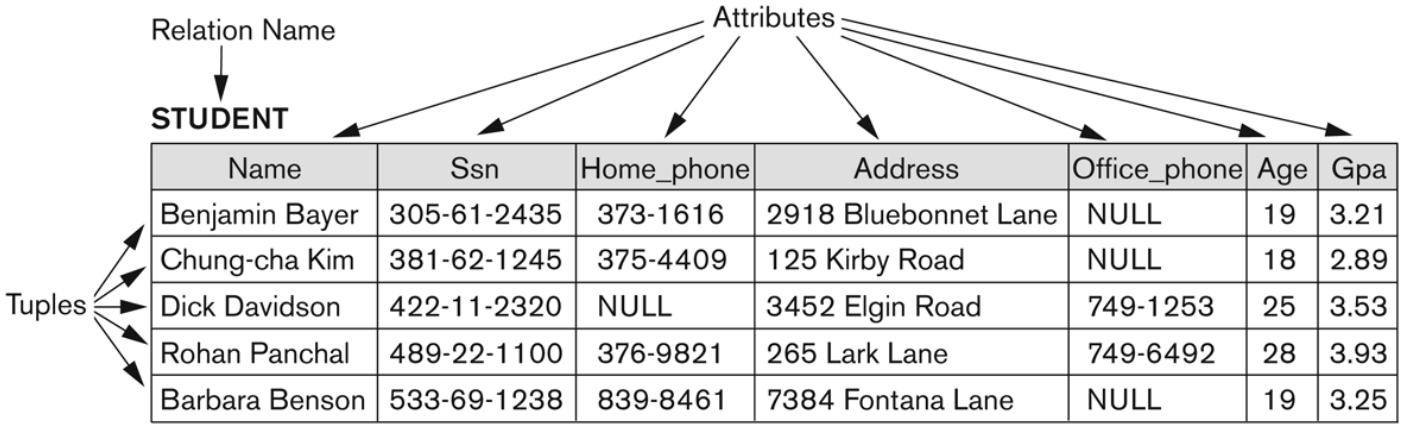
Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25

Formal Definitions - Summary

- Formally,
  - Given R(A1, A2, ..., An)
- R(A1, A2, …, An) is the **schema** of the relation
- R is the **name** of the relation
- A1, A2, …, An are the **attributes** of the relation
- Let dom(A1) = {0,1}
- r(R):
  - Table / *set of tuples/*rows
    - r(R) = {t1, t2, …, tn} where each ti is an n-tuple
    - Here, ti = <v1, v2, …, vn> where each vj *element-of* dom(Aj)
  - A specific **state/value/population** of relation R

Terminology Summery

Informal Terms		Formal Terms
Table		Relation
Column Header		Attribute Name
All possible Column Values / Data Type		Domain
Row		Tuple
Table Definition		Schema of a Relation
Populated Table		State of the Relation



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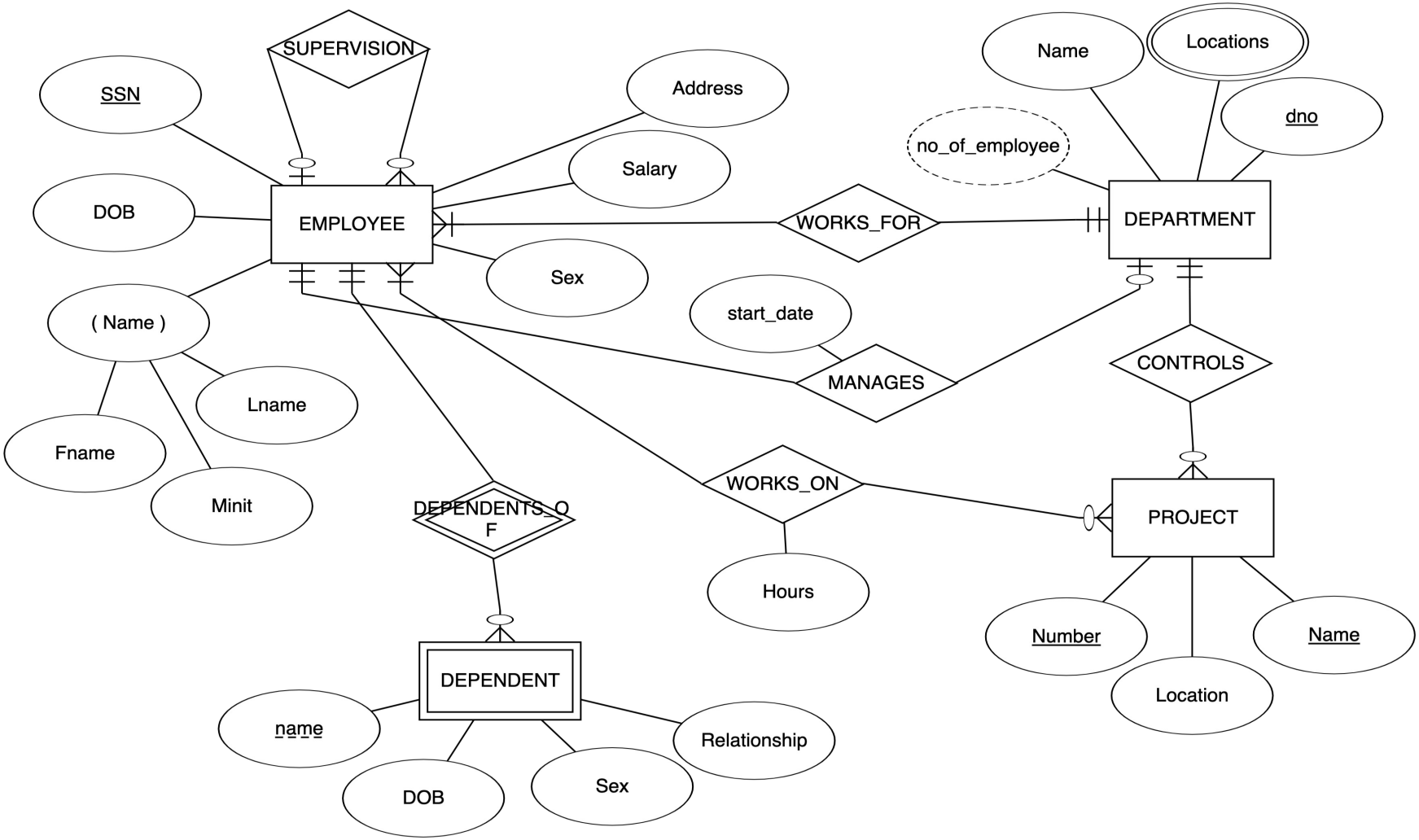
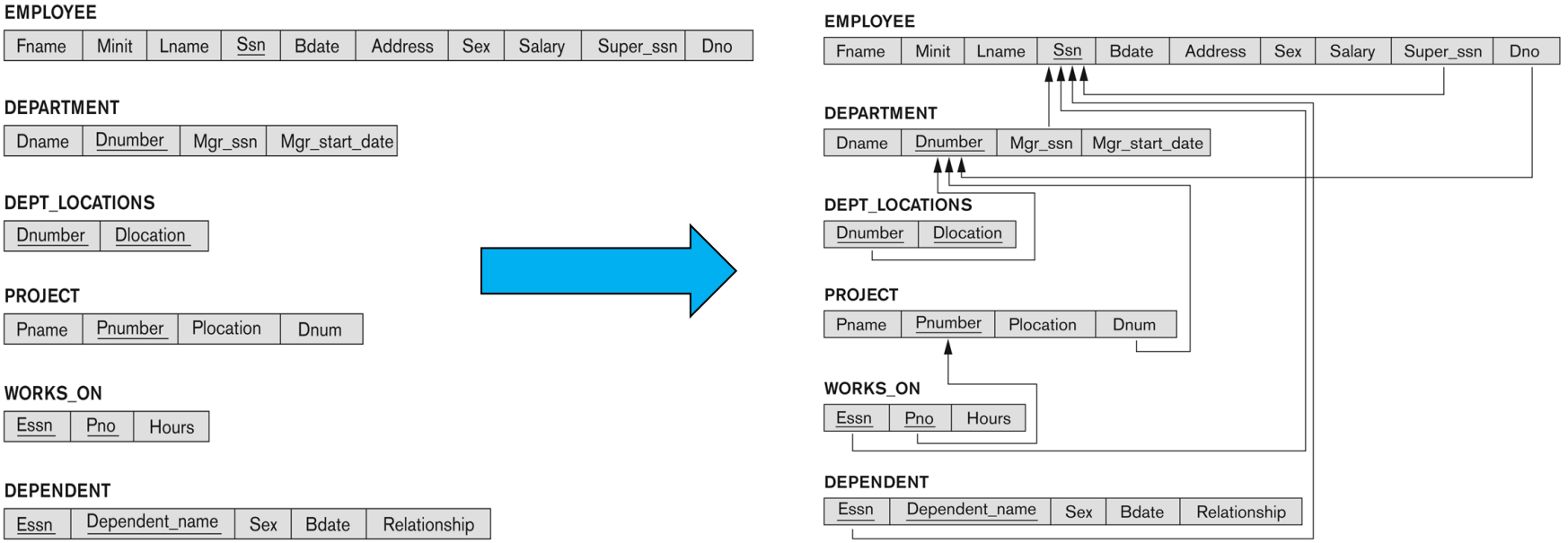
Part 2

COMPANY Database ER Model



COMPANY Database Relational Model



Populated database

- Basic operations for changing the database:
  - INSERT: a new tuple
  - DELETE: an existing tuple
  - MODIFY: an existing tuple
- New database ***state*** arises after every operation

DB must be in a *valid-state* after every operation.

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123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

Relational Integrity Constraints

- Constraints are **conditions** that must hold on **all valid states** (after every INSERT, UPDATE, DELETE)
- 3 type of constraints (***3Cs***):
  - **Key** constraints
  - **Entity integrity** constraints
  - **Referential integrity (Foreign Key)** constraints

1. Key constraints

- If a relation has several *candidate keys*, one is chosen arbitrarily as a ***primary key.*** **[Optional]**
- The primary-key value is used to ***uniquely identify*** each tuple in a relation.
- PK is used to reference the tuple from another tuple (FK)
  - General rule: Choose as primary key the smallest of the candidate keys (in terms of size)

CAR

License_number	Engine_serial_number	Make	Model	Year
Texas ABC-739	A69352	Ford	Mustang	02
Florida TVP-347	B43696	Oldsmobile	Cutlass	05
New York MPO-22	X83554	Oldsmobile	Delta	01
California 432-TFY	C43742	Mercedes	190-D	99
California RSK-629	Y82935	Toyota	Camry	04
Texas RSK-629	U028365	Jaguar	XJS	04

2. Entity Integrity Constraints

- The ***primary key*** attributes cannot be ***null***
  - Primary key values are used to *identify* the individual tuples
  - If PK has several attributes (i.e., composite PK), *null* is not allowed in any of these attributes
- Note: Although attributes of a relation (except PK) can have null values, we can still restrict it of not having null

3. Referential Integrity constraints

- Referential Integrity/Foreign Key (FK) Constraints: the value in the FK column(s) can be **either**:

  (1) a value of an existing PK value from another relation

  (2) a **null**

ProjectID	Manager
PR123	001
PR153	002
Pr12	001

EmpID	SSN	Name	Surname	Salary
001	18160421	Charlotte	Brontë	13 000
002	18180730	Emily	Brontë	12 500
003	18200117	Anne	Brontë	11 000

Other types of Constraints

- Constraints can be defined using SQL-99 (or later)
  - *E.g., max.-no.-of-hours per* employee can be set
  - **CREATE TRIGGER** *or* **CREATE ASSERTION** using SQL
- CREATE TABLE statement in SQL allows:
  - Defining Keys/Candidate-Keys, restrict Null values, FKs, etc

```
CREATE TABLE Employee (
        EmpID           int PRIMARY KEY,
        SSN             int UNIQUE,
        Name            varchar NOT NULL,
        Surname         varchar NOT NULL,
        Salary          int,
        Supervisor      int references Employee(EmpID),
        unique (Name, Surname)
);
```

Operations on Relations

DB must be in a hold *3Cs* after every *INSERT*, *DELETE*, *MODIFY*

- The 3Cs are:
  - **Key** constraints
  - **Entity integrity** constraints
  - **Referential integrity** constraints

EMPLOYEE

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Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

INSERT on Relations

- INSERT can violate:
  - Domain constraint: outside domain
  - Key constraint: value already exists
  - Referential integrity: FK not present
  - Entity integrity: PK value is null

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
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5	Bellaire
5	Sugarland
5	Houston

DELETE on Relations

- DELETE may violate referential integrity on FK: when the PK value is deleted from the original table. There are ***3 Solutions:***
  - RESTRICT: reject the deletion
  - CASCADE : propagate into the foreign keys
  - SET NULL: set the foreign keys value to NULL

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	19					
Jennifer	S	Wallace	987654321	19					
Ramesh	K	Narayan	666884444	19					
Joyce	A	English	453453453	19					
Ahmad	V	Jabbar	987987987	19					
James	E	Borg	888665555	19					

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

UPDATE on Relations

- UPDATE may violate the following Constraints:
  - Primary key (PK): Similar to (DELETE + INSERT)
  - Foreign key (FK): Similar to DELETE
  - An ordinary attribute (neither PK nor FK):
    - Can violate domain or Null value constraints

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	19					
Jennifer	S	Wallace	987654321	19					
Ramesh	K	Narayan	666884444	19					
Joyce	A	English	453453453	19					
Ahmad	V	Jabbar	987987987	19					
James	E	Borg	888665555	19					

DEPARTMENT

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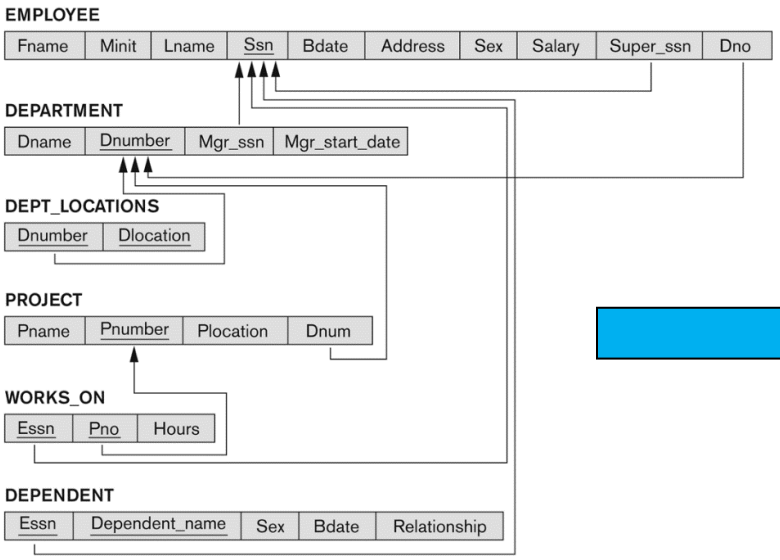
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

How the Data is Stored?



Relational Model
Close to DB Tables

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
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999887777	10	10.0
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333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

DBMS Tables

Exercise:

-- Exercise: 5.16 (From BOOK 7th Edition, page: 5:16)

Consider the following relations for a database that keeps track of student enrollment in courses and the books adopted for each course:

STUDENT(SSN, Name, Major, Bdate)

COURSE(Course#, Cname, Dept)

ENROLL(SSN, Course#, Quarter, Grade)

BOOK_ADOPTION(Course#, Quarter, Book_ISBN)

TEXT(Book_ISBN, Book_Title, Publisher, Author)

Draw a relational schema diagram specifying the foreign keys for this schema.

Exercise: *Ex-3-Relational-Model.pdf*

Full slide from book authors:

Chapter05.pdf