

# MODULE 2: Relational Model

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## SYLLABUS

- Structure of Relational Databases - Integrity Constraints, Synthesizing ER diagram to relational schema
- Introduction to Relational Algebra - select, project, cartesian product operations, join - Equi-join, natural join. query examples,
- Introduction to Structured Query Language (SQL), Data Definition Language (DDL), Table definitions and operations – CREATE, DROP, ALTER, INSERT, DELETE, UPDATE.

## Relational data model

- Represent database as a collection of relations
- Relation is a table which has values and rows in table is a collection of related data values
- Each row in table is a fact
- Row in relational table is called a tuple, column header is attribute and table is a relation

The diagram illustrates the components of a relational table. The word "EMPLOYEE" is labeled as the "Relation name". The word "Attributes" has arrows pointing to the column headers: "EMP NO", "Name", "Address", "Mobile number", "Age", and "Salary". The word "Tuples" has arrows pointing to the rows of data: the row with "101", the row with "102", and the row with "103".

<u>EMP NO</u>	Name	Address	Mobile number	Age	Salary
101	RAM	XYZ	9898989898	20	10000
102	SAM	CVF	9999999999	21	20000
103	SITA	FDFD	8888888888	22	30000

- In the relational model, all data is logically structured within **relations** (also called **table**)
- Informally a **relation may be viewed as a named two-dimensional table representing an entity set.**
- A relation has a fixed number of named columns and variable number of rows.

## Components of relational database

- The main components of relational database structure are as follows:
  1. **Domains**
  2. **Tuples (rows)**
  3. **Columns (attributes)**
  4. **Keys**
  5. **Relations (Tables)**

# Domain

- It has three parts
  - Name
  - Data type
  - Format
- A Domain is allowed set of atomic values.
- Atomic means each value in the domain is indivisible to the relational model.

- A **domain** has a logical definition:  
e.g. “USA\_phone\_numbers” are the set of 10 digit phone numbers valid in the U.S.
- A domain may have **a data-type or a format defined for it.**
  - The USA\_phone\_numbers may have a format: (ddd)-ddd-dddd where each d is a decimal digit. E.g.,
  - Dates have various formats such as month name, date, year or yyyy-mm-dd, or dd mm,yyyy etc

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Figure 2.2 shows the structure of an instance or extension, of a relation called EMPLOYEE. The EMPLOYEE relation has six attributes (field items), namely EMP-NO, LAST-NAME, FIRST-NAME, DATA-OF-BIRTH, SEX, TEL-NO and SALARY. The extension has seven tuples (records). Each attribute contains values drawn from a particular domain.

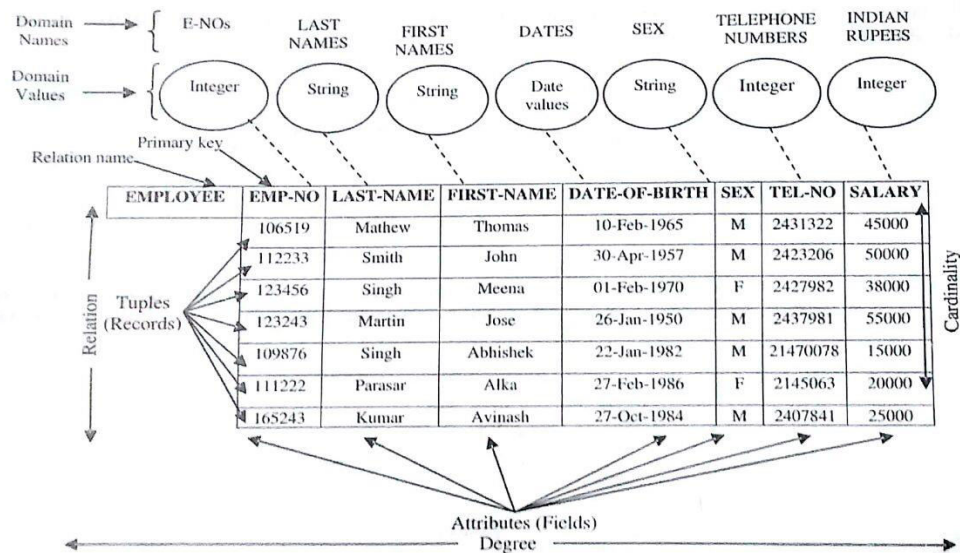


Figure 2.2: EMPLOYEE Relation

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## Tuples (rows)

- A tuple is an ordered set of values
- Tuple is a portion of a table containing data that described only entity, relationship, or object
- Also known as record
- Each value is derived from an appropriate domain.

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Diagram illustrating a table structure for a relation named **Customer**.

Attribute Names	CFirstName	CLastName	CStreet	CZipCode	CPhone
Row (tuple)	Kumar	Singh	52/57 store	223001	9889898989

Labels and arrows in the diagram:

- Scheme Name** points to the table name **Customer**.
- Attribute Names** points to the header row.
- Row (tuple)** points to the data row.
- Data Cell (Domain value assigned to attribute Name)** points to a cell in the data row.

- **<Kumar, Singh, 52/57 store, 223001, 9889898989>** is a tuple belonging to the CUSTOMER relation.

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## Columns

- Columns in a table are also called **attributes** or **fields** of the relation.
- A single cell in a table called **field value, attribute value or data element**.
- For example, for the entity person, attributes could include eye colour and height.

Diagram illustrating a table structure for a relation named **Person**.

Column (attribute) or Field	Person	Eye Color	Height	Phone No.
Field Value	Kumar	Gray	6	9889898989

Labels and arrows in the diagram:

- Attribute Name** points to the header row.
- Person** (Scheme Name) points to the table name.
- Column (attribute) or Field** points to the header row.
- Field Value** points to a cell in the data row.

## Key of a Relation

- Each row has a value of a data item (or set of items) that uniquely identifies that row in the table
  - Called the *key*
- Sometimes row-ids or sequential numbers are assigned as keys to identify the rows in a table
  - Called *artificial key or surrogate key*

## Relations (Tables)

- A table of values
- A relation may be thought of as a **set of rows**.
- A relation may alternately be thought of as a **set of columns**.
- That is a table is perceived as a two-dimensional structure composed of rows and columns.
- Each row represents a fact that corresponds to a real-world **entity or relationship**.
- Each row has a value of an item or set of items that uniquely identifies that row in the table

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- Sometimes row-ids or sequential numbers are assigned to identify the rows in the table.
- Each column typically is called by its column name or column header or attribute name.



## Schema of a Relation

- It is basically an outline of how data is organized
- It is denoted by  $R (A_1, A_2, \dots, A_n)$ 
  - Here  $R$  is relation name and
  - it has some attributes  $A_1$  to  $A_n$
- Each attribute have some domain and it is represented by  $\text{dom}(A_i)$
- Relation schema is used to describe a relation and  $R$  is name of the relation
- Each attribute has a **domain** or a set of valid values.
  - For example, the domain of Cust-id is 6 digit numbers.

## Degree of a relation

- Degree of a relation is **number of attributes** in a relation
- Eg
  - $\text{STUDENT}(\text{Id}, \text{Name}, \text{Age}, \text{Departmentno})$ 
    - Has degree 4
- Using datatype of each the definition can be written as
  - $\text{STUDENT}(\text{Id}:\text{Integer}, \text{Name}:\text{String}, \text{Age}:\text{integer}, \text{Departmentno}:\text{integer})$

## Relation State

- The **relation state** is a subset of the Cartesian product of the domains of its attributes
  - each domain contains the set of all possible values the attribute can take.
- Example: attribute Cust-name is defined over the domain of character strings of maximum length 25
  - $\text{dom}(\text{Cust-name})$  is `varchar(25)`
- The role these strings play in the CUSTOMER relation is that of the *name of a customer*.

Relation Name	Attributes						
STUDENT	Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Tuples	Benjamin Bayer	305-61-2435	(817)373-1616	2918 Bluebonnet Lane	NULL	19	3.21
	Chung-cha Kim	381-62-1245	(817)375-4409	125 Kirby Road	NULL	18	2.89
	Dick Davidson	422-11-2320	NULL	3452 Elgin Road	(817)749-1253	25	3.53
	Rohan Panchal	489-22-1100	(817)376-9821	265 Lark Lane	(817)749-6492	28	3.93
	Barbara Benson	533-69-1238	(817)839-8461	7384 Fontana Lane	NULL	19	3.25

**Figure 3.1**

The attributes and tuples of a relation STUDENT.

- A relation state  $r(R)$  is a mathematical relation of degree  $n$  on the domains  $\text{dom}(A_1), \text{dom}(A_2), \dots, \text{dom}(A_n)$  which is a subset of Cartesian product(X) of domains that define  $R$

$$r(R) \subseteq (\text{dom}(A_1) \times \text{dom}(A_2) \times \dots \times \text{dom}(A_n))$$

- Cartesian product specifies **all possible combination** of values from underlying domains

## Cardinality in domain D

- Cardinality in domain  $D$  by  $|D|$  then the total number of tuples in cartesian product is

$$|\text{dom}(A_1)| \times |\text{dom}(A_2)| \times \dots \times |\text{dom}(A_n)|$$

## Current relation state

- Reflects only the that represent a particular state of real world
- As the state of real world changes, so does the relation state, by being transformed into another relation state

## Alternative Definition of a Relation

- ordering of values in a tuple is *unnecessary*
- a relation schema  $R = \{A_1, A_2, \dots, A_n\}$  is a set of attributes, and
- a relation state  $r(R)$  is a finite set of mappings  $r = \{t_1, t_2, \dots, t_m\}$ , where each tuple  $t_i$  is a **mapping from  $R$  to  $D$** , and
- **$D$  is the union** (denoted by  $\cup$ ) of the attribute domains; that is,  $D = \text{dom}(A_1) \cup \text{dom}(A_2) \cup \dots \cup \text{dom}(A_n)$ .
- Here  $t[A_i]$  must be in  $\text{dom}(A_i)$  for  $1 \leq i \leq n$  for each mapping  $t$  in  $r$ .
- Each mapping  $t_i$  is called a tuple.

- a **tuple** can be considered as a set of (**<attribute>**, **<value>**) **pairs**, where each pair gives the value of the mapping from an attribute  **$A_i$  to a value  $v_i$  from  $dom(A_i)$** .
- *The ordering of attributes is not important, because the attribute name appears with its value.*

## Formal Definitions - Summary

- Formally,
  - Given  $R(A_1, A_2, \dots, A_n)$
  - $r(R) \subset \text{dom}(A_1) \times \text{dom}(A_2) \times \dots \times \text{dom}(A_n)$
- $R(A_1, A_2, \dots, A_n)$  is the **schema** of the relation
- $R$  is the **name** of the relation
- $A_1, A_2, \dots, A_n$  are the **attributes** of the relation
- $r(R)$ : a specific **state** (or "value" or "population") of relation  $R$  – this is a *set of tuples* (rows)
  - $r(R) = \{t_1, t_2, \dots, t_n\}$  where each  $t_i$  is an  $n$ -tuple
  - $t_i = \langle v_1, v_2, \dots, v_n \rangle$  where each  $v_j$  *element-of*  $\text{dom}(A_j)$

## Formal Definitions - Example

- Let  $R(A_1, A_2)$  be a relation schema:
  - Let  $\text{dom}(A_1) = \{0,1\}$
  - Let  $\text{dom}(A_2) = \{a,b,c\}$
- Then:  $\text{dom}(A_1) \times \text{dom}(A_2)$  is all possible combinations:
  - $\{ \langle 0,a \rangle, \langle 0,b \rangle, \langle 0,c \rangle, \langle 1,a \rangle, \langle 1,b \rangle, \langle 1,c \rangle \}$
- The relation state  $r(R) \subset \text{dom}(A_1) \times \text{dom}(A_2)$
- For example:  $r(R)$  could be  $\{ \langle 0,a \rangle, \langle 0,b \rangle, \langle 1,c \rangle \}$ 
  - this is one possible state (or “population” or “extension”)  $r$  of the relation  $R$ , defined over  $A_1$  and  $A_2$ .
  - It has three 2-tuples:  $\langle 0,a \rangle, \langle 0,b \rangle, \langle 1,c \rangle$

## Definition Summary

<u>Informal Terms</u>		<u>Formal Terms</u>
Table		Relation
Column Header		Attribute
All possible Column Values		Domain
Row		Tuple
Table Definition		Schema of a Relation
Populated Table		State of the Relation

## STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	749-1253	25	3.53
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

## Characteristics of Relation

- Ordering of tuples in a relation  $r(R)$ :
  - The tuples are *not considered to be ordered*, even though they appear to be in the tabular form.
- Ordering of attributes in a relation schema  $R$  (and of values within each tuple):
  - We will consider the attributes in  $R(A_1, A_2, \dots, A_n)$  and the values in  $t = \langle v_1, v_2, \dots, v_n \rangle$  to be ordered.
    - (However, a more general alternative definition of relation does not require this ordering).

**Figure 5.2**

The relation STUDENT from Figure 5.1 with a different order of tuples.

**STUDENT**

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	749-1253	25	3.53
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

- **Values in a tuple:**
  - All values are considered atomic (indivisible).
  - Each value in a tuple must be from the domain of the attribute for that column
    - If tuple  $t = \langle v_1, v_2, \dots, v_n \rangle$  is a tuple (row) in the relation state  $r$  of  $R(A_1, A_2, \dots, A_n)$
    - Then each  $v_i$  must be a value from  $dom(A_i)$
  - A special **null** value is used to represent values that are unknown or inapplicable to certain tuples.



- **Notation:**
  - We refer to **component values** of a tuple  $t$  by:
    - $t[A_i]$  or  $t.A_i$
    - This is the value  $v_i$  of attribute  $A_i$  for tuple  $t$
  - Similarly,  $t[A_u, A_v, \dots, A_w]$  refers to the subtuple of  $t$  containing the values of attributes  $A_u, A_v, \dots, A_w$ , respectively in  $t$

## Relational Integrity Constraints

- Constraints are **conditions** that must hold on **all** valid relation states.
- There are three *main types* of constraints in the relational model:
  - **Key** constraints
  - **Entity integrity** constraints
  - **Referential integrity** constraints
- Another implicit constraint is the **domain** constraint
  - Every value in a tuple must be from the *domain of its attribute* (or it could be **null**, if allowed for that attribute)

## Key Constraints

- **Superkey** of R:
  - Is a set of attributes SK of R with the following condition:
    - No two tuples in any valid relation state  $r(R)$  will have the same value for SK
    - That is, for any distinct tuples  $t_1$  and  $t_2$  in  $r(R)$ ,  $t_1[SK] \neq t_2[SK]$
    - This condition must hold in *any valid state*  $r(R)$

- **Key of R:**
  - A "minimal" superkey
  - That is, a key is a superkey K such that removal of any attribute from K results in a set of attributes that is not a superkey (does not possess the superkey uniqueness property)

- **Example: Consider the CAR relation schema:**
  - CAR(State, Reg#, SerialNo, Make, Model, Year)
  - CAR has two keys:
    - Key1 = {State, Reg#}
    - Key2 = {SerialNo}
  - Both are also superkeys of CAR
  - {SerialNo, Make} is a superkey but *not* a key.

- In general:
  - Any *key* is a *superkey* (but not vice versa)
  - Any set of attributes that *includes a key* is a *superkey*
  - A *minimal* superkey is also a key

- If a relation has several **candidate keys**, one is chosen arbitrarily to be the **primary key**.
  - The primary key attributes are underlined.
- Example: Consider the CAR relation schema:
  - CAR(State, Reg#, SerialNo, Make, Model, Year)
  - We chose SerialNo as the primary key
- The primary key value is used to *uniquely identify* each tuple in a relation
  - Provides the tuple identity
- Also used to *reference* the tuple from another tuple
  - General rule: Choose as primary key the smallest of the candidate keys (in terms of size)
  - Not always applicable – choice is sometimes subjective

## CAR table with two candidate keys - LicenseNumber chosen as Primary Key

**CAR**

<u>License_number</u>	<u>Engine_serial_number</u>	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

**Figure 5.4**

The CAR relation, with  
two candidate keys:  
License\_number and  
Engine\_serial\_number.

## Entity Integrity

- **Entity Integrity:**
  - The *primary key attributes* PK of each relation schema R in S cannot have null values in any tuple of r(R).
    - This is because primary key values are used to *identify* the individual tuples.
    - $t[PK] \neq \text{null}$  for any tuple t in r(R)
    - If PK has several attributes, null is not allowed in any of these attributes
  - Note: Other attributes of R may be constrained to disallow null values, even though they are not members of the primary key.

## Referential Integrity

- A constraint involving **two** relations
  - The previous constraints involve a single relation.
- Used to specify a **relationship** among tuples in two relations:
  - The **referencing relation** and the **referenced relation**.

- Tuples in the **referencing relation** R1 have attributes FK (called **foreign key** attributes) that reference the primary key attributes PK of the **referenced relation** R2.
  - A tuple t1 in R1 is said to **reference** a tuple t2 in R2 if  $t1[FK] = t2[PK]$ .
- A referential integrity constraint can be displayed in a relational database schema as a directed arc from R1.FK to R2.

- Statement of the constraint
  - The value in the foreign key column (or columns) FK of the the **referencing relation R1** can be **either**:
    - (1) a value of an existing primary key value of a corresponding primary key PK in the **referenced relation R2**, or
    - (2) a **null**.
- In case (2), the FK in R1 should **not** be a part of its own primary key.

## Other Types of Constraints

- Semantic Integrity Constraints:
  - based on application semantics and cannot be expressed by the model per se
  - Example: “the max. no. of hours per employee for all projects he or she works on is 56 hrs per week”
- A **constraint specification** language may have to be used to express these
- SQL-99 allows triggers and **ASSERTIONS** to express for some of these

# Relational Database Schema

- **Relational Database Schema:**
  - A set  $S$  of relation schemas that belong to the same database.
  - $S$  is the name of the whole **database schema**
  - $S = \{R_1, R_2, \dots, R_n\}$
  - $R_1, R_2, \dots, R_n$  are the names of the individual **relation schemas** within the database  $S$
- Following slide shows a COMPANY database schema with 6 relation schemas



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#### EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

#### DEPARTMENT

Dname	<u>Dnumber</u>	Mgr_ssn	Mgr_start_date
-------	----------------	---------	----------------

#### DEPT\_LOCATIONS

<u>Dnumber</u>	<u>Dlocation</u>
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#### PROJECT

Pname	<u>Pnumber</u>	Plocation	Dnum
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#### WORKS\_ON

<u>Essn</u>	<u>Pno</u>	Hours
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#### DEPENDENT

<u>Essn</u>	<u>Dependent_name</u>	Sex	Bdate	Relationship
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**Figure 5.5**  
Schema diagram for  
the COMPANY  
relational database  
schema.

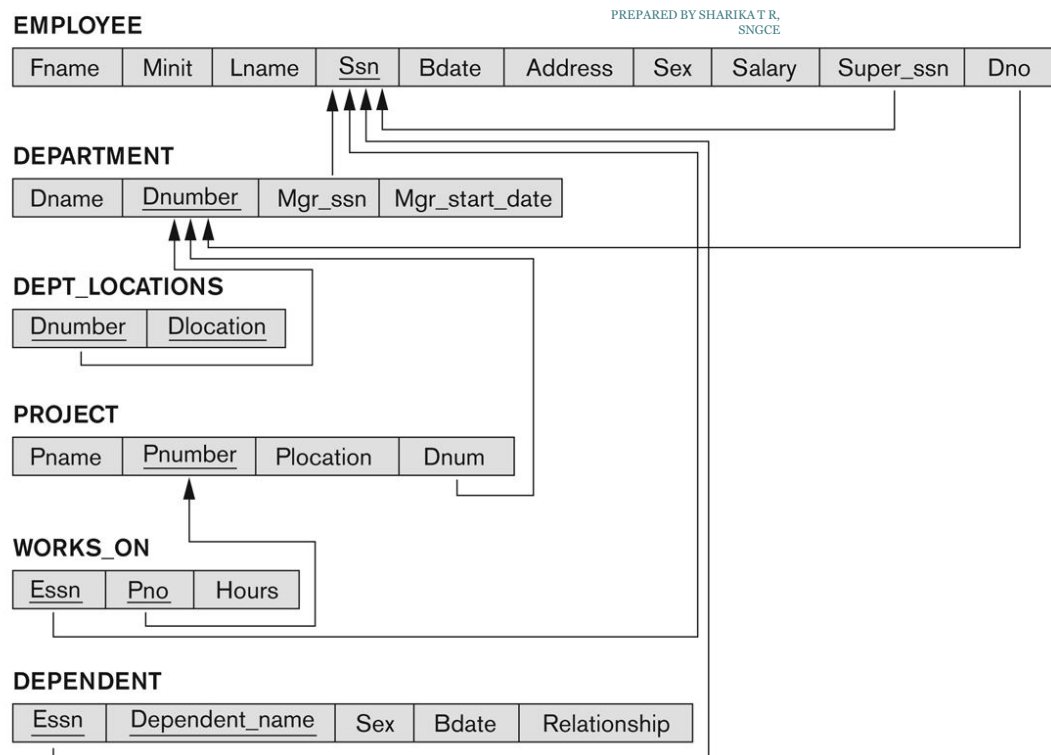
## Displaying a relational database schema and its constraints

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- Each relation schema can be displayed as **a row of attribute names**
- The name of the relation is written above the attribute names
- The **primary key** attribute (or attributes) will be **underlined**
- A **foreign key** (referential integrity) constraints is displayed as **a directed arc** (arrow) from the foreign key attributes to the referenced table
  - Can also point the the primary key of the referenced relation for clarity
- Next slide shows the COMPANY **relational schema diagram**

**Figure 5.7**

Referential integrity constraints displayed on the COMPANY relational database schema.



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## Populated database state

- Each *relation* will have many tuples in its current relation state
- The *relational database state* is a union of all the individual relation states
- Whenever the database is changed, a new state arises
- Basic operations for changing the database:
  - **INSERT** a new tuple in a relation
  - **DELETE** an existing tuple from a relation
  - **MODIFY** an attribute of an existing tuple
- Next slide shows an example state for the COMPANY database

Figure 5.6

One possible database state for the COMPANY relational database schema.

**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

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## Update Operations on Relations

1. INSERT a tuple.
2. DELETE a tuple.
3. MODIFY a tuple.
  - Integrity constraints should not be violated by the update operations.
  - Several update operations may have to be grouped together.
  - Updates may **propagate** to cause other updates automatically. This may be necessary to maintain integrity constraints.

## Update Operations on Relations

- In case of **integrity violation**, several actions can be taken:
  - **Cancel** the operation that causes the violation (**RESTRICT** or **REJECT** option)
  - Perform the operation but inform the user of the violation
  - Trigger additional updates so the violation is corrected (**CASCADE** option, **SET NULL** option)
  - Execute a user-specified error-correction routine

## Possible violations for each operation

- INSERT may violate any of the constraints:
  - **Domain constraint:**
    - if one of the attribute values provided for the new tuple is not of the specified attribute domain
  - **Key constraint:**
    - if the value of a key attribute in the new tuple already exists in another tuple in the relation
  - **Referential integrity:**
    - if a foreign key value in the new tuple references a primary key value that does not exist in the referenced relation
  - **Entity integrity:**
    - if the primary key value is null in the new tuple

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- DELETE may violate only referential integrity:
  - If the primary key value of the tuple being deleted is referenced from other tuples in the database
    - Can be remedied by several actions: RESTRICT, CASCADE, SET NULL
    - **RESTRICT** option: reject the deletion
    - **CASCADE** option: **propagate the new primary key value into the foreign keys** of the referencing tuples
    - **SET NULL option**: set the foreign keys of the referencing tuples to NULL
  - One of the above options must be specified during database design for each foreign key constraint

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- UPDATE may violate **domain constraint** and **NOT NULL** constraint on an attribute being modified
- Any of the other constraints may also be violated, depending on the attribute being updated:
  - Updating the primary key (PK):
    - Similar to a DELETE followed by an INSERT
    - Need to specify similar options to DELETE
  - Updating a foreign key (FK):
    - May violate referential integrity
  - Updating an ordinary attribute (neither PK nor FK):
    - Can only violate domain constraints

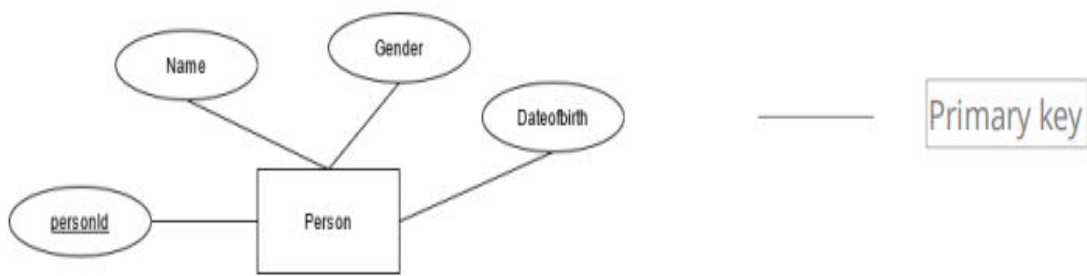
## homework

- 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.**

## Synthesizing ER Diagram to relational schema

### Entities and Simple attributes

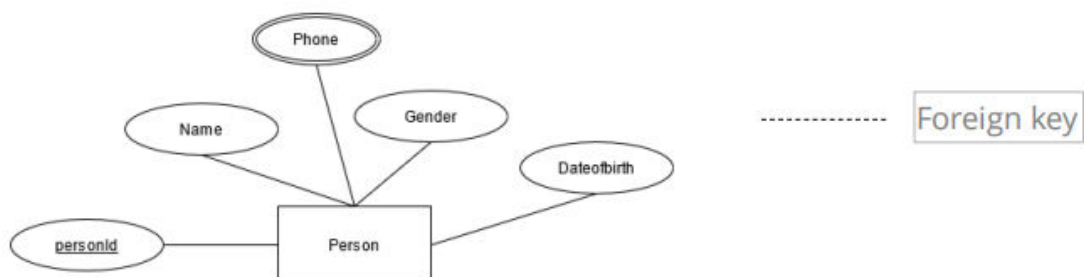
- An entity type within ER diagram is turned into a table.
- Each attribute turns into a column in the table.
- The key attribute of the entity is the primary key of the table which is usually underlined.
- It is highly recommended that every table should start with its primary key attribute conventionally named as TableNameID.



- The initial relational schema is expressed in the following format writing the table names with the attributes list inside a parentheses as shown below for
  - `PERSONS ( personid , name, dateOfBirth, gender)`
- personid is the primary key for the table : Persons

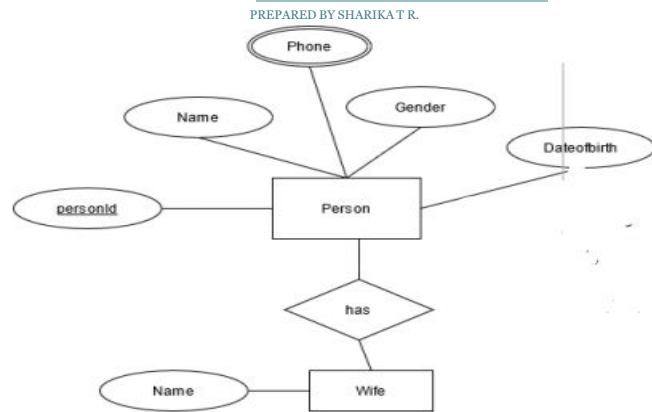
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## Multivalued Attributes



- If you have a multi-valued attribute, take the attribute and turn it into a new entity or table of its own.
- Then make a 1: N relationship between the new entity and the existing one.
- Create a table for the attribute.
  - Add the primary (id) column of the parent entity as a foreign key within the new table
  - `PERSONS ( personid , name, dateOfBirth, gender)`
  - `PERSONS_PHONE ( personid , phone )`
  - personid within the table Phones is a foreign key referring to the personid of Persons

## 1:1 Relationships



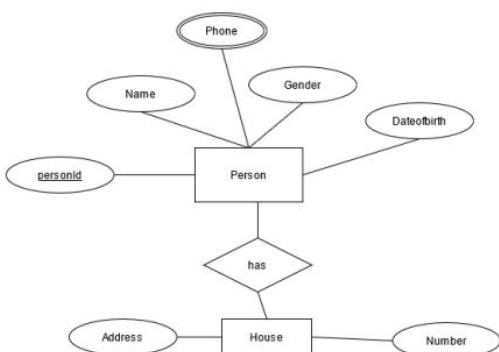
- For cases when the Person is not married i.e. has no wifeID, the attribute can set to NULL

**PERSONS** ( personid , name, dateOfBirth, gender, wifeid)

**PERSONS\_PHONE** (personid , phone)

**WIFE** (wifeid , name )

## 1:N Relationships



- For instance, the Person can have a House from zero to many, but a House can have only one Person.
- To represent such relationship the personid as the Parent node must be placed within the Child table as a foreign key

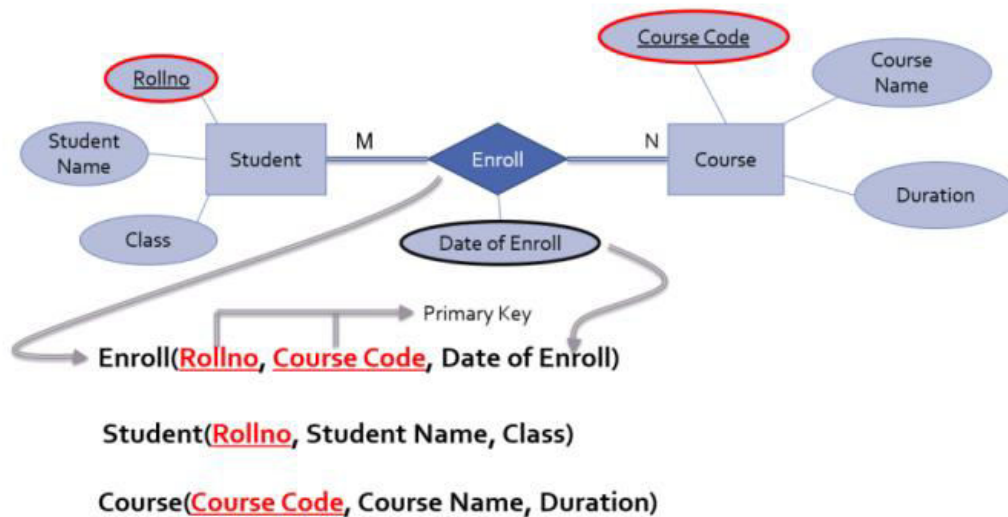
**PERSONS** ( personid , name, dateOfBirth, gender)

**PERSONS\_PHONE** (personid , phone)

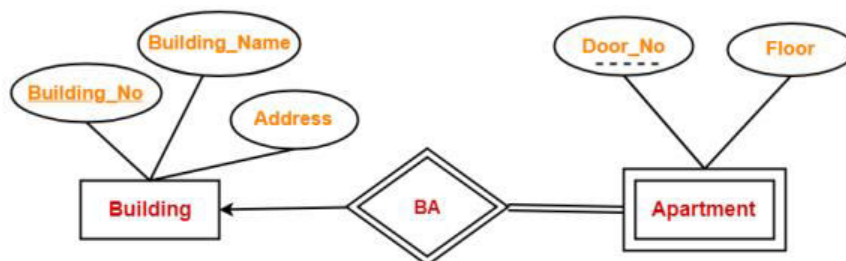
**HOUSE** (houseid , personid , number, address)



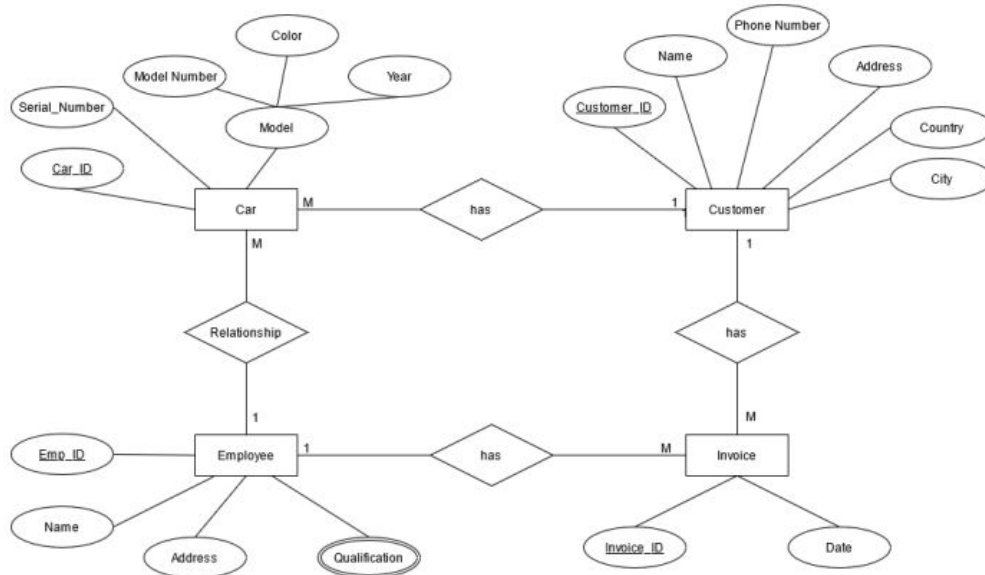
## M:N Relationships



## Weak Entity



# Homework



```

CAR (Car_ID, Serial_Number, Model_Number, Color, Year, Customer_ID, Emp_ID)
CUSTOMER (Customer_ID, Name, PhoneNumber, Address, Country, City)
EMPLOYEE (Emp_ID, Name, Address)
EMPLOYEE_QUALIFICATION (Emp_ID, Qualification)
INVOICE (Invoice_ID, Date, Emp_ID, Customer_ID)
    
```

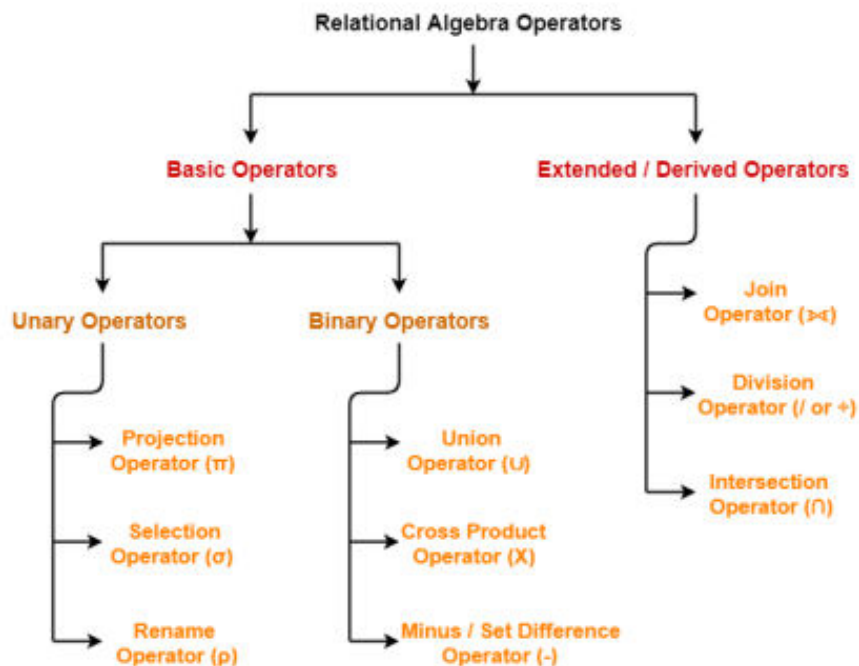
# Introduction to Relational Algebra

- select,
- project,
- cartesian product operations,
- join - Equi-join,
- natural join
- query examples

# Relational algebra

- Relational algebra is a **procedural query language**, which takes **instances of relations as input** and yields **instances of relations as output**.
- It uses operators to perform queries. An operator can be either **unary** or **binary**.
- They accept relations as their input and yield relations as their output.
- Relational algebra is performed recursively on a relation and intermediate results are also considered relations.

- The **basic set of operations for the relational model** is the **relational algebra**.
- These operations enable a user to specify basic retrieval requests as relational algebra expressions.
- The result of a retrieval is a new relation, which may have been formed from one or more relations.
- The algebra operations thus produce new relations, which can be further manipulated using operations of the same algebra.
- A sequence of relational algebra operations forms a relational algebra expression, whose result will also be a relation that represents the result of a **database query**



# Unary Relational Operations:

1. **SELECT and**
2. **PROJECT**

## The SELECT Operation

- The SELECT operation is used to *choose a subset of the tuples from a relation that satisfies a **selection condition***
- SELECT operation *restricts the tuples in a relation to only those tuples that satisfy the condition*
- ***horizontal partition** of the relation into two sets of tuples*
- those tuples that satisfy the condition and are selected, and those tuples that do not satisfy the condition and are discarded.

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- Select the EMPLOYEE tuples whose department is 4, or those whose salary is greater than \$30,000

$\sigma_{Dno=4}(EMPLOYEE)$   
 $\sigma_{Salary>30000}(EMPLOYEE)$

- In general, the SELECT operation is denoted by

$$\sigma_{\langle \text{selection condition} \rangle}(R)$$

- *R is generally a relational algebra expression whose result is a relation—the simplest such expression is just the name of a database relation.*
- *The relation resulting from the SELECT operation has the same attributes as R.*

- The Boolean expression specified in  $\langle \text{selection condition} \rangle$  is made up of a number of **clauses of the form**

$\langle \text{attribute name} \rangle \langle \text{comparison op} \rangle \langle \text{constant value} \rangle$

or

$\langle \text{attribute name} \rangle \langle \text{comparison op} \rangle \langle \text{attribute name} \rangle$

- *Clauses can be connected by the standard Boolean operators **and**, **or**, and **not** to form a general selection condition*

- Select the tuples for all employees who either work in department 4 and make over \$25,000 per year, or work in department 5 and make over \$30,000,

$\sigma_{(Dno=4 \text{ AND } Salary>25000) \text{ OR } (Dno=5 \text{ AND } Salary>30000)}(EMPLOYEE)$

(a)

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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

- the result of a SELECT operation can be determined as follows:
- The <selection condition> is applied independently to each *individual tuple t in R*.
- This is done by substituting each occurrence of an attribute  $A_i$  in the selection condition with its value in the tuple  $t[A_i]$ .
- If the condition evaluates to TRUE, then tuple  $t$  is selected.
- All the selected tuples appear in the result of the SELECT operation.



## Interpretation of Boolean conditions AND, OR, and NOT

- (cond1 AND cond2) is TRUE
  - if both (cond1) and (cond2) are TRUE;
  - otherwise, it is FALSE.
- (cond1 OR cond2) is TRUE
  - if either (cond1) or (cond2) or both are TRUE;
  - otherwise, it is FALSE.
- (NOT cond) is TRUE
  - if cond is FALSE;
  - otherwise, it is FALSE.

## Degree of the relation from SELECT operation

- its **number of attributes**
- is the **same as the degree of R**.
- *The number of tuples in the resulting relation is always less than or equal to the number of tuples in R.*

$$|\sigma_c(R)| \leq |R|$$

- The fraction of tuples selected by a selection condition is referred to as the **selectivity of the condition**.

## Commutative Property of SELECT

- SELECT operation is **commutative**

$$\sigma_{\langle \text{cond1} \rangle}(\sigma_{\langle \text{cond2} \rangle}(R)) = \sigma_{\langle \text{cond2} \rangle}(\sigma_{\langle \text{cond1} \rangle}(R))$$

- a sequence of SELECTs can be applied in any order.
- we can always combine a **cascade (or sequence) of SELECT operations into a single SELECT** operation with a conjunctive (AND) condition; that is,

$$\sigma_{\langle \text{cond1} \rangle}(\sigma_{\langle \text{cond2} \rangle}(\dots(\sigma_{\langle \text{condn} \rangle}(R)) \dots)) = \sigma_{\langle \text{cond1} \rangle \text{ AND } \langle \text{cond2} \rangle \text{ AND } \dots \text{ AND } \langle \text{condn} \rangle}(R)$$

## PROJECT Operation

- **PROJECT operation** selects certain *columns from the table and discards the other columns*.
- If we are interested in only certain attributes of a relation, we use the PROJECT operation to *project the relation over these attributes only*
- **vertical partition** of the relation into two relations
  - one has the needed columns (attributes) and contains the result of the operation, and
  - the other contains the discarded columns.

## The general form of PROJECT

$$\pi_{\langle \text{attribute list} \rangle}(R)$$

- Example: list each employee's first and last name and salary

$$\pi_{\text{Lname, Fname, Salary}}(\text{EMPLOYEE})$$

- The result of the PROJECT operation has only the attributes specified in  $\langle \text{attribute list} \rangle$  *in the same order as they appear in the list.*
- Hence, its **degree is equal to the number of attributes** in  $\langle \text{attribute list} \rangle$ .

## Duplicate Elimination in PROJECT

- The PROJECT operation *removes any duplicate tuples*, so the result of the PROJECT operation is a set of distinct tuples, and hence a valid relation.
- This is known as **duplicate elimination**.

## Example

$\pi_{\text{Sex, Salary}}(\text{EMPLOYEE})$

Sex	Salary
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	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

- The number of tuples in a relation resulting from a PROJECT operation is **always less than or equal to the number of tuples in  $R$ .**

$$\pi_{\langle \text{list1} \rangle} (\pi_{\langle \text{list2} \rangle} (R)) = \pi_{\langle \text{list1} \rangle} (R)$$

- as long as  $\langle \text{list2} \rangle$  contains the attributes in  $\langle \text{list1} \rangle$ ;
- otherwise, the left-hand side is an incorrect expression.
- commutativity does not hold on PROJECT.**

**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

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$$\sigma_{(Dno=4 \text{ AND } Salary > 25000) \text{ OR } (Dno=5 \text{ AND } Salary > 30000)}(EMPLOYEE).$$

(a)

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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

(b)  $\pi_{Lname, Fname, Salary}(EMPLOYEE).$ 

(b)

Lname	Fname	Salary
Smith	John	30000
Wong	Franklin	40000
Zelaya	Alicia	25000
Wallace	Jennifer	43000
Narayan	Ramesh	38000
English	Joyce	25000
Jabbar	Ahmad	25000
Borg	James	55000

(c)  $\pi_{Sex, Salary}(EMPLOYEE).$ 

(c)

Sex	Salary
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

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## Sequences of Operations and the RENAME Operation

- for most queries, we need to apply several relational algebra operations one after the other
  - Either we can write the operations as a single relational algebra expression by nesting the operations, or
  - we can apply one operation at a time and create intermediate result relations
    - we must give names to the relations that hold the intermediate results.

## Example- In-Line relational algebra expression

- retrieve the first name, last name, and salary of all employees who work in department number 5, we must apply a SELECT and a PROJECT operation

$$\pi_{Fname, Lname, Salary}(\sigma_{Dno=5}(EMPLOYEE))$$

(a)

Fname	Lname	Salary
John	Smith	30000
Franklin	Wong	40000
Ramesh	Narayan	38000
Joyce	English	25000

## Example- Intermediate Relation

$$\begin{aligned} \text{DEP5\_EMPS} &\leftarrow \sigma_{Dno=5}(EMPLOYEE) \\ \text{RESULT} &\leftarrow \pi_{Fname, Lname, Salary}(\text{DEP5\_EMPS}) \end{aligned}$$

## Rename

- The results of the operations that we are performing are saved without any name.
- If we want to give some name to the result of any operation then we can rename the result of the operations using the rename operation.
- It can also be used to rename an old relation. It is denoted by symbol rho ( $\rho$ ).
- Notation 1: Naming the result of an operation  $\rho_h(E)$ 
  - where the result of expression E is stored as h.
- Notation 2: Renaming an already existing column  $\rho_{\text{New\_Name/Old\_Name}}(E)$

## Rename

- To rename the attributes in a relation, we simply list the new attribute names in parentheses,

$TEMP \leftarrow \sigma_{Dno=5}(EMPLOYEE)$

$R(\text{First\_name}, \text{Last\_name}, \text{Salary}) \leftarrow \pi_{Fname, Lname, Salary}(TEMP)$

(b)  
TEMP

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
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

R

First_name	Last_name	Salary
John	Smith	30000
Franklin	Wong	40000
Ramesh	Narayan	38000
Joyce	English	25000



- If no renaming is applied, the names of the attributes in the resulting relation of a SELECT operation are the same as those in the original relation and in the same order.
- a PROJECT operation with no renaming, the resulting relation has the **same attribute names as those in the projection list** and in the same order in which they appear in the list.

## RENAME Operation General form

- RENAME operation when applied to a relation  $R$  of degree  $n$  is denoted by any of the following three forms

$$\rho_{S(B_1, B_2, \dots, B_n)}(R) \text{ or } \rho_S(R) \text{ or } \rho_{(B_1, B_2, \dots, B_n)}(R)$$

- symbol  $\rho$  (rho) is used to denote the RENAME operator,
- $S$  is the new relation name, and
- $B_1, B_2, \dots, B_n$  are the new attribute names.
  - The first expression renames both the relation and its attributes,
  - the second renames the relation only, and
  - the third renames the attributes only.
- If the attributes of  $R$  are  $(A_1, A_2, \dots, A_n)$  in that order, then each  $A_i$  is renamed as  $B_i$ .

## The UNION, INTERSECTION, and MINUS Operations

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- UNION:
  - The result of this operation, denoted by  $R \cup S$ , is a relation that includes all tuples that are **either in  $R$  or in  $S$  or in both  $R$  and  $S$** .
  - *Duplicate* tuples are eliminated.
- INTERSECTION:
  - The result of this operation, denoted by  $R \cap S$ , is a relation that **includes all tuples that are in both  $R$  and  $S$** .
- SET DIFFERENCE (or MINUS):
  - The result of this operation, denoted by  $R - S$ , is a relation that **includes all tuples that are in  $R$  but not in  $S$** .

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## Example

- retrieve the Social Security numbers of all employees who either work in department 5 or directly supervise an employee who works in department 5, we can use the UNION operation as follows

$$\begin{aligned} \text{DEP5\_EMPS} &\leftarrow \sigma_{\text{Dno}=5}(\text{EMPLOYEE}) \\ \text{RESULT1} &\leftarrow \pi_{\text{Ssn}}(\text{DEP5\_EMPS}) \\ \text{RESULT2}(\text{Ssn}) &\leftarrow \pi_{\text{Super\_ssn}}(\text{DEP5\_EMPS}) \\ \text{RESULT} &\leftarrow \text{RESULT1} \cup \text{RESULT2} \end{aligned}$$

- UNION operation produces the tuples that are in either RESULT1 or RESULT2 or both, while eliminating any duplicates.

**DEP5\_EMPS**

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
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

$$\begin{aligned} \text{DEP5\_EMPS} &\leftarrow \sigma_{\text{Dno}=5}(\text{EMPLOYEE}) \\ \text{RESULT1} &\leftarrow \pi_{\text{Ssn}}(\text{DEP5\_EMPS}) \\ \text{RESULT2}(\text{Ssn}) &\leftarrow \pi_{\text{Super\_ssn}}(\text{DEP5\_EMPS}) \\ \text{RESULT} &\leftarrow \text{RESULT1} \cup \text{RESULT2} \end{aligned}$$

**RESULT1**

Ssn
123456789
333445555
666884444
453453453

**RESULT2**

Ssn
333445555
888665555

**RESULT**

Ssn
123456789
333445555
666884444
453453453
888665555

- UNION, INTERSECTION, and SET DIFFERENCE are binary operations;
  - that is, each is applied to two sets

## Union compatibility or Type compatibility

- Two relations  $R(A_1, A_2, \dots, A_n)$  and  $S(B_1, B_2, \dots, B_n)$  are said to be union compatible (or type compatible)
  - if they have the same degree  $n$  and if  $\text{dom}(A_i) = \text{dom}(B_i)$  for  $1 \leq i \leq n$ .
  - This means that the two relations have the same number of attributes and each corresponding pair of attributes has the same domain.

(a) Two union-compatible relations.

(a) STUDENT

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

INSTRUCTOR

Fname	Lname
John	Smith
Ricardo	Browne
Susan	Yao
Francis	Johnson
Ramesh	Shah

(b) STUDENT  $\cup$  INSTRUCTOR

(b)

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert
John	Smith
Ricardo	Browne
Francis	Johnson

(c) STUDENT  $\cap$  INSTRUCTOR

(c)

Fn	Ln
Susan	Yao
Ramesh	Shah

(d) STUDENT – INSTRUCTOR

(d)

Fn	Ln
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

(e) INSTRUCTOR – STUDENT

(e)

Fname	Lname
John	Smith
Ricardo	Browne
Francis	Johnson

## The UNION, INTERSECTION, and MINUS Properties

- UNION and INTERSECTION are *commutative operations*

$$R \cup S = S \cup R \quad \text{and} \quad R \cap S = S \cap R$$

- Both UNION and INTERSECTION can be treated as *n-ary operations applicable to any number of relations* because both are also *associative operations*

$$R \cup (S \cap T) = (R \cup S) \cap T \quad \text{and} \quad (R \cap S) \cup T = R \cap (S \cup T)$$

- The MINUS operation is *not commutative; that is, in general,*

$$R - S \neq S - R$$

- INTERSECTION can be expressed in terms of union and set difference as follows

$$R \cap S = ((R \cup S) - (R - S)) - (S - R)$$

## CARTESIAN PRODUCT (CROSS PRODUCT) OR CROSS JOIN

- denoted by  $\times$
- This is also a binary set operation, but the relations on which it is applied *do not have to be union compatible*
- the result of  $R(A_1, A_2, \dots, A_n) \times S(B_1, B_2, \dots, B_m)$  is a relation  $Q$  with degree  $n + m$  attributes  $Q(A_1, A_2, \dots, A_n, B_1, B_2, \dots, B_m)$ , in that order.
- The resulting relation  $Q$  has one tuple for each combination of tuples—one from  $R$  and one from  $S$ .
- Hence, if  $R$  has  $n_R$  tuples (denoted as  $|R| = n_R$ ), and  $S$  has  $n_S$  tuples, then  $R \times S$  will have  $n_R * n_S$  tuples.

## *n*-ary **CARTESIAN PRODUCT**

- produces new tuples by concatenating all possible combinations of tuples from *n* *underlying relations*

## Example

- We want to retrieve a list of names of each female employee's dependents

**EMPLOYEE**

Fname	Minit	Lname	<u>Ssn</u>	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



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$FEMALE\_EMPS \leftarrow \sigma_{Sex='F'}(EMPLOYEE)$   
 $EMP\_NAMES \leftarrow \pi_{Fname, Lname, Ssn}(FEMALE\_EMPS)$   
 $EMP\_DEPENDENTS \leftarrow EMP\_NAMES \times DEPENDENT$   
 $ACTUAL\_DEPENDENTS \leftarrow \sigma_{Ssn=Essn}(EMP\_DEPENDENTS)$   
 $RESULT \leftarrow \pi_{Fname, Lname, Dependent\_name}(ACTUAL\_DEPENDENTS)$

**FEMALE\_EMPS**

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Alicia	J	Zelaya	999887777	1968-07-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5

**EMP\_NAMES**

Fname	Lname	Ssn
Alicia	Zelaya	999887777
Jennifer	Wallace	987654321
Joyce	English	453453453

$FEMALE\_EMPS \leftarrow \sigma_{Sex='F'}(EMPLOYEE)$   
 $EMP\_NAMES \leftarrow \pi_{Fname, Lname, Ssn}(FEMALE\_EMPS)$   
 $EMP\_DEPENDENTS \leftarrow EMP\_NAMES \times DEPENDENT$   
**EMP\_DEPENDENTS**

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Alicia	Zelaya	999887777	333445555	Alice	F	1986-04-05	...
Alicia	Zelaya	999887777	333445555	Theodore	M	1983-10-25	...
Alicia	Zelaya	999887777	333445555	Joy	F	1958-05-03	...
Alicia	Zelaya	999887777	987654321	Abner	M	1942-02-28	...
Alicia	Zelaya	999887777	123456789	Michael	M	1988-01-04	...
Alicia	Zelaya	999887777	123456789	Alice	F	1988-12-30	...
Alicia	Zelaya	999887777	123456789	Elizabeth	F	1967-05-05	...
Jennifer	Wallace	987654321	333445555	Alice	F	1986-04-05	...
Jennifer	Wallace	987654321	333445555	Theodore	M	1983-10-25	...
Jennifer	Wallace	987654321	333445555	Joy	F	1958-05-03	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...
Jennifer	Wallace	987654321	123456789	Michael	M	1988-01-04	...
Jennifer	Wallace	987654321	123456789	Alice	F	1988-12-30	...
Jennifer	Wallace	987654321	123456789	Elizabeth	F	1967-05-05	...
Joyce	English	453453453	333445555	Alice	F	1986-04-05	...
Joyce	English	453453453	333445555	Theodore	M	1983-10-25	...
Joyce	English	453453453	333445555	Joy	F	1958-05-03	...
Joyce	English	453453453	987654321	Abner	M	1942-02-28	...
Joyce	English	453453453	123456789	Michael	M	1988-01-04	...
Joyce	English	453453453	123456789	Alice	F	1988-12-30	...
Joyce	English	453453453	123456789	Elizabeth	F	1967-05-05	...

```

FEMALE_EMPS ←  $\sigma_{\text{Sex}='F'}(\text{EMPLOYEE})$ 
EMPNAMES ←  $\pi_{\text{Fname, Lname, Ssn}}(\text{FEMALE_EMPS})$ 
EMP_DEPENDENTS ←  $\text{EMPNAMES} \times \text{DEPENDENT}$ 
ACTUAL_DEPENDENTS ←  $\sigma_{\text{Ssn}=\text{Essn}}(\text{EMP_DEPENDENTS})$ 
RESULT ←  $\pi_{\text{Fname, Lname, Dependent\_name}}(\text{ACTUAL_DEPENDENTS})$ 

```

**ACTUAL\_DEPENDENTS**

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...

**RESULT**

Fname	Lname	Dependent_name
Jennifer	Wallace	Abner

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- The CARTESIAN PRODUCT creates tuples with the combined attributes of two relations.
- We can *SELECT related tuples only from the two relations by specifying an appropriate selection condition* after the Cartesian product, as we did in the preceding example.
- Because this sequence of CARTESIAN PRODUCT followed by SELECT is quite commonly used to combine *related tuples from two relations, a special operation, called JOIN*, was created to specify this sequence as a single operation

## The JOIN Operation

- The JOIN operation, denoted by  $\bowtie$ , is used to combine *related tuples from two relations* into single “longer” tuples.
- This operation is very important for any relational database with more than a single relation because it allows us to process relationships among relations.

## Example

- Retrieve the name of the manager of each department.
  - To get the manager's name, we need to combine each department tuple with the employee tuple whose Ssn value matches the Mgr\_ssn value in the department tuple.
  - We do this by using the JOIN operation and then projecting the result over the necessary attributes, as follows

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$DEPT\_MGR \leftarrow DEPARTMENT \bowtie_{Mgr\_ssn=Ssn} EMPLOYEE$   
 $RESULT \leftarrow \pi_{Dname, Lname, Fname}(DEPT\_MGR)$

DEPT\_MGR

Dname	Dnumber	Mgr_ssn	...	Fname	Minit	Lname	Ssn	...
Research	5	333445555	...	Franklin	T	Wong	333445555	...
Administration	4	987654321	...	Jennifer	S	Wallace	987654321	...
Headquarters	1	888665555	...	James	E	Borg	888665555	...

**Figure 6.6**

Result of the JOIN operation  $DEPT\_MGR \leftarrow DEPARTMENT \bowtie_{Mgr\_ssn=Ssn} EMPLOYEE$ .

**RESULT**

Dname	Lname	Fname
Research	Wong	Franklin
Administration	Wallance	Jennifer
Headquaters	Borg	James

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- The JOIN operation can be specified as a CARTESIAN PRODUCT operation followed by a SELECT operation.

$EMP\_DEPENDENTS \leftarrow EMPNAMES \times DEPENDENT$   
 $ACTUAL\_DEPENDENTS \leftarrow \sigma_{Ssn=Essn}(EMP\_DEPENDENTS)$

- These two operations can be replaced with a single JOIN operation as follows

$ACTUAL\_DEPENDENTS \leftarrow EMPNAMES \bowtie_{Ssn=Essn} DEPENDENT$

## General form of a JOIN

- JOIN operation on two relations<sup>5</sup>  $R(A_1, A_2, \dots, A_n)$  and  $S(B_1, B_2, \dots, B_m)$  is

$$R \bowtie_{\langle \text{join condition} \rangle} S$$

- The result of the JOIN is a relation  $Q$  with  $n + m$  attributes  $Q(A_1, A_2, \dots, A_n, B_1, B_2, \dots, B_m)$  in that order;
- $Q$  has one tuple for each combination of tuples—one from  $R$  and one from  $S$ —whenever the combination satisfies the join condition

## Difference between JOIN and CARTESIAN PRODUCT

- In JOIN, only combinations of tuples *satisfying the join condition appear in the result*,
- *whereas in the CARTESIAN PRODUCT all combinations of tuples are included in the result.*
- The join condition is specified on attributes from the two relations  $R$  and  $S$  and is *evaluated* for each combination of tuples.
- Each tuple combination for which the join condition evaluates to TRUE is included in the resulting relation  $Q$  *as a single combined tuple*.

## THETA JOIN

$\langle \text{condition} \rangle \text{ AND } \langle \text{condition} \rangle \text{ AND...AND } \langle \text{condition} \rangle$

- where each  $\langle \text{condition} \rangle$  is of the form  $A_i \theta B_j$ ,
  - $A_i$  is an attribute of  $R$ ,
  - $B_j$  is an attribute of  $S$ ,
  - $A_i$  and  $B_j$  have the same domain, and
  - $\theta$  (theta) is one of the comparison operators  $\{=, <, \leq, >, \geq, \neq\}$ .
- Tuples whose join attributes are **NULL** or for which the join condition is **FALSE** *do not appear in the result*
- the JOIN operation does *not necessarily preserve all of the information in the participating relations*,
  - *because tuples that do not get combined with matching ones in the other relation do not appear in the result.*

## EQUIJOIN

- a JOIN, where the only comparison operator **used is =**, is called an **EQUIJOIN**
- in the result of an EQUIJOIN we always have one or more pairs of attributes that have **identical values** in every tuple

## NATURAL JOIN

- NATURAL JOIN requires that the two join attributes (or each pair of join attributes) have the **same name in both relations**.
- If this is not the case, **a renaming** operation is applied first.

## Example

- combine each PROJECT tuple with the DEPARTMENT tuple that controls the project
  - first we **rename** the Dnumber attribute of DEPARTMENT to Dnum
  - so that it has the **same name as the Dnum** attribute in PROJECT—and then we apply **NATURAL JOIN**

$$\text{PROJ\_DEPT} \leftarrow \text{PROJECT} \star \rho_{(\text{Dname}, \text{Dnum}, \text{Mgr\_ssn}, \text{Mgr\_start\_date})}(\text{DEPARTMENT})$$

- The same query can be done in two steps by creating an intermediate table DEPT

$$\begin{aligned} \text{DEPT} &\leftarrow \rho_{(\text{Dname}, \text{Dnum}, \text{Mgr\_ssn}, \text{Mgr\_start\_date})}(\text{DEPARTMENT}) \\ \text{PROJ\_DEPT} &\leftarrow \text{PROJECT} \star \text{DEPT} \end{aligned}$$

(a)  $\text{PROJ\_DEPT} \leftarrow \text{PROJECT} \star \text{DEPT}.$

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(a)

PROJ\_DEPT

Pname	<u>Pnumber</u>	Plocation	Dnum	Dname	Mgr_ssn	Mgr_start_date
ProductX	1	Bellaire	5	Research	333445555	1988-05-22
ProductY	2	Sugarland	5	Research	333445555	1988-05-22
ProductZ	3	Houston	5	Research	333445555	1988-05-22
Computerization	10	Stafford	4	Administration	987654321	1995-01-01
Reorganization	20	Houston	1	Headquarters	888665555	1981-06-19
Newbenefits	30	Stafford	4	Administration	987654321	1995-01-01

- In the PROJ\_DEPT relation, each tuple combines a PROJECT tuple with the DEPARTMENT tuple for the department that controls the project, but *only one join attribute value is kept*.



- If the attributes on which the natural join is specified already *have the same names in both relations, renaming is unnecessary*
- to apply a natural join on the Dnumber attributes of DEPARTMENT and DEPT\_LOCATIONS

**DEPT\_LOCS ← DEPARTMENT \* DEPT\_LOCATIONS**

(b)

DEPT\_LOCS

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

- the join condition for NATURAL JOIN is constructed by equating *each pair of join attributes that have the same name in the two relations* and combining these conditions with **AND**.
- There can be a list of join attributes from each relation, and each corresponding pair must have the same name.

- more general, *but nonstandard definition for NATURAL JOIN is*

$$Q \leftarrow R \star_{(\langle \text{list1} \rangle), (\langle \text{list2} \rangle)} S$$

- *<list1> specifies a list of  $i$  attributes from  $R$ , and*
- *<list2> specifies a list of  $i$  attributes from  $S$ .*
- *The lists are used to form equality comparison conditions between pairs of corresponding attributes, and*
- *the conditions are then ANDed together.*

**Table 6.1** Operations of Relational Algebra

OPERATION	PURPOSE	NOTATION
SELECT	Selects all tuples that satisfy the selection condition from a relation $R$ .	$\sigma_{\langle \text{selection condition} \rangle}(R)$
PROJECT	Produces a new relation with only some of the attributes of $R$ , and removes duplicate tuples.	$\pi_{\langle \text{attribute list} \rangle}(R)$
THETA JOIN	Produces all combinations of tuples from $R_1$ and $R_2$ that satisfy the join condition.	$R_1 \bowtie_{\langle \text{join condition} \rangle} R_2$
EQUIJOIN	Produces all the combinations of tuples from $R_1$ and $R_2$ that satisfy a join condition with only equality comparisons.	$R_1 \bowtie_{\langle \text{join condition} \rangle} R_2$ , OR $R_1 \bowtie_{(\langle \text{join attributes 1} \rangle), (\langle \text{join attributes 2} \rangle)} R_2$
NATURAL JOIN	Same as EQUIJOIN except that the join attributes of $R_2$ are not included in the resulting relation; if the join attributes have the same names, they do not have to be specified at all.	$R_1 \star_{\langle \text{join condition} \rangle} R_2$ , OR $R_1 \star_{(\langle \text{join attributes 1} \rangle), (\langle \text{join attributes 2} \rangle)} R_2$
UNION	Produces a relation that includes all the tuples in $R_1$ or $R_2$ or both $R_1$ and $R_2$ ; $R_1$ and $R_2$ must be union compatible.	$R_1 \cup R_2$
INTERSECTION	Produces a relation that includes all the tuples in both $R_1$ and $R_2$ ; $R_1$ and $R_2$ must be union compatible.	$R_1 \cap R_2$
DIFFERENCE	Produces a relation that includes all the tuples in $R_1$ that are not in $R_2$ ; $R_1$ and $R_2$ must be union compatible.	$R_1 - R_2$
CARTESIAN PRODUCT	Produces a relation that has the attributes of $R_1$ and $R_2$ and includes as tuples all possible combinations of tuples from $R_1$ and $R_2$ .	$R_1 \times R_2$
DIVISION	Produces a relation $R(X)$ that includes all tuples $t[X]$ in $R_1(Z)$ that appear in $R_1$ in combination with every tuple from $R_2(Y)$ , where $Z = X \cup Y$ .	$R_1(Z) \div R_2(Y)$

## Different Types of SQL JOINS

- INNER JOIN
  - Returns records that have matching values in both tables
    1. Theta join
    2. EQUI join
    3. Natural join
- OUTER JOIN
  - In an outer join, along with tuples that satisfy the matching criteria, we also include some or all tuples that do not match the criteria.
    1. Left Outer JOIN
    2. Right Outer Join
    3. Full Outer Join

## Left Outer Join $(A \bowtie B)$

- In the left outer join, operation allows keeping all tuple in the left relation.
- if there is no matching tuple is found in right relation, then the attributes of right relation in the join result are filled with null values.



Consider the following 2 Tables

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A	
Num	Square
2	4
3	9
4	16

B	
Num	Cube
2	8
3	18
5	75

A ⋈ B		
Num	Square	Cube
2	4	4
3	9	9
4	16	-

## Right Outer Join $(A \bowtie B)$

- In the right outer join, operation allows keeping all tuple in the right relation.
- However, if there is no matching tuple is found in the left relation, then the attributes of the left relation in the join result are filled with null values.



Consider the following 2 Tables

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A	
Num	Square
2	4
3	9
4	16

B	
Num	Cube
2	8
3	18
5	75

(A ⋈ B)		
Num	Cube	Square
2	8	4
3	18	9
5	75	-

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## Full Outer Join (A ⋈ B)

- In a full outer join, all tuples from both relations are included in the result, irrespective of the matching condition.

Consider the following 2 Tables

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A	
Num	Square
2	4
3	9
4	16

B	
Num	Cube
2	8
3	18
5	75

(A ⋈ B)		
Num	Square	Cube
2	4	8
3	9	18
4	16	-
5	-	75

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Left Outer Join( $\bowtie$ )

In the left outer join, operation allows keeping all tuple in the left relation.

Right Outer join( $\bowtie$ )

In the right outer join, operation allows keeping all tuple in the right relation.

Full Outer Join( $\bowtie$ )

In a full outer join, all tuples from both relations are included in the result irrespective of the matching condition.

## Homework

1. Retrieve the name and address of all employees who work for the 'Research' department.
2. For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birth date.
3. Make a list of project numbers for projects that involve an employee whose last name is 'Smith', either as a worker or as a manager of the department that controls the project.

- **Query 1. Retrieve the name and address of all employees who work for the 'Research' department.**

```
RESEARCH_DEPT ←  $\sigma_{Dname='Research'}$ (DEPARTMENT)
RESEARCH_EMPS ← (RESEARCH_DEPT  $\bowtie_{Dnumber=Dno}$  EMPLOYEE)
RESULT ←  $\pi_{Fname, Lname, Address}$ (RESEARCH_EMPS)
```

As a single in-line expression, this query becomes:

```
 $\pi_{Fname, Lname, Address}(\sigma_{Dname='Research'}(DEPARTMENT \bowtie_{Dnumber=Dno}(EMPLOYEE)))$ 
```

- This query could be specified in other ways; for example, the order of the JOIN and
- SELECT operations could be reversed, or the JOIN could be replaced by a NATURAL JOIN after renaming one of the join attributes to match the other join attribute name.

Figure 5.6

One possible database state for the COMPANY relational database schema.

**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

- **Query 2. For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birth date.**

$STAFFORD\_PROJS \leftarrow \sigma_{Plocation='Stafford'}(PROJECT)$   
 $CONTR\_DEPTS \leftarrow (STAFFORD\_PROJS \bowtie_{Dnum=Dnumber} DEPARTMENT)$   
 $PROJ\_DEPT\_MGRS \leftarrow (CONTR\_DEPTS \bowtie_{Mgr\_ssn=Ssn} EMPLOYEE)$   
 $RESULT \leftarrow \pi_{Pnumber, Dnum, Lname, Address, Bdate}(PROJ\_DEPT\_MGRS)$

- we first select the projects located in Stafford, then join them with their controlling departments, and then join the result with the department managers.
- Finally, we apply a project operation on the desired attributes



- **Query 3. Make a list of project numbers for projects that involve an employee** whose last name is 'Smith', either as a worker or as a manager of the department that controls the project.

```

SMITHS(Essn) ←  $\pi_{Ssn} (\sigma_{Lname='Smith'}(EMPLOYEE))$ 
SMITH_WORKER_PROJS ←  $\pi_{Pno} (WORKS\_ON \star SMITHS)$ 
MGRS ←  $\pi_{Lname, Dnumber} (EMPLOYEE \bowtie_{Ssn=Mgr\_ssn} DEPARTMENT)$ 
SMITH_MANAGED_DEPTS(Dnum) ←  $\pi_{Dnumber} (\sigma_{Lname='Smith'}(MGRS))$ 
SMITH_MGR_PROJS(Pno) ←  $\pi_{Pnumber} (SMITH\_MANAGED\_DEPTS \star PROJECT)$ 
RESULT ←  $(SMITH\_WORKER\_PROJS \cup SMITH\_MGR\_PROJS)$ 
    
```

## SYLLABUS

- Structure of Relational Databases - Integrity Constraints, Synthesizing ER diagram to relational schema
- Introduction to Relational Algebra - select, project, cartesian product operations, join - Equi-join, natural join. query examples,
- **Introduction to Structured Query Language (SQL), Data Definition Language (DDL), Table definitions and operations – CREATE, DROP, ALTER, INSERT, DELETE, UPDATE.**

## SQL HISTORY

- Structured Query Language(SQL) was developed at IBM by Donald D. Chamberlin and Raymond F. Boyce in the early 1970s.
- This was initially called SEQUEL(Structured English QUery Language).
- The main objective of SQL is to update, store, manipulate and retrieve data stored in a relational database.

## SQL

- SQL provides
  - A data definition language (DDL)
  - A data manipulation language (DML)
  - A data control language (DCL)
- In addition SQL
  - Can be used from other languages
  - Is often extended to provide common programming constructs (such as if-then tests, loops, variables, etc.)

## Cont..

- SQL is a declarative (non-procedural) language
  - Procedural - say exactly what the computer has to do
  - Non-procedural – describe the required result (not the way to compute it)
- SQL is based on the relational model
  - It has many of the same ideas
  - Databases that support SQL are often described as relational databases
  - It is not always true to the model

## Cont..

- E/R designs can be implemented in SQL
  - Entities, attributes, and relationships can all be expressed in terms of SQL
  - Many-to-many relationships are a problem, so should be removed

# Relations, Entities, Tables

Relational model	E/R Diagram	SQL
Relation	Entity	Table
Tuple	Instance	Row
Attribute	Attribute	Column or Field
Foreign Key	M:1 Relationship	Foreign Key
Primary Key		Primary Key

## Implementing E/R Designs

- Given an E/R design
  - The entities become SQL tables
  - Attributes of an entity become columns in the corresponding table
  - Relationships may be represented by foreign keys

- Each entity becomes a table in the database
  - The name of the table is often the name of the entity
  - The attributes become columns of the table with the same name



- A table called Student
- With columns for ID, Name, Address, and Year

## Schema and Catalog Concepts in SQL

- An SQL schema is identified by a schema name, and includes an authorization identifier to indicate the user or account who owns the schema, as well as descriptors for each element in the schema.
- Schema elements include tables, constraints, views, domains, and other constructs that describe the schema
- A schema is created via the CREATE SCHEMA statement, which can include all the schema elements definitions.

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- Creates a schema called COMPANY, owned by the user with authorization identifier 'Jsmith'.

```
CREATE SCHEMA COMPANY AUTHORIZATION 'Jsmith';
```

- not all users are authorized to create schemas and schema elements.
- The privilege to create schemas, tables, and other constructs must be explicitly granted to the relevant user accounts by the system administrator or DBA.
- schema is synonymous with database. As the query is written to create the database, similarly the query can be written to create the schema.

```
create database yourDatabaseName;
```

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## SQL environment

- SQL environment is basically an installation of an SQL-compliant RDBMS on a computer system
- SQL uses the concept of a catalog a named collection of schemas in an SQL environment.
- A catalog always contains a special schema called INFORMATION\_SCHEMA,
  - which provides information on all the schemas in the catalog and all the element descriptors in these schemas

## Cont..

- Integrity constraints such as referential integrity can be defined between relations only if they exist in schemas within the same catalog.
- Schemas within the same catalog can also share certain elements, such as domain definitions.

## DATABASE LANGUAGES

1. Data Definition Language (DDL):
  - It is used to specify a database conceptual schema using set of definitions.
  - It supports the definition or declaration of database objects.
  - The more common DDL commands are
    - a.CREATE TABLE:
    - ALTER TABLE
    - DROP TABLE
    - TRUNCATE
    - COMMENT
    - RENAME

## 2. Data Manipulation Language (DML)

- It provides a set of operations to support the basic data manipulation operations on the data held in the database.
- It is used to query, update or retrieve data stored in a database.
- Some of the tasks that come under DML are
  - **SELECT**
    - Used to query and display data from a database.
  - **INSERT**
    - Adds new rows to a table.
  - **UPDATE**
    - Changes an existing value in a column or group of columns in a table.
  - **DELETE:**
    - Removes a specified row or set of rows from a table.
  - **MERGE.**

## SQL Data Definition

- The set of relations in a database are specified using a data-definition language (DDL)
- The SQL DDL allows specification of not only a set of relations, but also information about each relation, including:
  - The schema for each relation.
  - The types of values associated with each attribute.
  - The integrity constraints.
  - The set of indices to be maintained for each relation.
  - The security and authorization information for each relation.
  - The physical storage structure of each relation on disk.



## Basic Schema Definition: CREATE TABLE Command in SQL

- CREATE TABLE command is used to specify a new relation by giving it a name and specifying its attributes and initial constraints.
- The attributes are specified first, and each attribute is given a name, a data type to specify its domain of values, and any attribute constraints, such as NOT NULL.
- The key, entity integrity, and referential integrity constraints can be specified within the CREATE TABLE statement

## CREATE TABLE

- Specifies a new base relation by giving it a **name**, and specifying each of its **attributes** and their **data types** (INTEGER, FLOAT, DECIMAL(i,j), CHAR(n), VARCHAR(n))
- A constraint NOT NULL may be specified on an attribute

```
CREATE TABLE DEPARTMENT (  
    DNAME          VARCHAR(10)    NOT NULL,  
    DNUMBER        INTEGER        NOT NULL,  
    MGRSSN         CHAR(9) ,  
    MGRSTARTDATE   CHAR(9)      ) ;
```

The general form of the **create table** command is:

```
create table r
    (A1 D1,
     A2 D2,
     ...,
     An Dn,
     ⟨integrity-constraint1⟩,
     ...,
     ⟨integrity-constraintk⟩);
```

- The relations declared through **CREATE TABLE** statements are called base tables
- this means that the relation and its tuples are actually created and stored as a file by the DBMS

- In SQL2, can use the CREATE TABLE command for specifying the primary key attributes, secondary keys, and referential integrity constraints (foreign keys).
- Key attributes can be specified via the PRIMARY KEY and UNIQUE phrases

```
CREATE TABLE DEPT (  
    DNAME          VARCHAR(10)    NOT NULL,  
    DNUMBER        INTEGER        NOT NULL,  
    MGRSSN         CHAR(9) ,  
    MGRSTARTDATE   CHAR(9) ,  
    PRIMARY KEY (DNUMBER) ,  
    UNIQUE (DNAME) ,  
    FOREIGN KEY (MGRSSN) REFERENCES EMP ) ;
```

## Attribute Data Types and Domains in SQL

- The basic data types available for attributes include
  - numeric,
  - character string,
  - bit string,
  - Boolean,
  - date, and time
  - timestamp

## Domain Types in SQL

- **char(n)**: Fixed length character string, with user-specified length n.
- **varchar(n)**: Variable length character strings, with user-specified maximum length n.
- **int**: Integer (a finite subset of the integers that is machine-dependent).
- **smallint**: Small integer (a machine-dependent subset of the integer domain type).
- **numeric(p,d)**: Fixed point number, with user-specified precision of p digits, with d digits to the right of decimal point. (ex., numeric(3,1), allows 44.5 to be stored exactly, but not 444.5 or 0.32)
- **real, double precision**: Floating point and double-precision floating point numbers, with machine-dependent precision.
- **float(n)**: Floating point number, with user-specified precision of at least n digits.

## Specifying Constraints in SQL

- Specifying Attribute Constraints and Attribute Defaults
- Specifying Key and Referential Integrity Constraints
- Giving Names to Constraints
- Specifying Constraints on Tuples Using **CHECK**

## Specifying Attribute Constraints and Attribute Defaults

- a constraint **NOT NULL** may be specified if NULL is not permitted for a particular attribute.
- This is always implicitly specified for the attributes that are part of the primary key of each relation,
  - but it can be specified for any other attributes whose values are required not to be NULL
- It is also possible to define a default value for an attribute by appending the clause **DEFAULT <value>** to an attribute definition.

- If no default clause is specified, the default default value is NULL for attributes that do not have the NOT NULL constraint.
- Another type of constraint can restrict attribute or domain values using the **CHECK clause** following an attribute or domain definition.

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- suppose that department numbers are restricted to integer numbers between 1 and 20;
- then, we can change the attribute declaration of Dnumber in the DEPARTMENT table

**Dnumber INT NOT NULL CHECK (Dnumber > 0 AND Dnumber < 21);**

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## Specifiying Key and Referential

- **PRIMARY KEY**
  - specifies one or more attributes that make up the primary key of a relation.
  - If a primary key has a single attribute, the clause can follow the attribute directly

**Dnumber INT PRIMARY KEY;**

- **UNIQUE**

- specifies alternate (secondary) keys
- can also be specified directly for a secondary key if the secondary key is a single attribute

```
Dname VARCHAR(15) UNIQUE;
```

- **FOREIGN KEY**

- a referential integrity constraint can be **violated** when tuples are **inserted or deleted**, or when a **foreign key or primary key attribute value is modified**
- the schema designer
  - can specify an alternative action to be taken by attaching a referential **triggered action clause** to any foreign key constraint. The options include:
    - ✓ **SET NULL**,
    - ✓ **CASCADE**, and
    - ✓ **SET DEFAULT**.
  - An option must be qualified with either
    - ✓ **ON DELETE** or
    - ✓ **ON UPDATE**

```
CREATE TABLE EMPLOYEE
(
    ...,
    Dno      INT          NOT NULL      DEFAULT 1,
    CONSTRAINT EMPPK
    PRIMARY KEY (Ssn),
    CONSTRAINT EMPSUPERFK
    FOREIGN KEY (Super_ssn) REFERENCES EMPLOYEE(Ssn)
        ON DELETE SET NULL ON UPDATE CASCADE,
    CONSTRAINT EMPDEPTFK
    FOREIGN KEY (Dno) REFERENCES DEPARTMENT(Dnumber)
        ON DELETE SET DEFAULT ON UPDATE CASCADE);
```

- ON DELETE SET NULL and ON UPDATE CASCADE for the foreign key Super\_ssn of EMPLOYEE means
  - if the tuple for a supervising employee is deleted,
  - the value of Super\_ssn is automatically set to NULL for all employee tuples that were referencing the deleted employee tuple
  - if the Ssn value for a supervising employee is updated the new value is cascaded to Super\_ssn for all employee tuples referencing the updated employee tuple

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## Giving Names to Constraints

- a constraint may be given a constraint name, following the keyword CONSTRAINT
- The names of all constraints within a particular schema must be unique.
- A constraint name is used to identify a particular constraint
  - in case the constraint must be dropped later and replaced with another constraint



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```
CREATE TABLE DEPARTMENT
(
    ...,
    Mgr_ssn CHAR(9) NOT NULL DEFAULT '88866555',
    ...,
    CONSTRAINT DEPTPK
    PRIMARY KEY(Dnumber),
    CONSTRAINT DEPTSK
    UNIQUE (Dname),
    CONSTRAINT DEPTMGFK
    FOREIGN KEY (Mgr_ssn) REFERENCES EMPLOYEE(Ssn)
    ON DELETE SET DEFAULT ON UPDATE CASCADE);
```

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## Specifying Constraints on Tuples Using CHECK

- CHECK clauses is specified at the end of a CREATE TABLE statement
- These can be called tuple-based constraints because they apply to each tuple individually and are checked whenever a tuple is inserted or modified

- The following SQL creates a CHECK constraint on the "Age" column when the "Persons" table is created. The CHECK constraint ensures that the age of a person must be 18, or older:

```
CREATE TABLE Persons (  
    ID int NOT NULL,  
    LastName varchar(255) NOT NULL,  
    FirstName varchar(255),  
    Age int,  
    CHECK (Age>=18)  
);
```

## DROP TABLE

- The SQL DROP TABLE statement is used to remove a table definition and all the data, indexes, triggers, constraints and permission specifications for that table.
- You should be very careful while using this command because once a table is deleted then all the information available in that table will also be lost forever.

```
DROP TABLE table_name;
```

## ALTER TABLE

- The SQL ALTER TABLE command is used to add, delete or modify columns in an existing table.
- You should also use the ALTER TABLE command to add and drop various constraints on an existing table.
- The basic syntax of an ALTER TABLE command to add a New Column in an existing table is as follows.

```
ALTER TABLE table_name ADD column_name datatype;
```

- The basic syntax of an ALTER TABLE command to DROP COLUMN in an existing table is as follows.

```
ALTER TABLE table_name DROP COLUMN column_name;
```

- The basic syntax of an ALTER TABLE command to change the DATA TYPE of a column in a table is as follows.

```
ALTER TABLE table_name MODIFY COLUMN column_name datatype;
```

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- The basic syntax of an ALTER TABLE command to add a NOT NULL constraint to a column in a table is as follows.

```
ALTER TABLE table_name MODIFY column_name datatype NOT NULL;
```

- The basic syntax of ALTER TABLE to ADD UNIQUE CONSTRAINT to a table is as follows

```
ALTER TABLE table_name  
ADD CONSTRAINT MyUniqueConstraint UNIQUE(column1, column2...);
```

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- The basic syntax of an ALTER TABLE command to ADD CHECK CONSTRAINT to a table is as follows.

```
ALTER TABLE table_name  
ADD CONSTRAINT MyUniqueConstraint CHECK (CONDITION);
```

- The basic syntax of an ALTER TABLE command to ADD PRIMARY KEY constraint to a table is as follows.

```
ALTER TABLE table_name  
ADD CONSTRAINT MyPrimaryKey PRIMARY KEY (column1, column2...);
```

- The basic syntax of an ALTER TABLE command to DROP CONSTRAINT from a table is as follows.

```
ALTER TABLE table_name  
DROP CONSTRAINT MyUniqueConstraint;
```

## INSERT Command

- INSERT is used to add a single tuple to a relation.
- We must specify the relation name and a list of values for the tuple.
- The values should be listed in the same order in which the corresponding attributes were specified in the CREATE TABLE command.

**U1:**     **INSERT INTO**     **EMPLOYEE**  
          **VALUES**            ( 'Richard', 'K', 'Marini', '653298653', '1962-12-30', '98  
                                 Oak Forest, Katy, TX', 'M', 37000, '653298653', 4 );

**EMPLOYEE**

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
			↑↑↑↑						

- A second form of the INSERT statement allows the user to specify explicit attribute names that correspond to the values provided in the INSERT command.
- This is useful if a relation has many attributes but only a few of those attributes are assigned values in the new tuple.
- However, the values must include all attributes with NOT NULL specification and no default value.
- Attributes with NULL allowed or DEFAULT values are the ones that can be left out.
- For example, to enter a tuple for a new EMPLOYEE for whom we know only the Fname, Lname, Dno, and Ssn attributes

**U1A:**     **INSERT INTO**     **EMPLOYEE (Fname, Lname, Dno, Ssn)**  
          **VALUES**            ( 'Richard', 'Marini', 4, '653298653' );

- Attributes not specified in U1A are set to their DEFAULT or to NULL, and the values are listed in the same order as the attributes are listed in the INSERT command itself.
- It is also possible to insert into a relation multiple tuples separated by commas in a single INSERT command.
- The attribute values forming each tuple are enclosed in parentheses.

- A DBMS that fully implements SQL should support and enforce all the integrity constraints that can be specified in the DDL

**U3:**    **INSERT INTO**    EMPLOYEE (Fname, Lname, Ssn, Dno)  
         **VALUES**        ('Robert', 'Hatcher', '980760540', 2);  
         (U2 is rejected if referential integrity checking is provided by DBMS.)

**U2A:**   **INSERT INTO**    EMPLOYEE (Fname, Lname, Dno)  
         **VALUES**        ('Robert', 'Hatcher', 5);  
         (U2A is rejected if NOT NULL checking is provided by DBMS.)

no department  
no 2 is available

- A variation of the INSERT command inserts multiple tuples into a relation in conjunction with creating the relation and loading it with the result of a query.
- For example,
  - to create a temporary table that has the employee last name, project name, and hours per week for each employee working on a project

```
U3A:  CREATE TABLE      WORKS_ON_INFO
      ( Emp_name          VARCHAR(15),
        Proj_name         VARCHAR(15),
        Hours_per_week    DECIMAL(3,1) );
```

```
U3B:  INSERT INTO      WORKS_ON_INFO ( Emp_name, Proj_name,
                                         Hours_per_week )
      SELECT            E.Lname, P.Pname, W.Hours
      FROM              PROJECT P, WORKS_ON W, EMPLOYEE E
      WHERE             P.Pnumber=W.Pno AND W.Essn=E.Ssn;
```

## The DELETE Command

- The DELETE command removes tuples from a relation.
- It includes a WHERE clause, similar to that used in an SQL query, to select the tuples to be deleted.
- Tuples are explicitly deleted from only one table at a time.
- However, the deletion may propagate to tuples in other relations if referential triggered actions are specified in the referential integrity constraints of the DDL



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U4A:	DELETE FROM	EMPLOYEE
	WHERE	Lname='Brown';
U4B:	DELETE FROM	EMPLOYEE
	WHERE	Ssn='123456789';
U4C:	DELETE FROM	EMPLOYEE
	WHERE	Dno=5;
U4D:	DELETE FROM	EMPLOYEE;

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- Depending on the number of tuples selected by the condition in the WHERE clause, zero, one, or several tuples can be deleted by a single DELETE command.
- A missing WHERE clause specifies that all tuples in the relation are to be deleted; however, the table remains in the database as an empty table.
- We must use the DROP TABLE command to remove the table definition

## TRUNCATE TABLE COMMAND

- The SQL TRUNCATE TABLE command is used to delete complete data from an existing table.
- You can also use DROP TABLE command to delete complete table but it would remove complete table structure from the database and you would need to re-create this table once again if you wish you store some data.

```
TRUNCATE TABLE table_name;
```

## The UPDATE Command

- The UPDATE command is used to modify attribute values of one or more selected tuples.
- As in the DELETE command, a WHERE clause in the UPDATE command selects the tuples to be modified from a single relation

The basic syntax of the UPDATE query with a WHERE clause is as follows –

```
UPDATE table_name  
SET column1 = value1, column2 = value2..., columnN = valueN  
WHERE [condition];
```

Consider the CUSTOMERS table having the following records –

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000.00
2	Khilan	25	Delhi	1500.00
3	kaushik	23	Kota	2000.00
4	Chaitali	25	Mumbai	6500.00
5	Hardik	27	Bhopal	8500.00
6	Komal	22	MP	4500.00
7	Muffy	24	Indore	10000.00

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```
SQL> UPDATE CUSTOMERS
SET ADDRESS = 'Pune'
WHERE ID = 6;
```



Now, the CUSTOMERS table would have the following records –

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000.00
2	Khilan	25	Delhi	1500.00
3	kaushik	23	Kota	2000.00
4	Chaitali	25	Mumbai	6500.00
5	Hardik	27	Bhopal	8500.00
6	Komal	22	Pune	4500.00
7	Muffy	24	Indore	10000.00

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- updating a primary key value may propagate to the foreign key values of tuples in other relations if such a referential triggered action is specified in the referential integrity constraints of the DDL
- An additional SET clause in the UPDATE command specifies the attributes to be modified and their new values.
- It is also possible to specify NULL or DEFAULT as the new attribute value
- each UPDATE command explicitly refers to a single relation only.
- To modify multiple relations, we must issue several UPDATE commands.

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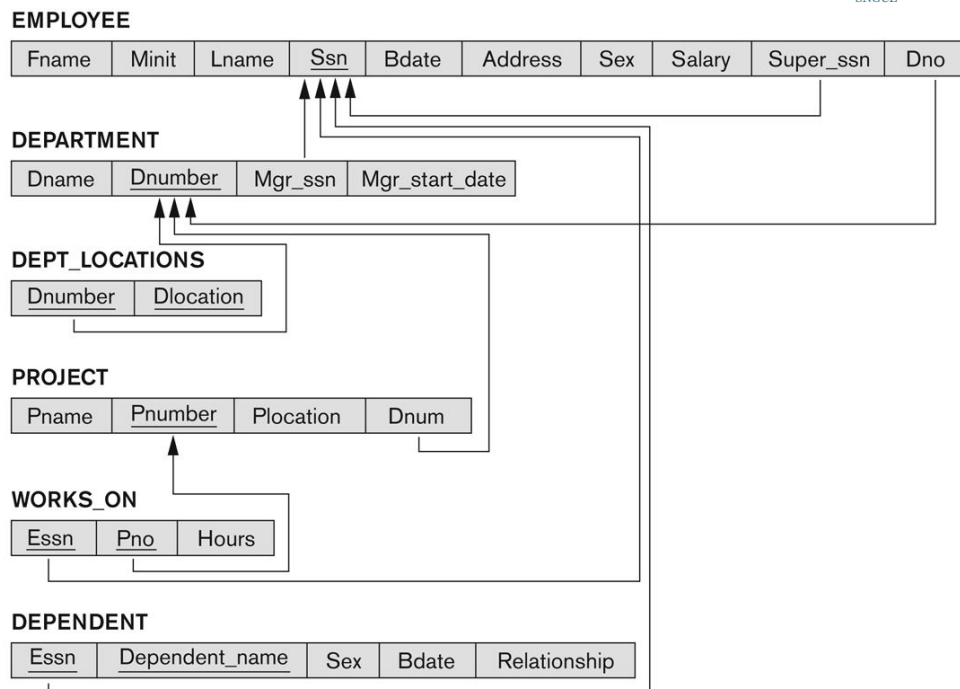
**U5:      UPDATE      PROJECT**  
**SET        Plocation = 'Bellaire', Dnum = 5**  
**WHERE      Pnumber=10;**

**U6:      UPDATE      EMPLOYEE**  
**SET        Salary = Salary \* 1.1**  
**WHERE      Dno = 5;**

**Figure 5.7**

Referential integrity constraints displayed on the COMPANY relational database schema.

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**MODULE 2 ENDS**