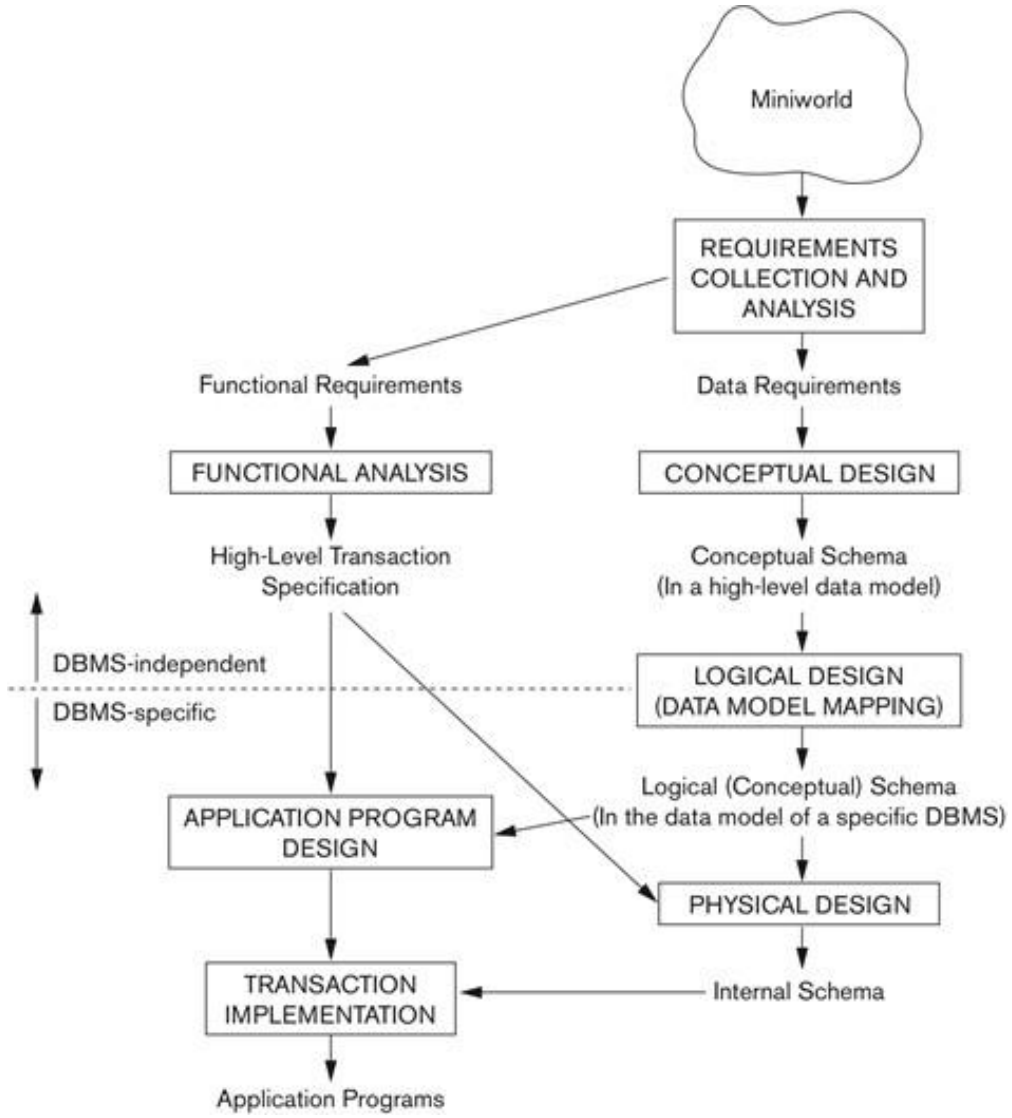
Lesson 5: Relational Data Model & Relational Database Constraints

CSC430/530 – DATABASE MANAGEMENT SYSTEMS

OUTLINE

- Relational model concepts.
- Characteristics of relations.
- Relational model constraints.
- Operations & constraints violations.

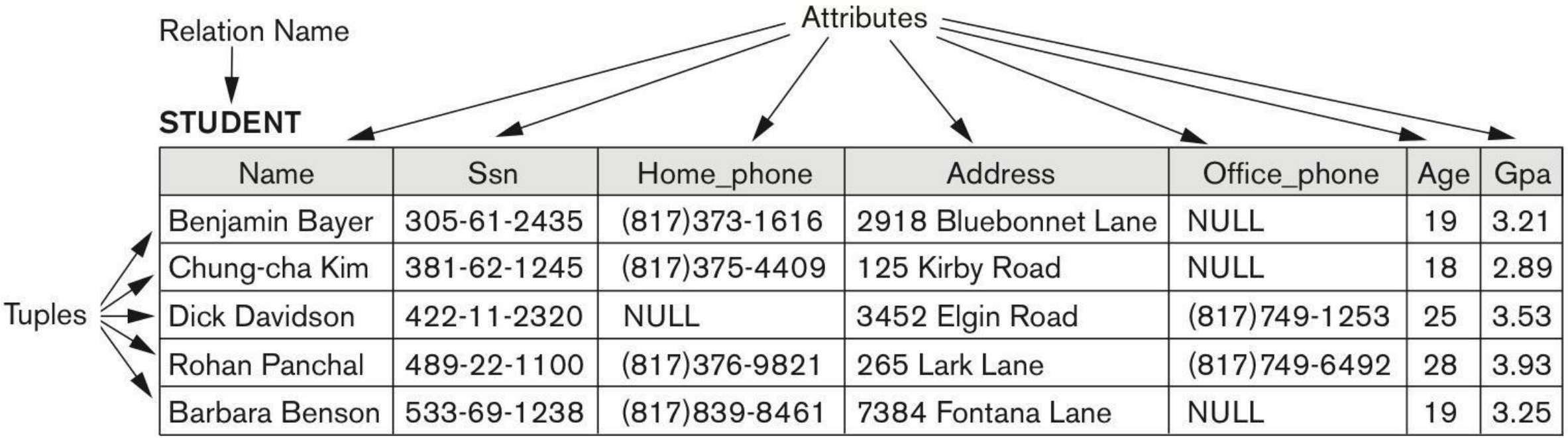


RELATIONAL MODEL CONCEPTS: INTRO

- **Relational model** represents the database as a **collection** of **relations**.
- Relation looks like a **table** of values:
  - **Table name**.
    - Describes the meaning of the relation.
  - **Column header**.
    - Indicates the meaning of the data items in that column.
    - Formally – **attribute**.
  - **Row**.
    - Collection of related data values.
    - Represents certain facts that correspond to a real-world entity or relationship**.**
    - Formally – **tuple**.
  - **Domain**.
    - Data type describing the types of values that can appear in each column.

RELATIONAL MODEL CONCEPTS: EXAMPLE

- **Example** of *STUDENT* relation.
  - **Attributes** - *Name*, *Ssn*, *Home_phone*, *Address*, *Office_phone*, *Age*, *Gpa*.



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
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

Attributes and tuples of STUDENT relation

RELATIONAL MODEL CONCEPTS: SCHEMA

- **Schema** (*description*) of a relation is denoted by $R(A_1, A_2, \ldots, A_n)$, where:
  - R – **name** of the relation;
  - $A_1, A_2, \ldots, A_n$ – list of **attributes** of the relation.
    - A_i – **name** of the role played by **attribute** in the relational schema R.
- **Example**:
  - CUSTOMER (CID, CName, Address, Phone#)
    - *CUSTOMER* is the **relation name** defined over the four **attributes**: *CID*, *CName*, *Address*, *Phone#*.

RELATIONAL MODEL CONCEPTS: TUPLE

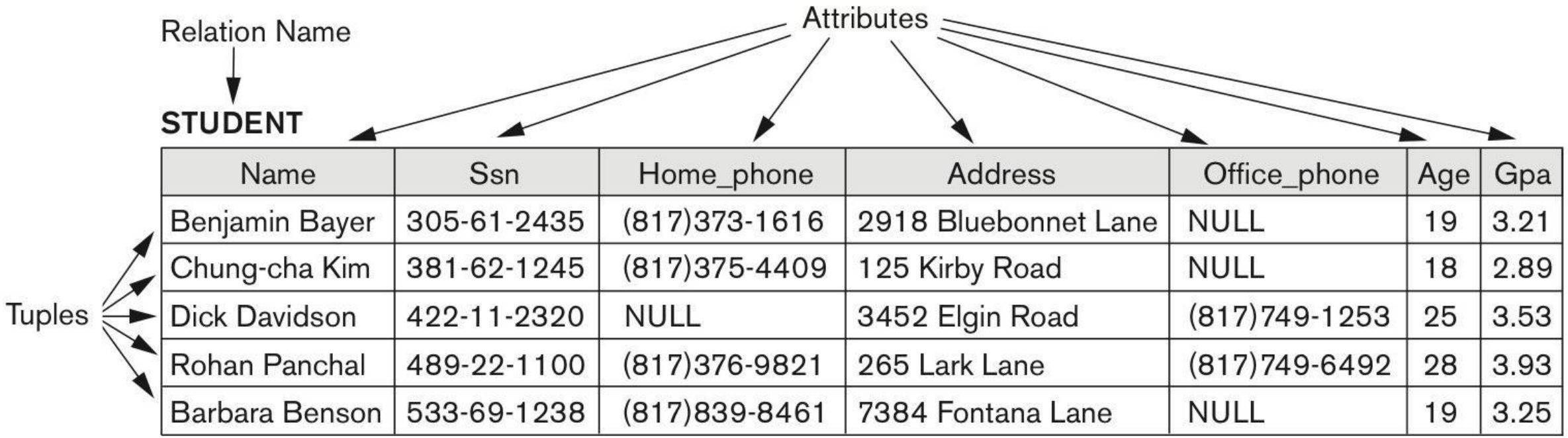
- **Tuple** is an ordered set of values.
  - Enclosed in angled brackets ‘<…>’.
  - Each value is derived from an appropriate **domain**.
  - **Relation** is a **set** of **tuples**.
- **Example**:
  - A row in the *CUSTOMER* relation consists of four values:
    - <632895, "John Smith", "101 Main St. Atlanta, GA 30332", "(404)894-2000">
      - This is called a **4-tuple** of the *CUSTOMER* relation.

RELATIONAL MODEL CONCEPTS: DOMAIN

- **Domain** *D* is a **set** of atomic values.
  - Atomic values are **indivisible**.
- Domain specifies **data type** and **format** for an attribute.
  - *"Phone#"* has a format: (ddd)ddd-dddd where each d is a decimal digit.
- In addition, domain provides a **logical definition**.
  - *"Phone#"* is the set of 10-digit phone numbers valid in the U.S.
- **Domain role** in a relation is designated by the **attribute name**.
  - Interprets the **meaning** of the data elements corresponding to that **attribute**.
  - The domain *"Phone#"* may be used to define two attributes - "Home-phone" and "Work-phone".

RELATIONAL MODEL CONCEPTS: STATE

- **Relation state** *r* of the relation schema $R(A_1, A_2, \ldots, A_n)$ is denoted by $r(R)$.
  - Set of n-tuples $r = \{t_1, t_2, \ldots, t_m\}$.
    - Each n-tuple *t* is an ordered list of *n* values, $t = \langle v_1, v_2, \ldots, v_n \rangle$.
    - Each value v_i is an element of $dom(A_i)$ or a *NULL* value.



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	(817)373-1616	2918 Bluebonnet Lane	NULL	19	3.21
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Barbara Benson	533-69-1238	(817)839-8461	7384 Fontana Lane	NULL	19	3.25

Attributes and tuples of STUDENT relation

RELATIONAL MODEL CONCEPTS: SUMMARY

- $R(A_1, A_2, \ldots, A_n)$ - **schema** of the relation.
  - R - **name** of the relation.
  - $A_1, A_2, \ldots, A_n$ - **attributes** of the relation.
- $r(R) = \{t_1, t_2, \ldots, t_m\}$ - **state** of the relation R.
  - $t_i = \langle v_1, v_2, \ldots, v_n \rangle$ - **n-tuple** of the state.
  - v_j - **element** of $dom(A_j)$.

Informal Terms		**Formal Terms**
Table	=	Relation
Column Header	=	Attribute
All possible Column Values	=	Domain
Row	=	Tuple
Table Definition	=	Schema of the Relation
Populated Table	=	State of the Relation

CHARACTERISTICS OF RELATIONS (1)

- **Ordering** of **tuples** in a relation *r(R)*.
  - Relation is defined as a **set** of tuples.
  - The tuples are **not ordered**.
- **Ordering** of **attributes** in a relation schema *R*.
  - Attributes in $R(A_1, A_2, ..., A_n)$ and the values in $t = <v_1, v_2, ..., v_n>$ are **ordered**.
    - Alternatively, tuple can be represented as a set of {<attribute>, <value>} pairs.
      - t = {<name, "John" >, <SSN, 123456789>}.

STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	(817)749-1253	25	3.53
Barbara Benson	533-69-1238	(817)839-8461	7384 Fontana Lane	NULL	19	3.25
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Relation STUDENT with different order of tuples

CHARACTERISTICS OF RELATIONS (2)

- **Values** in a tuple.
  - All values are considered **atomic** (*indivisible*).
    - Composite and multivalued attributes are **not allowed**.
  - Each value in a tuple must be from the **domain** of the attribute for that column.
  - A special **NULL** value is used when:
    - Value is **unknown**;
    - Value exists, but is **not available**;
    - Value is **undefined**.

RELATIONAL MODEL CONSTRAINTS

- Relational model **constraints** are **restrictions** on actual values in a database state.
  - Derived from the **rules** of database mini-world.
- **Three main types of constraints**:
  - **Inherent** (*implicit*) **constraints**.
    - Expressed as the characteristics of the relations.
  - **Schema-based** (*explicit*) **constraints**.
    - Directly expressed in the schemas of the data model.
  - **Application-based** (*semantic*) **constraints**.
    - Expressed and enforced by the application programs.
- In addition, there are **data dependencies** (*functional* & *multivalued*).
  - For testing the "goodness" of the design of a relational database.
  - Utilized during **normalization** process.

SCHEMA-BASED CONSTRAINTS

- **Schema-based constraints** include:
  - **Domain** constraint.
  - **Key** constraint.
  - **Entity integrity** constraint.
  - **Referential integrity** constraint.

SCHEMA-BASED CONSTRAINTS: DOMAIN

- **Domain constraint** - the value of an **attribute** *A* within tuple must be an **atomic value** from the **domain** *dom(A)*.
- **Typical data types**:
  - Numeric data types for integers and real numbers.
  - Characters.
  - Booleans.
  - Fixed-length and variable-length strings.
  - Date, time, timestamp.
  - Currency.
  - Other special data types.

SCHEMA-BASED CONSTRAINTS: KEY (1)

- **Key constraint -** no two tuples can have the **same** combination of values for all their attributes.
  - **Uniqueness constraint**.
- **Superkey** (SK) of *R*.
  - **Set** of attributes *SK* of *R* with the following condition:
    - No two tuples in any valid relation state *r(R)* have the same value for *SK*.
      - For any distinct tuples t_1 and t_2 in *r(R)*, $t_1[SK] \neq t_2[SK]$.
- **Key** of *R*.
  - A **"minimal"** superkey.
  - Removal of any attribute from key results in a set of attributes that is **NOT** a **superkey** anymore.
  - Satisfies two **properties**:
    - **Two distinct tuples** in any state of the relation **cannot** have **identical values** for (all) the attributes in the key.
    - Cannot **remove** any attributes and still have the **uniqueness constraint** to hold.

SCHEMA-BASED CONSTRAINTS: KEY (2)

- **Example**:
  - *STUDENT* relation schema:
    - STUDENT(Name, Ssn, Home_phone, Address, Office_phone, Age, Gpa)
    - Attribute set *{Ssn}* is a **key**.
      - No two students can have the same value for SSN.
    - Any set of attributes that includes *Ssn* is a **superkey**, but not a **key**.
      - {Name, Ssn, Age}.
      - {Ssn, Age, Gpa}.

SCHEMA-BASED CONSTRAINTS: KEY (3)

- If a relation has several **candidate keys**, one is chosen arbitrarily to be the **primary key**.
  - The primary key attributes are underlined.
- **Value** of **primary key** is used to:
  - **Uniquely identify** each tuple in a relation.
  - **Reference** the tuple from another tuple.

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

CAR relation with two candidate keys

RELATIONAL DATABASE SCHEMA

- **Relational database schema**:
  - **Set** of **relation schemas** $S = \{R_1, R_2, ..., R_n\}$.
    - $R_1, R_2, ..., R_n$ are the names of the **individual relation schemas** within the database S.
  - Represents **set** of **integrity constraints**.

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date

DEPT_LOCATIONS

Dnumber	Dlocation

PROJECT

Pname	Pnumber	Plocation	Dnum

WORKS_ON

Essn	Pno	Hours

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship

COMPANY relational database schema

RELATIONAL DATABASE STATE (1)

- **Relational database state** (snapshot)**:**
  - **Set** of **relation states** $DB = \{r_1, r_2, ..., r_m\}$.
  - Each r_i is a state of R_i, such that the r_i relation states satisfy the integrity constraints specified in relational schema.
- **Valid state** satisfies all the **integrity constraints**.
- **Invalid state** does not satisfy the **integrity constraints**.

RELATIONAL DATABASE STATE (2)

- **Example** of populated state of *COMPANY* database.

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

State of COMPANY relational database schema

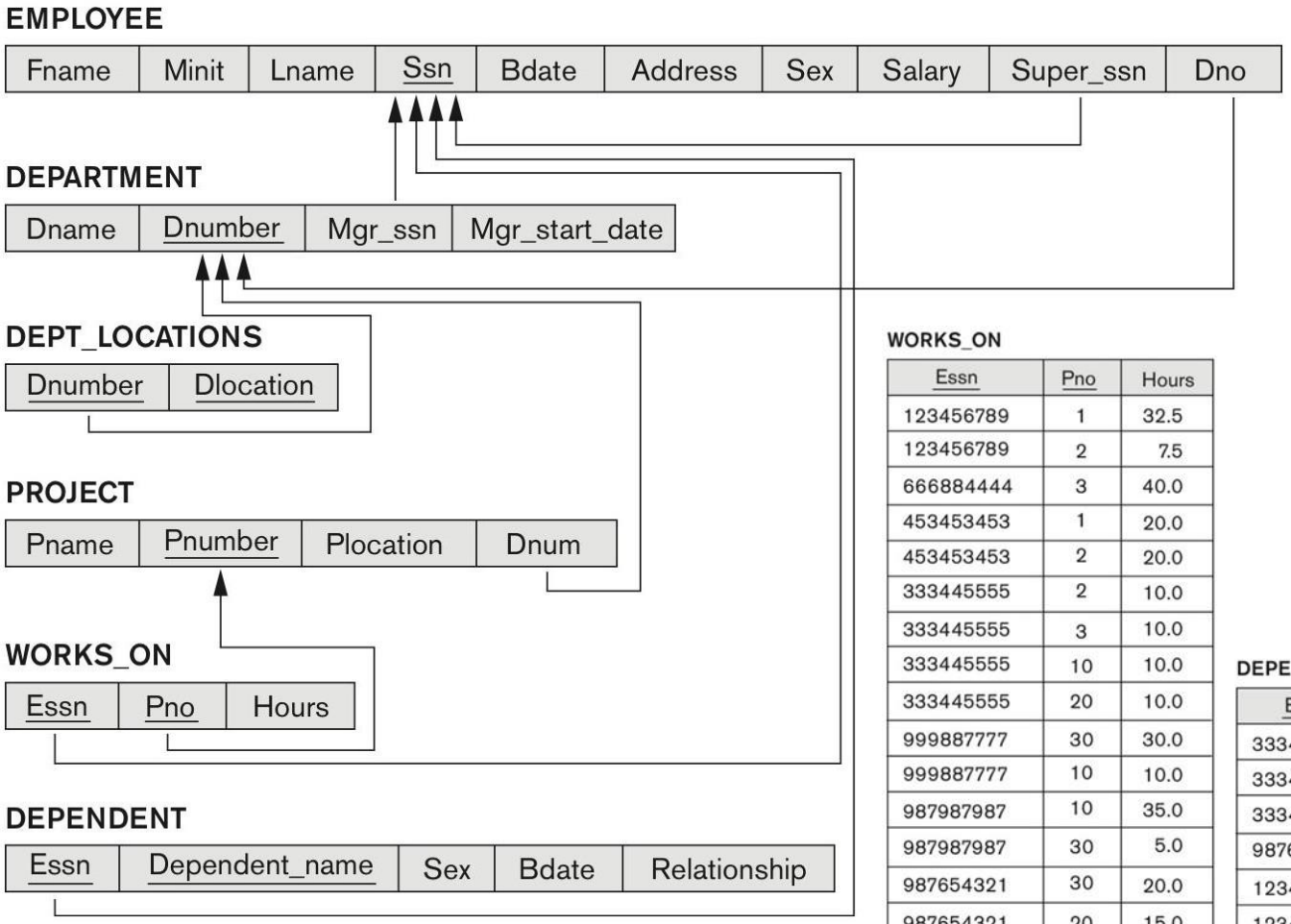
SCHEMA-BASED CONSTRAINTS: ENTITY INTEGRITY

- **Entity integrity constraint** – **primary key** attributes *PK* of each relation schema *R* in database schema *S* **cannot** have **NULL** values in any tuple of *r(R)*.
  - $t[PK] \neq NULL$ for any tuple *t* in *r(R)*.
    - If *PK* has several attributes, NULL is not allowed in any of these attributes
  - Other attributes of *R* may be **constrained** to **disallow** NULL values.
    - Even if not members of the primary key.

SCHEMA-BASED CONSTRAINTS: REFERENTIAL INTEGRITY (1)

- **Referential integrity constraint** is used to specify a **relationship** among tuples in two **relations**.
  - **Referencing** relation R_1 and **referenced** relation R_2.
  - Tuples in R_1 have **foreign key** attributes *FK* that reference the **primary key** attributes *PK* of R_2.
    - A tuple t_1 in R_1 is said to **reference** a tuple t_2 in R_2 if $t_1[FK] = t_2[PK]$.
- **Foreign key rule**:
  - The value of the ***FK*** in the **referencing relation** R_1 can either be a value of an existing ***PK*** in the **referenced relation** R_2, or **NULL**.

SCHEMA-BASED CONSTRAINTS: REFERENTIAL INTEGRITY (2)



Referential integrity constraints

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

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
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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
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Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

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

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
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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

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

Database state

OPERATIONS & CONSTRAINTS VIOLATIONS

- **Operations** of relational model:
  - **Retrievals**.
  - **Updates**.
    - **Insert** a tuple.
    - **Delete** a tuple.
    - **Modify** a tuple.
- **Update** (*modification*) operations **change** the state of the relations in database and can **violate** schema-based **constraints**.

OPERATIONS: INSERT (1)

- Provides a **list of attribute** values for a **new** tuple *t* that is to be inserted into a relation *R*.
- Insert operation can violate **any** of the **four 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.
  - **Entity integrity**.
    - If the primary key value is NULL in the new tuple
  - **Referential integrity**.
    - If a foreign key value in the new tuple references a primary key value that does not exist in the referenced relation.
- In case of violation the default option is to **reject** the insertion.

OPERATIONS: INSERT (2)

- **Examples**:
  - Insert <*'Cecilia', 'F', 'Kolonsky', NULL, '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, NULL, 4*> into EMPLOYEE.
  - Insert <*'Alicia', 'J', 'Zelaya', '999887777', '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, '987654321', 4*> into EMPLOYEE.

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
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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

OPERATIONS: INSERT (2)

- **Examples**:
  - Insert <*'Cecilia', 'F', 'Kolonsky', NULL, '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, NULL, 4*> into EMPLOYEE.
    - Violates **entity integrity constraint** (NULL for the primary key Ssn) → **rejected**.
  - Insert <*'Alicia', 'J', 'Zelaya', '999887777', '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, '987654321', 4*> into EMPLOYEE.
    - Violates **key constraint** (another tuple with the same Ssn exists in the EMPLOYEE) → **rejected**.

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

OPERATIONS: INSERT (3)

- **Examples**:
  - Insert *<'Cecilia', 'F', 'Kolonsky', '677678989', '1960-04-05', '6357 Windswept, Katy, TX', F, 28000, '987654321', 7>* into EMPLOYEE.

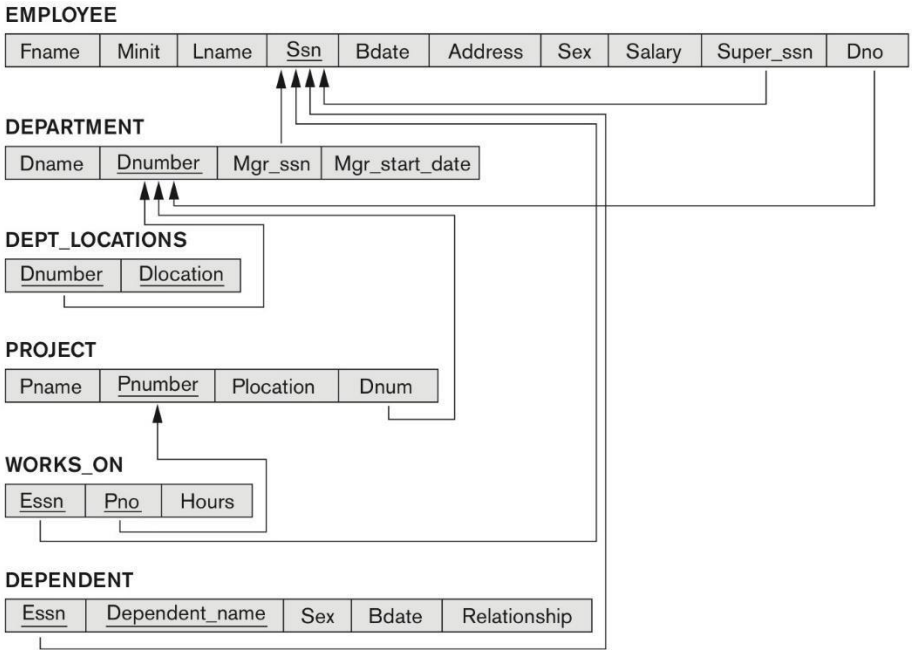
  - Insert *<'Cecilia', 'F', 'Kolonsky', '677678989', '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, NULL, 4>* into EMPLOYEE.

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



OPERATIONS: INSERT (3)

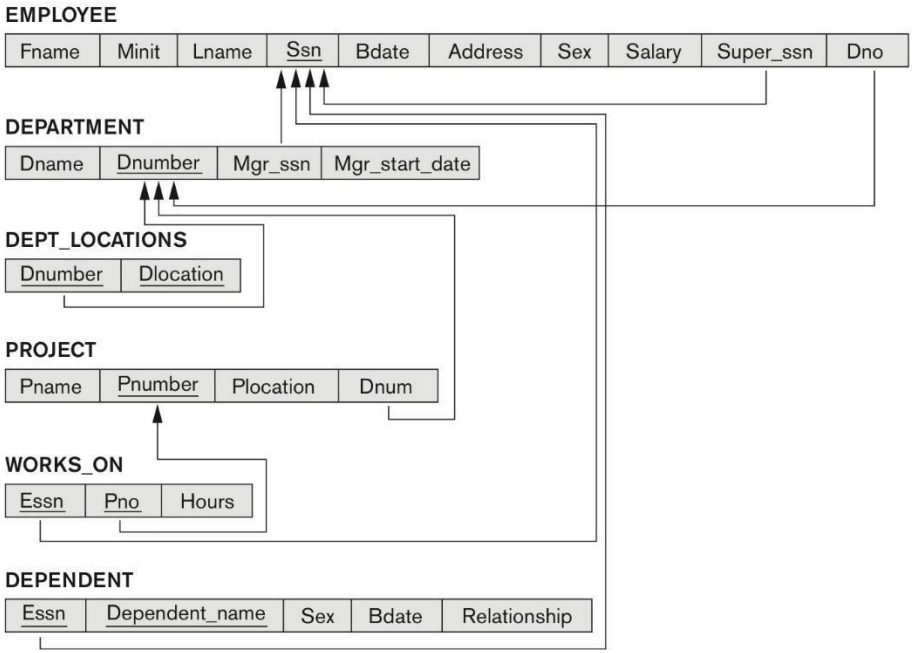
- **Examples**:
  - Insert *<'Cecilia', 'F', 'Kolonsky', '677678989', '1960-04-05', '6357 Windswept, Katy, TX', F, 28000, '987654321', 7>* into EMPLOYEE.
    - Violates **referential integrity constraint** specified on Dno in EMPLOYEE (no tuple in DEPARTMENT with Dnumber = 7) → **rejected**.
  - Insert *<'Cecilia', 'F', 'Kolonsky', '677678989', '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, NULL, 4>* into EMPLOYEE.
    - Satisfies all **constraints → accepted.**

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



OPERATIONS: DELETE (1)

- Can only violate **referential integrity**.
  - Tuple being deleted is **referenced** by **foreign keys** from other tuples in the database.
- Can be **handled** by:
  - **Restrict**.
    - Reject the deletion.
  - **Cascade**.
    - Delete the tuples referenced by the foreign key.
  - **Set NULL**.
    - Set the foreign keys of the referencing tuples to NULL.

OPERATIONS: DELETE (2)

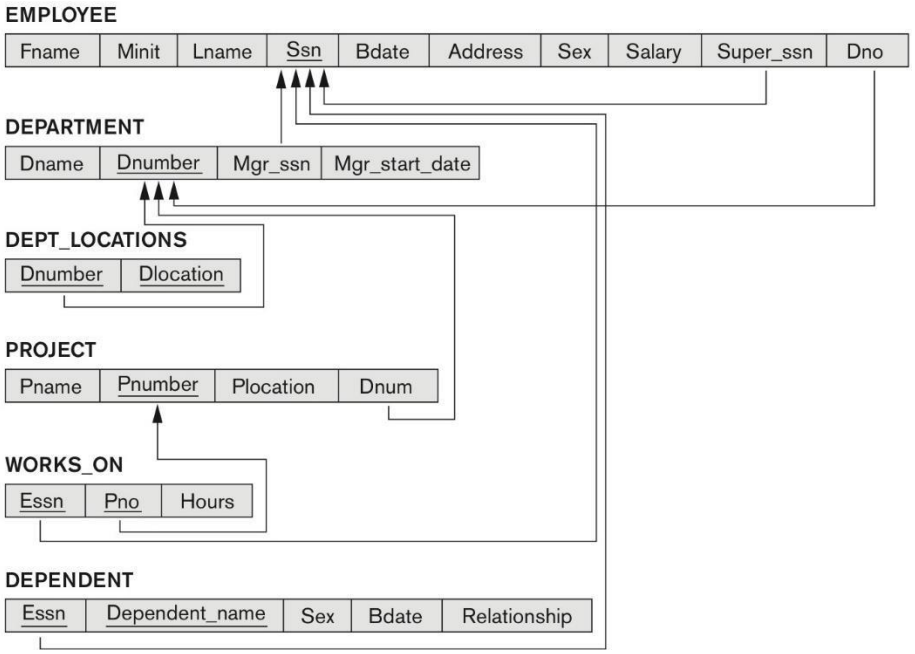
- **Examples**:
  - Delete EMPLOYEE tuple with *Ssn = '999887777'*.

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

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



OPERATIONS: DELETE (2)

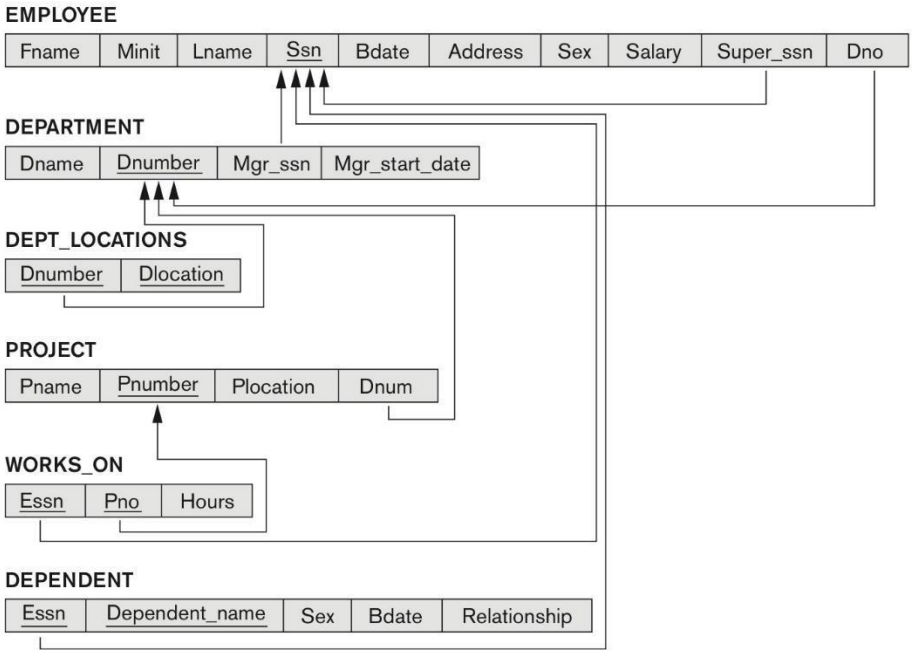
- **Examples**:
  - Delete EMPLOYEE tuple with *Ssn = '999887777'*.
    - Not acceptable, because there are tuples in WORKS_ON relation that refer to this tuple.
    - Deletion will result in **referential integrity** constraint **violations**.

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

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



OPERATIONS: DELETE (3)

- **Examples**:
  - Delete EMPLOYEE tuple with *Ssn = '333445555'*.
  - Delete WORKS_ON tuple with *Essn = '999887777'* and *Pno = 10*.

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

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

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

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

OPERATIONS: DELETE (3)

- **Examples**:
  - Delete EMPLOYEE tuple with *Ssn = '333445555'*.
    - Not acceptable, because there are tuples in EMPLOYEE, DEPARTMENT, WORKS_ON & DEPENDENT relations that refer to this tuple.
    - Deletion will result in severe **referential integrity** constraint **violations**.
  - Delete WORKS_ON tuple with *Essn = '999887777'* and *Pno = 10*.
    - Acceptable (no **referential integrity** constraint **violations**) and deletes exactly **one tuple**.

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

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

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

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

OPERATIONS: MODIFY (1)

- Used to **change** the values of one or more **attributes** in a tuple(s) of relation *R*.
  - Tuple to be modified is selected **based** on the **condition** on the **attributes** of the relation.
- **No issues** when updating the attribute that is **NOT** a part of a **primary** or **foreign key**.
  - Possibly a domain constraint violation but our DBMS should prevent this
- **Updating** attributes of a **primary** or **foreign** key causes similar issues as **insert** / **delete** operations.
  - DBMS will prevent Key and Entity integrity constraints, but Referential integrity constraint is possible

OPERATIONS: MODIFY (2)

- Can violate **referential integrity**.
  - Tuple being deleted is **referenced** by **foreign keys** from other tuples in the database.
- Can be **handled** by:
  - **Restrict**.
    - Reject the modification.
  - **Cascade**.
    - Propagate the new primary key value into the foreign keys of the referencing tuples.
  - **Set NULL**.
    - Set the foreign keys of the referencing tuples to NULL.

OPERATIONS: MODIFY (2)

- **Examples**:
  - Update the Dno of EMPLOYEE tuple with *Ssn = '999887777'* to *7*.
  - Update the Ssn of EMPLOYEE tuple with *Ssn = '999887777'* to *'987654321'*.

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

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

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

OPERATIONS: MODIFY (2)

- **Examples**:
  - Update the Dno of EMPLOYEE tuple with *Ssn = '999887777'* to *7*.
    - Not acceptable – violates **referential integrity**. No DEPARTMENT tuple with *Dnumber = 7.*
  - Update the Ssn of EMPLOYEE tuple with *Ssn = '999887777'* to *'987654321'*.
    - Not acceptable – violates **primary key constraint** ('987654321' is the SSN of another EMPLOYEE tuple).
    - In addition, it violates **referential integrity constraints** – there are other relations that refer to the existing value of Ssn.

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

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

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

OPERATIONS: MODIFY (3)

- **Examples**:
  - Update the salary of EMPLOYEE tuple with *Ssn = '999887777'* to *28000*.
  - Update the Dno of EMPLOYEE tuple with *Ssn = '999887777'* to *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

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

OPERATIONS: MODIFY (3)

- **Examples**:
  - Update the salary of EMPLOYEE tuple with *Ssn = '999887777'* to *28000*.
    - **Acceptable**.
  - Update the Dno of EMPLOYEE tuple with *Ssn = '999887777'* to *1*.
    - **Acceptable**.

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

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

SUMMARY

- Relation model concepts.
  - Relation, attribute, domain, tuple, schema and state of relation.
- Characteristics of relations.
  - Ordering of tuples, ordering of attributes, values of attributes.
- Constraints, schema & state.
  - Schema-based constraints, schema and state of relational database.
    - Domain, key, entity integrity & referential integrity constraints.
- Operations & constraints violations.
  - Insert, delete & modify operations.