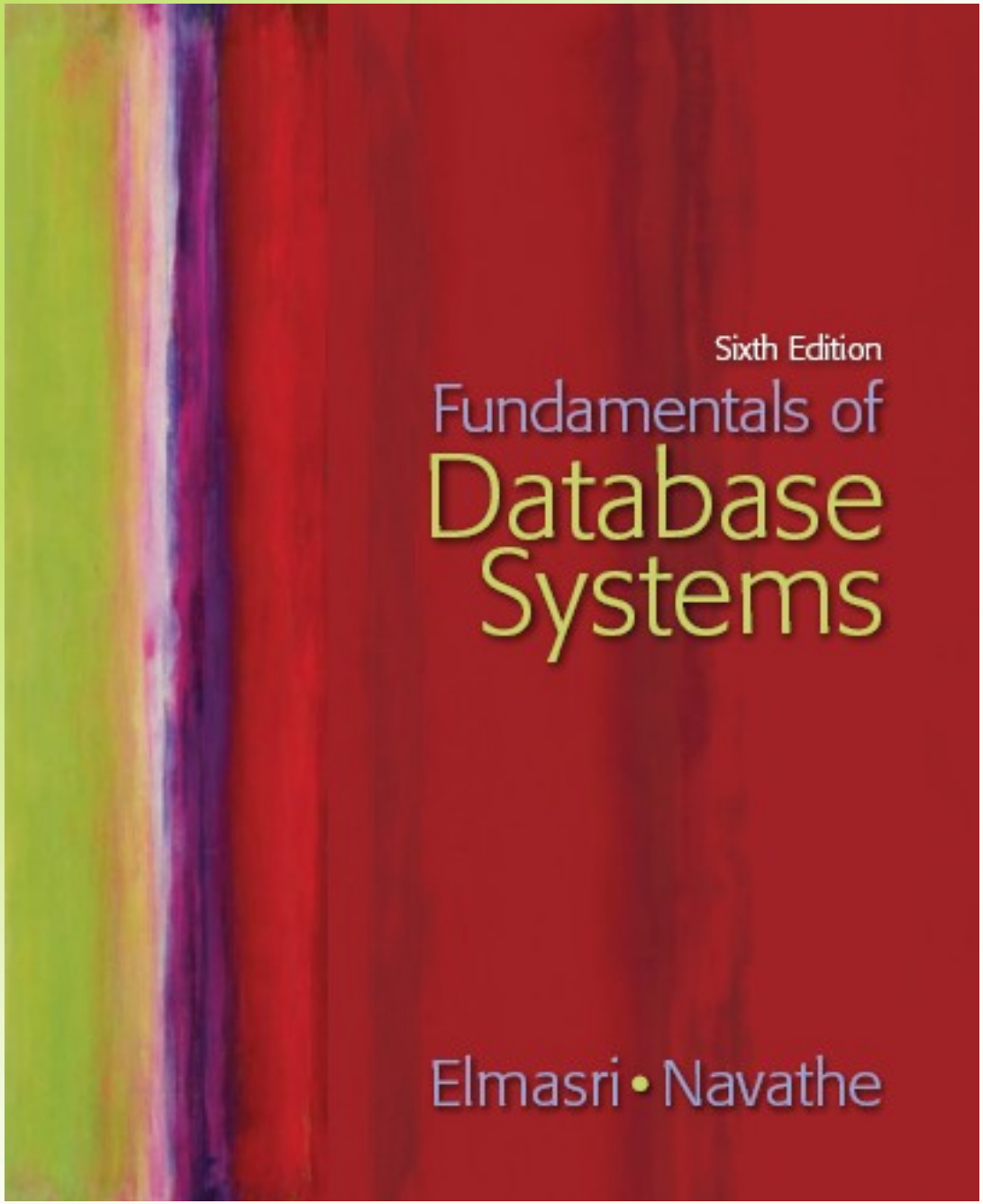
# Chapter 3

# The Relational Data Model and Relational Database Constraints

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# Chapter 3 Outline

- The Relational Data Model and Relational Database Constraints
- Relational Model Constraints and Relational Database Schemas
- Update Operations, Transactions, and Dealing with Constraint Violations

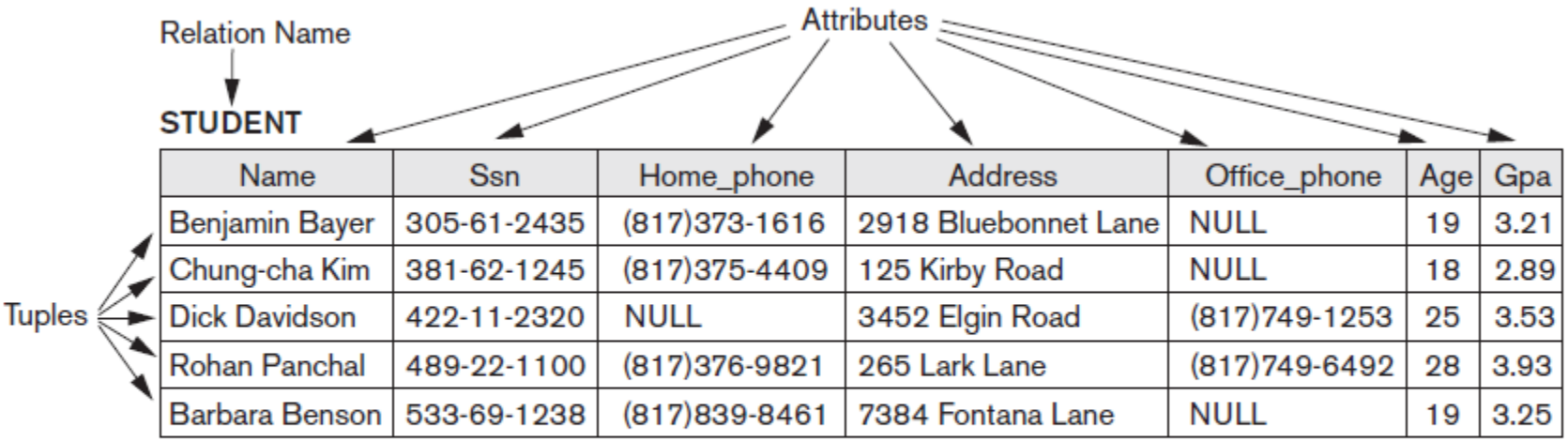
# The Relational Data Model and Relational Database Constraints

- Relational model
  - First commercial implementations available in early 1980s
  - Has been implemented in a large number of commercial system
- Hierarchical and network models
  - Preceded the relational model

# Relational Model Concepts

- Represents data as a collection of relations
- **Table** of values
  - Row
    - Represents a collection of related data values
    - Fact that typically corresponds to a real-world entity or relationship
    - *Tuple*
  - Table name and column names
    - Interpret the meaning of the values in each row *attribute*

# Relational Model Concepts (cont'd.)




| 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 |

**Figure 3.1**
The attributes and tuples of a relation STUDENT.

# Domains, Attributes, Tuples, and Relations

- **Domain** D
  - Set of atomic values
- **Atomic**
  - Each value indivisible
- Specifying a domain
  - **Data type** specified for each domain

# Domains, Attributes, Tuples, and Relations (cont'd.)

- **Relation schema** $R$
  - Denoted by $R(A_1, A_2, ..., A_n)$
  - Made up of a relation name $R$ and a list of attributes, $A_1, A_2, ..., A_n$
- Attribute $A_i$
  - Name of a role played by some domain $D$ in the relation schema $R$
- **Degree** (or **arity**) of a relation
  - Number of attributes n of its relation schema

# Domains, Attributes, Tuples, and Relations (cont'd.)

- **Relation** (or **relation state**)
  - Set of ***n*-tuples** $r = \{t_1, t_2, \ldots, t_m\}$
  - Each $n$-tuple $t$
    - Ordered list of $n$ values $t = <v_1, v_2, \ldots, v_n>$
    - Each value $v_i$, $1 \leq i \leq n$, is an element of dom($A_i$) or is a special NULL value

# Domains, Attributes, Tuples, and Relations (cont'd.)

- Relation (or relation state) $r(R)$
  - **Mathematical relation** of degree $n$ on the domains $\text{dom}(A_1)$, $\text{dom}(A_2)$, ..., $\text{dom}(A_n)$
  - **Subset** of the **Cartesian product** of the domains that define R:
    - $r(R) \subseteq (\text{dom}(A_1) \times \text{dom}(A_2) \times ... \times \text{dom}(A_n))$

# Domains, Attributes, Tuples, and Relations (cont'd.)

- **Cardinality**
  - Total number of values in domain
- **Current relation state**
  - Relation state at a given time
  - Reflects only the valid tuples that represent a particular state of the real world
- Attribute names
  - Indicate different **roles**, or interpretations, for the domain

# Characteristics of Relations

- Ordering of tuples in a relation
  - Relation defined as a set of tuples
  - Elements have no order among them
- Ordering of values within a tuple and an alternative definition of a relation
  - Order of attributes and values is not that important
  - As long as correspondence between attributes and values maintained

# Characteristics of Relations (cont'd.)

- Alternative definition of a relation
  - Tuple considered as a set of (<attribute>, <value>) pairs
  - Each pair gives the value of the mapping from an attribute $A_i$ to a value $v_i$ from dom($A_i$)
- Use the first definition of relation
  - Attributes and the values within tuples are ordered
  - Simpler notation

# Characteristics of Relations (cont'd.)

**Figure 3.2**
The relation STUDENT from Figure 3.1 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 | (817)749-1253 | 25 | 3.53 |
| Barbara Benson | 533-69-1238 | (817)839-8461 | 7384 Fontana Lane | NULL | 19 | 3.25 |
| Rohan Panchal | 489-22-1100 | (817)376-9821 | 265 Lark Lane | (817)749-6492 | 28 | 3.93 |
| Chung-cha Kim | 381-62-1245 | (817)375-4409 | 125 Kirby Road | NULL | 18 | 2.89 |
| Benjamin Bayer | 305-61-2435 | (817)373-1616 | 2918 Bluebonnet Lane | NULL | 19 | 3.21 |

# Characteristics of Relations (cont'd.)

- Values and NULLs in tuples
  - Each value in a tuple is atomic
  - **Flat relational model**
    - Composite and multivalued attributes not allowed
    - **First normal form** assumption
  - Multivalued attributes
    - Must be represented by separate relations
  - Composite attributes
    - Represented only by simple component attributes in basic relational model

# Characteristics of Relations (cont'd.)

- NULL values
  - Represent the values of attributes that may be unknown or may not apply to a tuple
  - Meanings for NULL values
    - *Value unknown*
    - *Value exists but is not available*
    - *Attribute does not apply to this tuple (also known as value undefined)*

# Characteristics of Relations (cont'd.)

- Interpretation (meaning) of a relation
  - **Assertion**
    - Each tuple in the relation is a **fact** or a particular instance of the assertion
  - **Predicate**
    - Values in each tuple interpreted as values that satisfy predicate

# Relational Model Notation

- Relation schema $R$ of degree $n$
  - Denoted by $R(A_1, A_2, ..., A_n)$
- Uppercase letters $Q$, $R$, $S$
  - Denote relation names
- Lowercase letters $q$, $r$, $s$
  - Denote relation states
- Letters $t$, $u$, $v$
  - Denote tuples

# Relational Model Notation

- Name of a relation schema: STUDENT
  - Indicates the current set of tuples in that relation
- Notation: STUDENT(Name, Ssn, ...)
  - Refers only to relation schema
- Attribute *A* can be qualified with the relation name *R* to which it belongs
  - Using the dot notation *R.A*

# Relational Model Notation

- *n-tuple t* in a relation $r(R)$
  - Denoted by $t = \langle v_1, v_2, ..., v_n \rangle$
  - $v_i$ is the value corresponding to attribute $A_i$
- Component values of tuples:
  - $t[A_i]$ and $t.A_i$ refer to the value $v_i$ in $t$ for attribute $A_i$
  - $t[A_u, A_w, ..., A_z]$ and $t.(A_u, A_w, ..., A_z)$ refer to the subtuple of values $\langle v_u, v_w, ..., v_z \rangle$ from $t$ corresponding to the attributes specified in the list

# Relational Model Constraints

- Constraints
  - Restrictions on the actual values in a database state
  - Derived from the rules in the miniworld that the database represents
- **Inherent model-based constraints** or **implicit constraints**
  - Inherent in the data model

# Relational Model Constraints (cont'd.)

- **Schema-based constraints** or **explicit constraints**
  - Can be directly expressed in schemas of the data model
- **Application-based** or **semantic constraints** or **business rules**
  - Cannot be directly expressed in schemas
  - Expressed and enforced by application program

# Domain Constraints

- Typically include:
  - Numeric data types for integers and real numbers
  - Characters
  - Booleans
  - Fixed-length strings
  - Variable-length strings
  - Date, time, timestamp
  - Money
  - Other special data types

# Key Constraints and Constraints on NULL Values

- No two tuples can have the same combination of values for all their attributes.
- **Superkey**
  - No two distinct tuples in any state *r* of *R* can have the same value for SK
- **Key**
  - Superkey of R
  - Removing any attribute *A* from *K* leaves a set of attributes *K* that is not a superkey of *R* any more

# Key Constraints and Constraints on NULL Values (cont'd.)

- Key satisfies two properties:
  - Two distinct tuples in any state of relation cannot have identical values for (all) attributes in key
  - Minimal superkey
    - Cannot remove any attributes and still have uniqueness constraint in above condition hold

# Key Constraints and Constraints on NULL Values (cont'd.)

- **Candidate key**
  - Relation schema may have more than one key
- **Primary key** of the relation
  - Designated among candidate keys
  - Underline attribute
- Other candidate keys are designated as **unique keys**

# Key Constraints and Constraints on NULL Values (cont'd.)

**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 |

**Figure 3.4**
The CAR relation, with two candidate keys: License_number and Engine_serial_number.

# Relational Databases and Relational Database Schemas

- **Relational database schema** $S$
  - Set of relation schemas $S = \{R_1, R_2, ..., R_m\}$
  - Set of integrity constraints IC
- **Relational database state**
  - Set of relation states $DB = \{r_1, r_2, ..., r_m\}$
  - Each $r_i$ is a state of $R_i$ and such that the $r_i$ relation states satisfy integrity constraints specified in IC

# Relational Databases and Relational Database Schemas (cont'd.)

- **Invalid state**
  - Does not obey all the integrity constraints
- **Valid state**
  - Satisfies all the constraints in the defined set of integrity constraints IC

# Integrity, Referential Integrity, and Foreign Keys

- **Entity integrity constraint**
  - No primary key value can be NULL
- **Referential integrity constraint**
  - Specified between two relations
  - Maintains consistency among tuples in two relations

# Integrity, Referential Integrity, and Foreign Keys (cont'd.)

- **Foreign key** rules:
  - The attributes in FK have the same domain(s) as the primary key attributes PK
  - Value of FK in a tuple $t_1$ of the current state $r_1(R_1)$ either occurs as a value of PK for some tuple $t_2$ in the current state $r_2(R_2)$ or is NULL

# Integrity, Referential Integrity, and Foreign Keys (cont'd.)

- Diagrammatically display referential integrity constraints
  - Directed arc from each foreign key to the relation it references
- All integrity constraints should be specified on relational database schema

# Other Types of Constraints

- Semantic integrity constraints
  - May have to be specified and enforced on a relational database
  - Use **triggers** and **assertions**
  - More common to check for these types of constraints within the application programs

# Other Types of Constraints (cont'd.)

- Functional dependency constraint
  - Establishes a functional relationship among two sets of attributes *X* and *Y*
  - Value of *X* determines a unique value of *Y*
- **State constraints**
  - Define the constraints that a valid state of the database must satisfy
- **Transition constraints**
  - Define to deal with state changes in the database

# Update Operations, Transactions, and Dealing with Constraint Violations

- Operations of the relational model can be categorized into retrievals and updates
- Basic operations that change the states of relations in the database:
  - Insert
  - Delete
  - Update (or Modify)

**Figure 3.6**
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 |

**Figure 3.6**
One possible database state for the COMPANY relational database schema.

**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 |

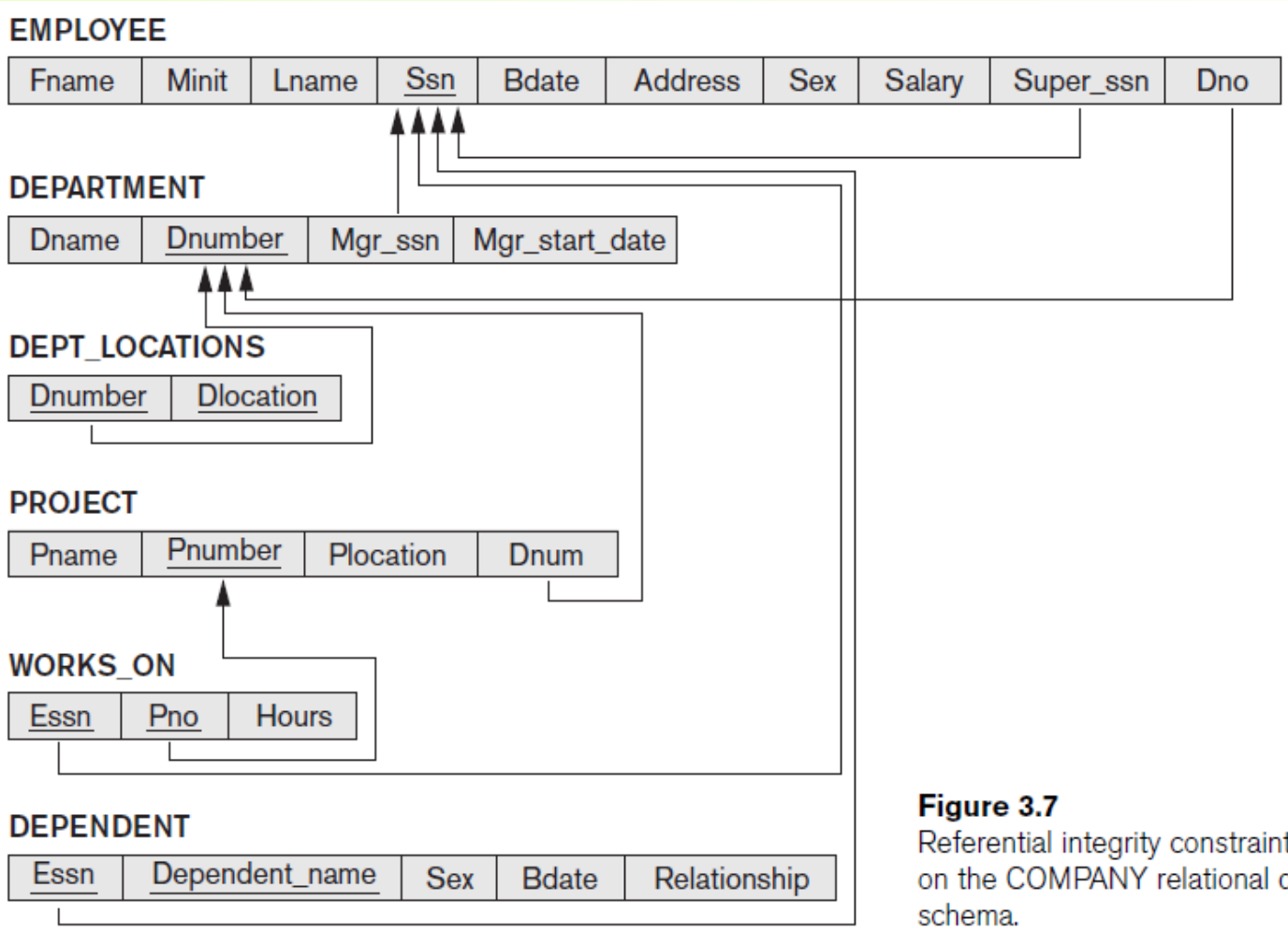



**Figure 3.7**
Referential integrity constraints displayed on the COMPANY relational database schema.

# The Insert Operation

- Provides a list of attribute values for a new tuple t that is to be inserted into a relation R
- Can violate any of the four types of constraints
- If an insertion violates one or more constraints
  - Default option is to reject the insertion

# The Delete Operation

- Can violate only referential integrity
  - If tuple being deleted is referenced by foreign keys from other tuples
  - **Restrict**
    - Reject the deletion
  - **Cascade**
    - Propagate the deletion by deleting tuples that reference the tuple that is being deleted
  - **Set null** or **set default**
    - Modify the referencing attribute values that cause the violation

# The Update Operation

- Necessary to specify a condition on attributes of relation
  - Select the tuple (or tuples) to be modified
- If attribute not part of a primary key nor of a foreign key
  - Usually causes no problems
- Updating a primary/foreign key
  - Similar issues as with Insert/Delete

# The Transaction Concept

- **Transaction**
  - Executing program
  - Includes some database operations
  - Must leave the database in a valid or consistent state
- **Online transaction processing (OLTP) systems**
  - Execute transactions at rates that reach several hundred per second

# Summary

- Characteristics differentiate relations from ordinary tables or files
- Classify database constraints into:
  - Inherent model-based constraints, explicit schema-based constraints, and application-based constraints
- Modification operations on the relational model:
  - Insert, Delete, and Update