Course Code: IS201
Course Title : Database System

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Text Book

The concepts and presentation of this course are drawn from:

- R. ElMasri & S. Navathe, “Fundamentals of Database Systems”, Addison Wesley, Fifth Edition, 20011.
- Carlos M. Coronel - Database Systems_ Design, Implementation, & Management-Cengage Learning (2018).
- Learn SQL Database Programming_ Query and manipulate databases from popular relational database servers using SQL-Packt Publishing (2020)

SQL: Schema Definition, Constraints, and Queries and Views

Data Definition, Constraints, and Schema Changes

- Used to CREATE, DROP, and ALTER the descriptions of the tables (relations) of a database

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)  );
```

CREATE TABLE

- 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  );
```

DROP TABLE

- Used to remove a relation (base table) and its definition
- The relation can no longer be used in queries, updates, or any other commands since its description no longer exists
- Example:

```
DROP TABLE  DEPENDENT;
```

ALTER TABLE

- Used to add an attribute to one of the base relations
  - The new attribute will have NULLs in all the tuples of the relation right after the command is executed; hence, the NOT NULL constraint is not allowed for such an attribute
- Example:

```
ALTER TABLE EMPLOYEE ADD JOB
VARCHAR(12);
```

- The database users must still enter a value for the new attribute JOB for each EMPLOYEE tuple.
  - This can be done using the UPDATE command.

Features Added in SQL2 and SQL-99

- Create schema
- Referential integrity options

CREATE SCHEMA

- Specifies a new database schema by giving it a name

REFERENTIAL INTEGRITY OPTIONS

- We can specify RESTRICT, CASCADE, SET NULL or SET DEFAULT on referential integrity constraints (foreign keys)

```
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
  ON DELETE SET DEFAULT ON UPDATE
  CASCADE);
```

REFERENTIAL INTEGRITY OPTIONS (continued)

```
CREATE TABLE EMP(
  ENAME        VARCHAR(30)    NOT NULL,
  ESSN         CHAR(9),
  BDATE        DATE,
  DNO          INTEGER  DEFAULT 1,
  SUPERSSN     CHAR(9),
  PRIMARY KEY (ESSN),
  FOREIGN KEY (DNO) REFERENCES DEPT
   ON DELETE SET DEFAULT ON UPDATE
  CASCADE,
  FOREIGN KEY (SUPERSSN) REFERENCES EMP
  ON DELETE SET NULL ON UPDATE CASCADE);
```

Additional Data Types in SQL2 and SQL-99

Has DATE, TIME, and TIMESTAMP data types

- **DATE:**
  - Made up of year-month-day in the format yyyy-mm-dd
- **TIME:**
  - Made up of hour:minute:second in the format hh:mm:ss
- **TIME(i):**
  - Made up of hour:minute:second plus i additional digits specifying fractions of a second
  - format is hh:mm:ss:ii...i

Additional Data Types in SQL2 and SQL-99 (contd.)

- **TIMESTAMP:**
  - Has both DATE and TIME components
- **INTERVAL:**
  - Specifies a relative value rather than an absolute value
  - Can be DAY/TIME intervals or YEAR/MONTH intervals
  - Can be positive or negative when added to or subtracted from an absolute value, the result is an absolute value

Specifying Updates in SQL

- There are three SQL commands to modify the database: **INSERT**, **DELETE**, and **UPDATE**

INSERT

- In its simplest form, it is used to add one or more tuples to a relation
- Attribute values should be listed in the same order as the attributes were specified in the **CREATE TABLE** command

INSERT (contd.)

- Example:

```
U1: INSERT INTO       EMPLOYEE
    VALUES ('Richard','K','Marini', '653298653', '30-DEC-52',
    '98 Oak Forest,Katy,TX', 'M', 37000,'987654321', 4 )
```

- An alternate form of INSERT specifies explicitly the attribute names that correspond to the values in the new tuple
  - Attributes with NULL values can be left out
- Example: Insert a tuple for a new EMPLOYEE for whom we only know the FNAME, LNAME, and SSN attributes.

```
U1A:  INSERT INTO    EMPLOYEE (FNAME, LNAME,
                                    SSN)
        VALUES ('Richard', 'Marini', '653298653')
```

INSERT (contd.)

- Important Note: Only the constraints specified in the DDL commands are automatically enforced by the DBMS when updates are applied to the database
  - Another variation of INSERT allows insertion of *multiple tuples* resulting from a query into a relation

INSERT (contd.)

- Example: Suppose we want to create a temporary table that has the name, number of employees, and total salaries for each department.
  - A table DEPTS_INFO is created by U2A, and is loaded with the summary information retrieved from the database by the query in U2B.

```
U2A:    CREATE TABLE  DEPTS_INFO
                 (DEPT_NAME           VARCHAR(10),
                  NO_OF_EMPS          INTEGER,
                  TOTAL_SAL           INTEGER);


U2B:    INSERT INTO   DEPTS_INFO (DEPT_NAME,
                      NO_OF_EMPS, TOTAL_SAL)
        SELECT        DNAME, COUNT (*), SUM (SALARY)
        FROM          DEPARTMENT, EMPLOYEE
        WHERE         DNUMBER=DNO
        GROUP BY      DNAME ;
```

INSERT (contd.)

- Note: The DEPTS_INFO table may not be up-to-date if we change the tuples in either the DEPARTMENT or the EMPLOYEE relations *after* issuing U3B. We have to create a view (see later) to keep such a table up to date.

DELETE

- Removes tuples from a relation
  - Includes a WHERE-clause to select the tuples to be deleted
  - Referential integrity should be enforced
  - Tuples are deleted from only *one table* at a time (unless CASCADE is specified on a referential integrity constraint)
  - A missing WHERE-clause specifies that *all tuples* in the relation are to be deleted; the table then becomes an empty table
  - The number of tuples deleted depends on the number of tuples in the relation that satisfy the WHERE-clause

DELETE (contd.)

- Examples:

```
U3A:    DELETE FROM    EMPLOYEE
        WHERE          LNAME='Brown’

U3B:    DELETE FROM    EMPLOYEE
        WHERE          SSN='123456789’

U3C:    DELETE FROM    EMPLOYEE
        WHERE          DNO  IN
                       (SELECT      DNUMBER
                       FROM   DEPARTMENT
                       WHERE
                       DNAME='Research')

U3D:    DELETE FROM    EMPLOYEE
```

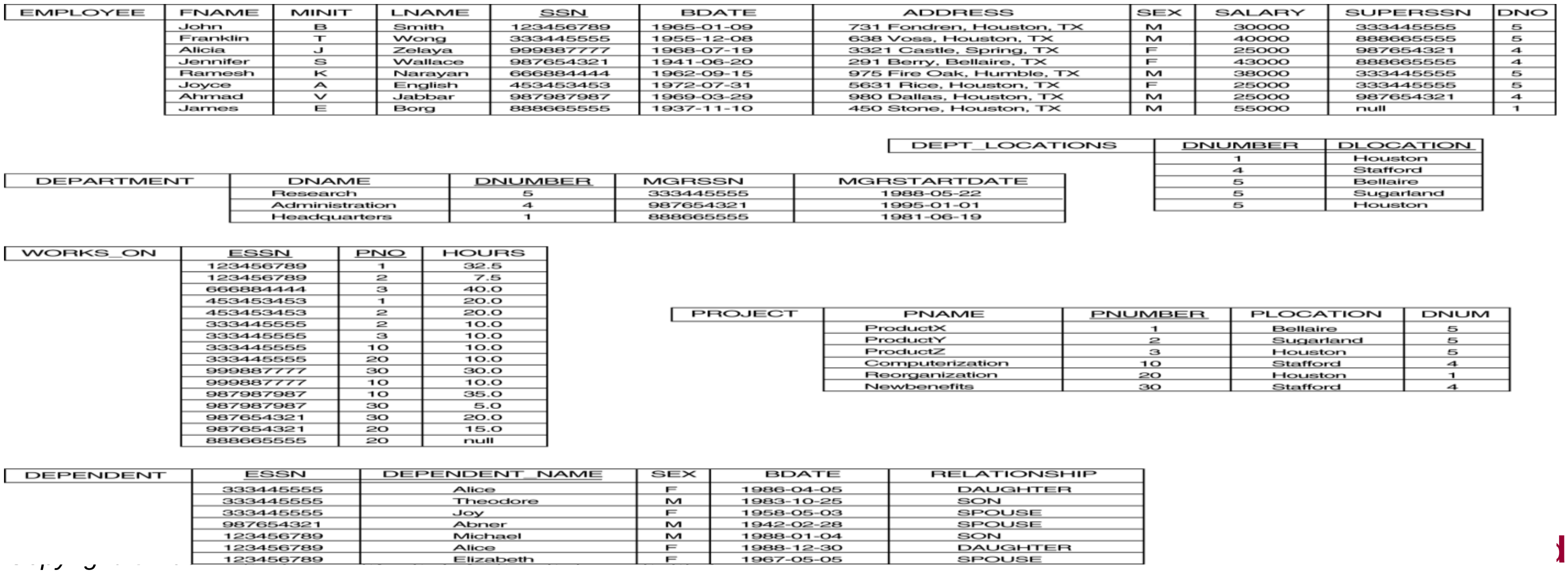
UPDATE

- Used to modify attribute values of one or more selected tuples
- A WHERE-clause selects the tuples to be modified
- An additional SET-clause specifies the attributes to be modified and their new values
- Each command modifies tuples *in the same relation*
- Referential integrity should be enforced

UPDATE (contd.)

- Example: Change the location and controlling department number of project number 10 to 'Bellaire' and 5, respectively.

```
U4:   UPDATE   PROJECT
      SET      PLOCATION = 'Bellaire',
                    DNUM = 5
      WHERE    PNUMBER=10
```



EMPLOYEE	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	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	1968-07-19	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
	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

DEPT_LOCATIONS	DNUMBER	DLOCATION
	1	Houston
	4	Stafford
	5	Bellaire
	5	Sugarland
	5	Houston

DEPARTMENT	DNAME	DNUMBER	MGRSSN	MGRSTARTDATE
	Research	5	333445555	1988-05-22
	Administration	4	987654321	1995-01-01
	Headquarters	1	888665555	1981-06-19

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

UPDATE (contd.)

- Example: Give all employees in the 'Research' department a 10% raise in salary.

```
U5: UPDATE      EMPLOYEE
    SET         SALARY = SALARY *1.1
    WHERE       DNO  IN (SELECT    DNUMBER
                   FROM       DEPARTMENT
                   WHERE      DNAME='Research')
```

- In this request, the modified SALARY value depends on the original SALARY value in each tuple
  - The reference to the SALARY attribute on the right of = refers to the old SALARY value before modification
  - The reference to the SALARY attribute on the left of = refers to the new SALARY value after modification

Retrieval Queries in SQL

- SQL has one basic statement for retrieving information from a database; the **SELECT** statement
  - This is *not the same as* the SELECT operation of the relational algebra
- Important distinction between SQL and the formal relational model:
  - SQL allows a table (relation) to have two or more tuples that are identical in all their attribute values
  - Hence, an SQL relation (table) is a **multi-set** (sometimes called a **bag**) of tuples; it is *not* a set of tuples
- SQL relations can be constrained to be sets by specifying PRIMARY KEY or UNIQUE attributes, or by using the DISTINCT option in a query

Retrieval Queries in SQL (contd.)

- A **bag** or **multi-set** is like a set, but an element may appear more than once.
  - Example: {A, B, C, A} is a bag. {A, B, C} is also a bag that also is a set.
  - Bags also resemble lists, but the order is irrelevant in a bag.
- Example:
  - {A, B, A} = {B, A, A} as bags
  - However, [A, B, A] is not equal to [B, A, A] as lists

Retrieval Queries in SQL (contd.)

- Basic form of the SQL SELECT statement is called a *mapping* or a SELECT-FROM-WHERE *block*

```
SELECT      <attribute list>
   FROM     <table list>
   WHERE    <condition>
```

  - <attribute list> is a list of attribute names whose values are to be retrieved by the query
  - <table list> is a list of the relation names required to process the query
  - <condition> is a conditional (Boolean) expression that identifies the tuples to be retrieved by the query

Recap of SQL Queries

- A query in SQL can consist of up to six clauses, but only the first two, SELECT and FROM, are mandatory. The clauses are specified in the following order:

```
SELECT          <attribute list>
FROM            <table list>
[WHERE          <condition>]
[GROUP BY       <grouping attribute(s)>]
[HAVING         <group condition>]
[ORDER BY       <attribute list>]
```

- There are three SQL commands to modify the database: **INSERT**, **DELETE**, and **UPDATE**

Relational Database Schema

EMPLOYEE

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO

DEPARTMENT

DNAME	DNUMBER	MGRSSN	MGRSTARTDATE

DEPT_LOCATIONS

DNUMBER	DLOCATION

PROJECT

PNAME	PNUMBER	PLOCATION	DNUM

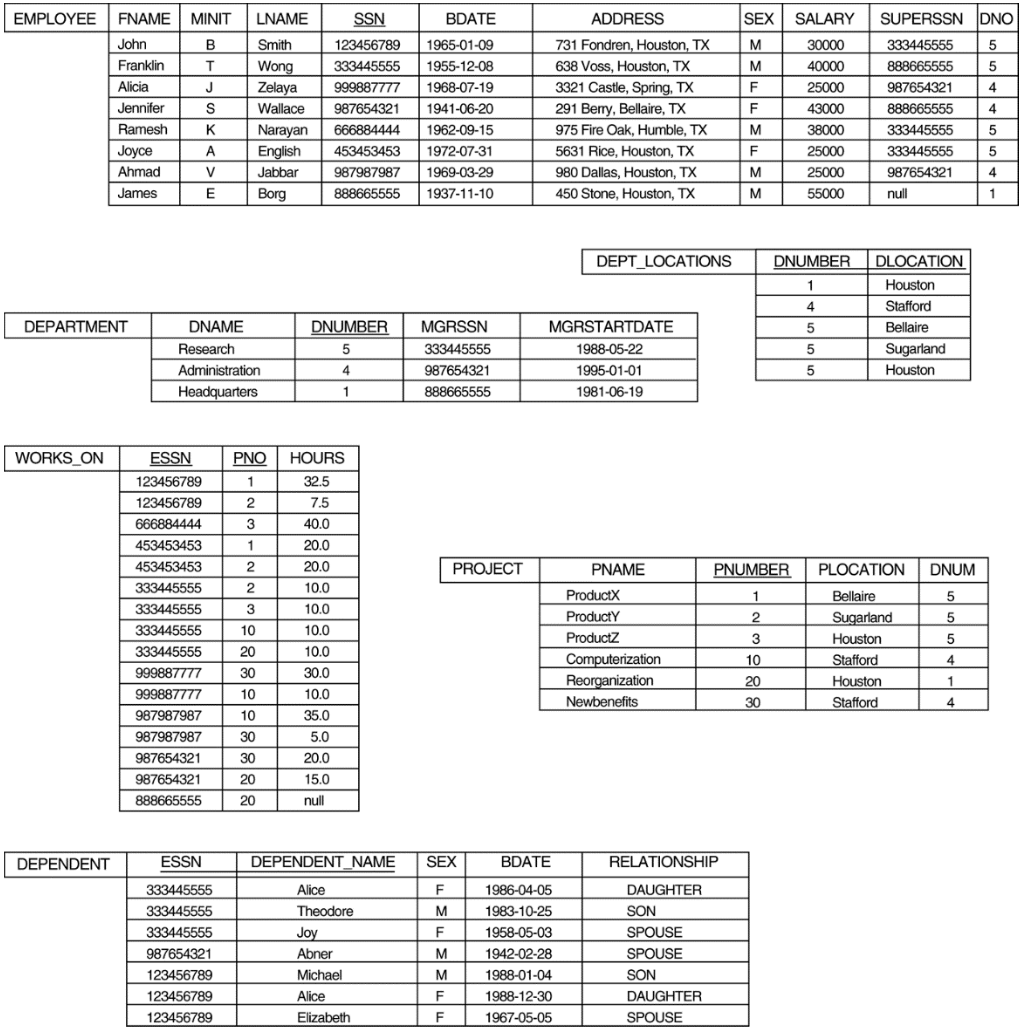
WORKS_ON

ESSN	PNO	HOURS

DEPENDENT

ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP

Populated Database



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	333445555	10	10.0
	333445555	20	10.0
	999887777	30	30.0
	999887777	10	10.0
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	987987987	30	5.0
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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

Simple SQL Queries

- Basic SQL queries correspond to using the following operations of the relational algebra:
  - SELECT
  - PROJECT
  - JOIN
- All subsequent examples use the COMPANY database

Simple SQL Queries (contd.)

```
SELECT      *
 FROM       tab
```

Simple SQL Queries (contd.)

- Example of a simple query on one relation
- Query 1: Retrieve the birthdate and address of the employee whose name is 'John B. Smith'.

```
Q1:SELECT     BDATE, ADDRESS
   FROM       EMPLOYEE
   WHERE      FNAME='John' AND MINIT='B’
   AND        LNAME='Smith’
```

  - Similar to a SELECT-PROJECT pair of relational algebra operations:
    - The SELECT-clause specifies the projection attributes and the WHERE-clause specifies the selection condition
  - However, the result of the query may contain duplicate tuples

Simple SQL Queries (contd.)

- Query 2: Retrieve the name and address of all employees who work for the 'Research' department.

```
Q2:SELECT      FNAME, LNAME, ADDRESS
   FROM        EMPLOYEE, DEPARTMENT
   WHERE       DNAME='Research' AND DNUMBER=DNO
```

  - Similar to a SELECT-PROJECT-JOIN sequence of relational algebra operations
  - (DNAME='Research') is a selection condition (corresponds to a SELECT operation in relational algebra)
  - (DNUMBER=DNO) is a join condition (corresponds to a JOIN operation in relational algebra)

Simple SQL Queries (contd.)

- Query 3: For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birthdate.

```
Q3: SELECT     PNUMBER, DNUM, LNAME, BDATE, ADDRESS
        FROM            PROJECT, DEPARTMENT, EMPLOYEE
        WHERE           DNUM=DNUMBER AND MGRSSN=SSN
                             AND PLOCATION='Stafford'
```

- In Q3, there are two join conditions
- The join condition DNUM=DNUMBER relates a project to its controlling department
- The join condition MGRSSN=SSN relates the controlling department to the employee who manages that department

Aliases, * and DISTINCT, Empty WHERE-clause

- In SQL, we can use the same name for two (or more) attributes as long as the attributes are in *different relations*
- A query that refers to two or more attributes with the same name must *qualify* the attribute name with the relation name by *prefixing* the relation name to the attribute name
- Example:

- **EMPLOYEE.**LNAME, **DEPARTMENT.**DNAME

ALIASES

- Some queries need to refer to the same relation twice
  - In this case, *aliases* are given to the relation name
- Query 4: For each employee, retrieve the employee's name, and the name of his or her immediate supervisor.

```
Q4:  SELECT    E.FNAME, E.LNAME, S.FNAME, S.LNAME
     FROM      EMPLOYEE E S
     WHERE     E.SUPERSSN=S.SSN
```

  - In Q4, the alternate relation names E and S are called *aliases* or *tuple variables* for the EMPLOYEE relation
  - We can think of E and S as two different *copies* of EMPLOYEE; E represents employees in role of *supervisees* and S represents employees in role of *supervisors*

ALIASES (contd.)

- Aliasing can also be used in any SQL query for convenience
- Can also use the AS keyword to specify aliases

```
Q4A:   SELECT     E.FNAME, E.LNAME,
                  S.FNAME, S.LNAME
       FROM       EMPLOYEE AS E,
                  EMPLOYEE AS S
       WHERE      E.SUPERSSN=S.SSN
```

UNSPECIFIED WHERE-clause

- A *missing WHERE-clause* indicates no condition; hence, all tuples of the relations in the FROM-clause are selected
  - This is equivalent to the condition WHERE TRUE
- Query 5: Retrieve the SSN values for all employees.
  - Q5:

    ```
    SELECT    SSN
    FROM      EMPLOYEE
    ```
- If more than one relation is specified in the FROM-clause *and* there is no join condition, then the *CARTESIAN PRODUCT* of tuples is selected

UNSPECIFIED WHERE-clause (contd.)

- Example:

```
Q6:     SELECT   SSN, DNAME
        FROM     EMPLOYEE, DEPARTMENT
```

  - It is extremely important not to overlook specifying any selection and join conditions in the WHERE-clause; otherwise, incorrect and very large relations may result

USE OF *

- To retrieve all the attribute values of the selected tuples, a * is used, which stands for *all the attributes*
  Examples:
  - Query 7: Retrieve all employees who work for department number 5.

```
Q7:     SELECT    *
        FROM      EMPLOYEE
        WHERE     DNO=5
```

  - Query 8: Retrieve all employees who work for the 'Research' department.

```
Q8:     SELECT    *
        FROM      EMPLOYEE, DEPARTMENT
        WHERE     DNAME='Research' AND
                  DNO=DNUMBER
```

USE OF DISTINCT

- SQL does not treat a relation as a set; duplicate tuples can appear
- To eliminate duplicate tuples in a query result, the keyword **DISTINCT** is used
- For example, the result of Q9 may have duplicate SALARY values whereas Q9A does not have any duplicate values

```
Q9:     SELECT      SALARY
        FROM        EMPLOYEE
Q9A:    SELECT      DISTINCT SALARY
        FROM        EMPLOYEE
```

SET OPERATIONS

- SQL has directly incorporated some set operations
- There is a union operation (UNION), and in *some versions* of SQL there are set difference (MINUS) and intersection (INTERSECT) operations
- The resulting relations of these set operations are sets of tuples; *duplicate tuples are eliminated from the result*
- The set operations apply only to *union compatible relations*; the two relations must have the same attributes and the attributes must appear in the same order

SET OPERATIONS (contd.)

- Query 10: Make a list of all project numbers for projects that involve an employee whose last name is 'Smith' as a worker or as a manager of the department that controls the project.

```
Q10:        (SELECT        PNAME
            FROM           PROJECT, DEPARTMENT,
                                EMPLOYEE
            WHERE          DNUM=DNUMBER AND
                           MGRSSN=SSN AND LNAME='Smith')
            UNION
            (SELECT        PNAME
            FROM           PROJECT, WORKS_ON, EMPLOYEE
            WHERE          PNUMBER=PNO AND

                           ESSN=SSN AND NAME='Smith')
```

NESTING OF QUERIES

- A complete SELECT query, called a *nested query*, can be specified within the WHERE-clause of another query, called the *outer query*
  - Many of the previous queries can be specified in an alternative form using nesting
- Query 11: Retrieve the name and address of all employees who work for the 'Research' department.

```
Q11:      SELECT     FNAME, LNAME, ADDRESS
          FROM       EMPLOYEE
          WHERE      DNO IN  (SELECT  DNUMBER
          FROM       DEPARTMENT
          WHERE      DNAME='Research' )
```

NESTING OF QUERIES (contd.)

- The nested query selects the number of the 'Research' department
- The outer query select an EMPLOYEE tuple if its DNO value is in the result of either nested query
- The comparison operator IN compares a value v with a set (or multi-set) of values V, and evaluates to TRUE if v is one of the elements in V
- In general, we can have several levels of nested queries
- A reference to an *unqualified attribute* refers to the relation declared in the *innermost nested query*
- In this example, the nested query is *not correlated* with the outer query

CORRELATED NESTED QUERIES

- If a condition in the WHERE-clause of a *nested query* references an attribute of a relation declared in the *outer query*, the two queries are said to be *correlated*
  - The result of a correlated nested query is different for each tuple (or combination of tuples) of the relation(s) the outer query
- Query 12: Retrieve the name of each employee who has a dependent with the same first name as the employee.

```
Q12: SELECT        E.FNAME, E.LNAME
     FROM          EMPLOYEE AS E
     WHERE         E.SSN IN
                        (SELECT     ESSN
                        FROM        DEPENDENT
                        WHERE       ESSN=E.SSN AND
                        E.FNAME=DEPENDENT_NAME)
```

CORRELATED NESTED QUERIES (contd.)

- In Q12, the nested query has a different result in the outer query
- A query written with nested SELECT... FROM... WHERE... blocks and using the = or IN comparison operators can ***always*** be expressed as a single block query. For example, Q12 may be written as in Q12A

```
Q12A:  SELECT    E.FNAME, E.LNAME
       FROM      EMPLOYEE E, DEPENDENT D
       WHERE     E.SSN=D.ESSN AND
                 E.FNAME=D.DEPENDENT_NAME
```

CORRELATED NESTED QUERIES (contd.)

- The original SQL as specified for SYSTEM R also had a **CONTAINS** comparison operator, which is used in conjunction with nested correlated queries
  - This operator was *dropped from the language*, possibly because of the difficulty in implementing it efficiently
  - Most implementations of SQL do not have this operator
  - The CONTAINS operator compares *two sets of values*, and returns TRUE if one set contains all values in the other set
    - Reminiscent of the division operation of algebra

CORRELATED NESTED QUERIES (contd.)

- Query 13: Retrieve the name of each employee who works on all the projects controlled by department number 5.

```
Q13:   SELECT      FNAME, LNAME
       FROM        EMPLOYEE
       WHERE  (    (SELECT     PNO
                   FROM        WORKS_ON
                   WHERE       SSN=ESSN)
                         CONTAINS
                   (SELECT     PNUMBER
                   FROM        PROJECT
                   WHERE       DNUM=5) )
```

CORRELATED NESTED QUERIES (contd.)

- In Q13, the second nested query, which is *not correlated* with the outer query, retrieves the project numbers of all projects controlled by department 5
- The first nested query, which is correlated, retrieves the project numbers on which the employee works, which is *different for each employee tuple* because of the correlation

THE EXISTS FUNCTION

- EXISTS is used to check whether the result of a correlated nested query is empty (contains no tuples) or not
  - We can formulate Query 12 in an alternative form that uses EXISTS as Q12B

THE EXISTS FUNCTION (contd.)

- Query 12: Retrieve the name of each employee who has a dependent with the same first name as the employee.

```
Q12B:     SELECT      FNAME, LNAME
          FROM        EMPLOYEE
          WHERE       EXISTS  (SELECT    *
                               FROM      DEPENDENT
                               WHERE     SSN=ESSN
                                    AND

   FNAME=DEPENDENT_NAME)
```

THE EXISTS FUNCTION (contd.)

- Query 14: Retrieve the names of employees who have no dependents.

```
Q14:    SELECT      FNAME, LNAME
        FROM        EMPLOYEE
        WHERE       NOT EXISTS  (SELECT      *
                                 FROM        DEPENDENT
                                 WHERE       SSN=ESSN)
```

- In Q14, the correlated nested query retrieves all DEPENDENT tuples related to an EMPLOYEE tuple. If *none exist*, the EMPLOYEE tuple is selected
  - EXISTS is necessary for the expressive power of SQL

EXPLICIT SETS

- It is also possible to use an **explicit (enumerated) set of values** in the WHERE-clause rather than a nested query
- Query 15: Retrieve the social security numbers of all employees who work on project number 1, 2, or 3.

```
Q15:    SELECT   DISTINCT ESSN
        FROM     WORKS_ON
        WHERE    PNO IN  (1, 2, 3)
```

NULLS IN SQL QUERIES

- SQL allows queries that check if a value is **NULL** (missing or undefined or not applicable)
- SQL uses **IS** or **IS NOT** to compare NULLs because it considers each NULL value distinct from other NULL values, so *equality comparison is not appropriate*.
- Query 16: Retrieve the names of all employees who do not have supervisors.

```
Q16:      SELECT      FNAME, LNAME
          FROM        EMPLOYEE
          WHERE       SUPERSSN  IS  NULL
```

  - Note: If a join condition is specified, tuples with NULL values for the join attributes are not included in the result

Joined Relations Feature

- Can specify a "joined relation" in the FROM-clause
  - Looks like any other relation but is the result of a join
  - Allows the user to specify different types of joins (regular "theta" JOIN, NATURAL JOIN, LEFT OUTER JOIN, RIGHT OUTER JOIN, CROSS JOIN, etc)

Joined Relations Feature (cont.)

inner join

- An inner join essentially combines the records from two tables (A and B) based on a given join-predicate.
- The SQL-engine computes the cross-product of all records in the tables. Thus, processing combines each record in table A with every record in table B. Only those records in the joined table that satisfy the join predicate remain.
- This type of join occurs the most commonly in applications, and represents the default join-type.
- ***Types of inner joins: equi-join, natural join, and cross join.***

Joined Relations Feature (cont.)

Example of an explicit inner join:

```
SELECT * FROM employee INNER JOIN department ON
employee.DepartmentID = department.DepartmentID
```

Example of an implicit inner join:

```
SELECT * FROM employee, department WHERE employee.DepartmentID =
department.DepartmentID
```

Inner join result:

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Smith	34	Clerical	34
Jones	33	Engineering	33
Robinson	34	Clerical	34
Steinberg	33	Engineering	33
Rafferty	31	Sales	31

Joined Relations Feature (cont.)

Equi-join

- An **equi-join** (also known as an **equijoin**), a specific type of comparator-based join, or *theta join*, uses only equality comparisons in the join-predicate. Using other comparison operators (such as <) disqualifies a join as an equi-join.
- Example of an equi-join:

  SELECT * FROM employee INNER JOIN department ON employee.DepartmentID = department.DepartmentID
- The resulting joined table contains two columns named DepartmentID, one from table Employee and one from table Department.
- There is no a specific syntax to express equi-joins, but some database engines provide a shorthand syntax: for example, MySQL and PostgreSQL support USING(DepartmentID) in addition to the ON ... syntax.

Joined Relations Feature (cont.)

Natural join

- A natural join offers a further specialization of equi-joins. The join predicate arises implicitly by comparing all columns in both tables that have the same column-name in the joined tables. The resulting joined table contains only one column for each pair of equally-named columns.
- natural join ican be expressed n the following way:

  SELECT * FROM employee NATURAL JOIN department
- The result appears slightly different, however, because <u>only one DepartmentID column</u> occurs in the joined table.

Employee.LastName	DepartmentID	Department.DepartmentName
Smith	34	Clerical
Jones	33	Engineering
Robinson	34	Clerical
Steinberg	33	Engineering
Rafferty	31	Sales

Joined Relations Feature (cont.)

Cross join

- A **cross join** or **cartesian join** provides the foundation upon which all types of inner joins operate. A cross join returns the cartesian product of the sets of records from the two joined tables. Thus it equates to an inner join where the join-condition always evaluates to *True*.
- If A and B are two sets then cross join = A X B.
- The SQL code for a cross join lists the tables for joining (FROM), but does not include any filtering join-predicate.
- Example of an explicit cross join:

```
SELECT * FROM employee CROSS JOIN department
```

- Example of an implicit cross join:

```
SELECT * FROM employee, department;
```

Joined Relations Feature (cont.)

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Rafferty	31	Sales	31
Jones	33	Sales	31
Steinberg	33	Sales	31
Smith	34	Sales	31
Robinson	34	Sales	31
Jasper	36	Sales	31
Rafferty	31	Engineering	33
Jones	33	Engineering	33
Steinberg	33	Engineering	33
Smith	34	Engineering	33
Robinson	34	Engineering	33
Jasper	36	Engineering	33
Rafferty	31	Clerical	34
Jones	33	Clerical	34
Steinberg	33	Clerical	34
Smith	34	Clerical	34
Robinson	34	Clerical	34
Jasper	36	Clerical	34
Rafferty	31	Marketing	35
Jones	33	Marketing	35
Steinberg	33	Marketing	35
Smith	34	Marketing	35
Robinson	34	Marketing	35
Jasper	36	Marketing	35

Joined Relations Feature (cont.)

outer join

- An outer join does not require each record in the two joined tables to have a matching record in the other table.
- The joined table retains each record — even if no other matching record exists.
- Outer joins subdivide further into left outer joins, right outer joins, and full outer joins, depending on which table(s) one retains the rows from (left, right, or both).
- (For a table to qualify as *left* or *right* its name has to appear after the FROM or JOIN keyword, respectively.)
- No implicit join-notation for outer joins exists in.

Joined Relations Feature (cont.)

Left outer join

- The result of a **left outer join** for tables A and B always contains all records of the "left" table (A), even if the join-condition does not find any matching record in the "right" table (B).
- This means that if the ON clause matches 0 (zero) records in B, the join will still return a row in the result — but with NULL in each column from B.
- A left outer join returns all the values from the left table, plus matched values from right table (or NULL in case of no matching join predicate).

Joined Relations Feature (cont.)

- Example of a left outer join:

```
SELECT * FROM employee LEFT OUTER JOIN department ON
employee.DepartmentID = department.DepartmentID
```

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Jones	33	Engineering	33
Rafferty	31	Sales	31
Robinson	34	Clerical	34
Smith	34	Clerical	34
Jasper	36	NULL	NULL
Steinberg	33	Engineering	33

Joined Relations Feature (cont.)

Right outer join

- A right outer join closely resembles a left outer join, except with the tables reversed. Every record from the "right" table (B) will appear in the joined table at least once.
- If no matching row from the "left" table (A) exists, NULL will appear in columns from A for those records that have no match in A.
- A right outer join returns all the values from right table and matched values from left table (or NULL in case of no matching join predicate).

Joined Relations Feature (cont.)

Example right outer join:

SELECT * FROM employee RIGHT OUTER JOIN department ON employee.DepartmentID = department.DepartmentID

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Smith	34	Clerical	34
Jones	33	Engineering	33
Robinson	34	Clerical	34
Steinberg	33	Engineering	33
Rafferty	31	Sales	31
NULL	NULL	Marketing	35

Joined Relations Feature (cont.)

Full outer join

- A **full outer join** combines the results of both left and right outer joins. The joined table will contain all records from both tables, and fill in NULLs for missing matches on either side.
- Example full outer join:

```
SELECT * FROM employee FULL OUTER JOIN department ON
employee.DepartmentID = department.DepartmentID
```

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Smith	34	Clerical	34
Jones	33	Engineering	33
Robinson	34	Clerical	34
Jasper	36	NULL	NULL
Steinberg	33	Engineering	33
Rafferty	31	Sales	31

Joined Relations Feature (cont.)

- Examples:

```
Q4:SELECT      E.FNAME, E.LNAME, S.FNAME, S.LNAME
     FROM      EMPLOYEE E S
     WHERE     E.SUPERSSN=S.SSN
```

- can be written as:

```
Q4B:SELECT     E.FNAME, E.LNAME, S.FNAME, S.LNAME
      FROM     (EMPLOYEE E LEFT OUTER JOIN
               EMPLOYEES ON  E.SUPERSSN=S.SSN)
```

Joined Relations Feature (cont.)

- Examples:

```
Q2:SELECT       FNAME, LNAME, ADDRESS
    FROM EMPLOYEE, DEPARTMENT
    WHERE           DNAME='Research' AND DNUMBER=DNO
```

- could be written as:

```
Q2A:SELECT      FNAME, LNAME, ADDRESS
    FROM            (EMPLOYEE JOIN DEPARTMENT
                    ON DNUMBER=DNO)
    WHERE           DNAME='Research’
```

- or as:

```
Q2B:SELECT      FNAME, LNAME, ADDRESS
    FROM            (EMPLOYEE NATURAL JOIN
   DEPARTMENT
                    AS DEPT(DNAME, DNO, MSSN, MSDATE)
    WHERE           DNAME='Research’
```

Joined Relations Feature (cont.)

- Another Example: Q3 could be written as follows; this illustrates multiple joins in the joined tables

```
Q3A:    SELECT    PNUMBER, DNUM, LNAME,
                       BDATE, ADDRESS
        FROM      (PROJECT JOIN
                  DEPARTMENT ON
                  DNUM=DNUMBER) JOIN
                       EMPLOYEE ON
                       MGRSSN=SSN) )
        WHERE     PLOCATION='Stafford’
```

AGGREGATE FUNCTIONS

- Include **COUNT, SUM, MAX, MIN, and AVG**
- Query 17: Find the maximum salary, the minimum salary, and the average salary among all employees.

```
Q17:    SELECT    MAX(SALARY),
                  MIN(SALARY), AVG(SALARY)
        FROM      EMPLOYEE
```

- Some SQL implementations *may not allow more than one function* in the SELECT-clause

AGGREGATE FUNCTIONS (contd.)

- Query 18: Find the maximum salary, the minimum salary, and the average salary among employees who work for the 'Research' department.

```
Q18:    SELECT   MAX(SALARY),
                 MIN(SALARY), AVG(SALARY)
        FROM     EMPLOYEE, DEPARTMENT
        WHERE    DNO=DNUMBER AND
                 DNAME='Research'
```

AGGREGATE FUNCTIONS (contd.)

- Queries 19 and 20: Retrieve the total number of employees in the company (Q19), and the number of employees in the 'Research' department (Q20).

```
Q19:    SELECT    COUNT (*)
        FROM      EMPLOYEE


Q20:    SELECT    COUNT (*)
        FROM      EMPLOYEE, DEPARTMENT
        WHERE     DNO=DNUMBER AND
                  DNAME='Research’
```

GROUPING

- In many cases, we want to apply the aggregate functions to *subgroups of tuples* in a relation
- Each subgroup of tuples consists of the set of tuples that have the *same value* for the *grouping attribute(s)*
- The function is applied to each subgroup independently
- SQL has a **GROUP BY**-clause for specifying the grouping attributes, which *must also appear in the SELECT-clause*

GROUPING (contd.)

- Query 21: For each department, retrieve the department number, the number of employees in the department, and their average salary.

```
Q21:      SELECT      DNO, COUNT (*), AVG (SALARY)
          FROM        EMPLOYEE
          GROUP BY    DNO
```

  - In Q21, the EMPLOYEE tuples are divided into groups-
    - Each group having the same value for the grouping attribute DNO
  - The COUNT and AVG functions are applied to each such group of tuples separately
  - The SELECT-clause includes only the grouping attribute and the functions to be applied on each group of tuples
  - A join condition can be used in conjunction with grouping

GROUPING (contd.)

- Query 22: For each project, retrieve the project number, project name, and the number of employees who work on that project.

```
Q22:    SELECT      PNUMBER, PNAME, COUNT (*)
        FROM        PROJECT, WORKS_ON
        WHERE       PNUMBER=PNO
        GROUP BY    PNUMBER, PNAME
```

  - In this case, the grouping and functions are applied after the joining of the two relations

THE HAVING-CLAUSE

- Sometimes we want to retrieve the values of these functions for only those *groups that satisfy certain conditions*
- The **HAVING**-clause is used for specifying a selection condition on groups (rather than on individual tuples)

THE HAVING-CLAUSE (contd.)

- Query 23: For each project *on which more than two employees work*, retrieve the project number, project name, and the number of employees who work on that project.

```
Q23:    SELECT      PNUMBER, PNAME,
                    COUNT(*)
        FROM        PROJECT, WORKS_ON
        WHERE       PNUMBER=PNO
        GROUP BY PNUMBER, PNAME
        HAVING      COUNT (*) > 2
```

SUBSTRING COMPARISON

- The **LIKE** comparison operator is used to compare partial strings
- Two reserved characters are used: '**%**' (or '*****' in some implementations) replaces an arbitrary number of characters, and '_' replaces a single arbitrary character

SUBSTRING COMPARISON (contd.)

- Query 24: Retrieve all employees whose address is in Houston, Texas. Here, the value of the ADDRESS attribute must contain the substring 'Houston,TX‘ in it.

```
Q24:    SELECT    FNAME, LNAME
        FROM      EMPLOYEE
        WHERE     ADDRESS LIKE
                  '%Houston,TX%'
```

SUBSTRING COMPARISON (contd.)

- Query 25: Retrieve all employees who were born during the 1950s.
  - Here, '5' must be the 8th character of the string (according to our format for date), so the BDATE value is '_______5_', with each underscore as a place holder for a single arbitrary character.

```
Q25:    SELECT    FNAME, LNAME
        FROM      EMPLOYEE
        WHERE     BDATE LIKE  '_______5_’
```

- The LIKE operator allows us to get around the fact that each value is considered atomic and indivisible
  - Hence, in SQL, character string attribute values are not atomic

ARITHMETIC OPERATIONS

- The standard arithmetic operators **'+', '-'. '*', and '/'** (for addition, subtraction, multiplication, and division, respectively) can be applied to numeric values in an SQL query result
- Query 26: Show the effect of giving all employees who work on the 'ProductX' project a 10% raise.

```
Q26:      SELECT     FNAME, LNAME, 1.1*SALARY
          FROM       EMPLOYEE, WORKS_ON,
                     PROJECT
          WHERE      SSN=ESSN AND PNO=PNUMBER
                          AND PNAME='ProductX’
```

ORDER BY

- The **ORDER BY** clause is used to sort the tuples in a query result based on the values of some attribute(s)
- Query 27: Retrieve a list of employees and the projects each works in, ordered by the employee's department, and within each department ordered alphabetically by employee last name.

```
Q27:      SELECT      DNAME, LNAME, FNAME, PNAME
          FROM        DEPARTMENT, EMPLOYEE,
                            WORKS_ON, PROJECT
          WHERE       DNUMBER=DNO AND SSN=ESSN
                            AND PNO=PNUMBER
          ORDER BY    DNAME, LNAME
```

ORDER BY (contd.)

- The default order is in ascending order of values
- We can specify the keyword **DESC** if we want a descending order; the keyword **ASC** can be used to explicitly specify ascending order, even though it is the default

Summary of SQL Queries

- A query in SQL can consist of up to six clauses, but only the first two, SELECT and FROM, are mandatory. The clauses are specified in the following order:

```
SELECT        <attribute list>
FROM          <table list>
[WHERE        <condition>]
[GROUP BY     <grouping attribute(s)>]
[HAVING       <group condition>]
[ORDER BY     <attribute list>]
```

Summary of SQL Queries (contd.)

- The SELECT-clause lists the attributes or functions to be retrieved
- The FROM-clause specifies all relations (or aliases) needed in the query but not those needed in nested queries
- The WHERE-clause specifies the conditions for selection and join of tuples from the relations specified in the FROM-clause
- GROUP BY specifies grouping attributes
- HAVING specifies a condition for selection of groups
- ORDER BY specifies an order for displaying the result of a query
    - A query is evaluated by first applying the WHERE-clause, then GROUP BY and HAVING, and finally the SELECT-clause

Recap of SQL Queries

- A query in SQL can consist of up to six clauses, but only the first two, SELECT and FROM, are mandatory. The clauses are specified in the following order:

```
SELECT          <attribute list>
FROM            <table list>
[WHERE          <condition>]
[GROUP BY       <grouping attribute(s)>]
[HAVING         <group condition>]
[ORDER BY       <attribute list>]
```

- There are three SQL commands to modify the database: **INSERT**, **DELETE**, and **UPDATE**