Structured Query Language (SQL)

Outlines

- SQL Data Definition and Data Types
- Specifying Constraints in SQL
- Basic Retrieval Queries in SQL
- INSERT, DELETE, and UPDATE Statements in SQL
- Additional Features of SQL

Basic Retrieval Queries in SQL

SQL has one basic statement for retrieving information from a database: the **SELECT** statement. The SELECT statement *is not the same as* the SELECT operation of relational algebra, which we shall discuss in Chapter 8. There are many options and flavors to the SELECT statement in SQL, so we will introduce its features gradually.

We will use example queries specified on the schema of Figure 5.5 and will refer to the sample database state shown in Figure 5.6 to show the results of some of these queries. In this section, we present the features of SQL for *simple retrieval queries*. Features of SQL for specifying more complex retrieval queries are presented in Section 7.1.

Before proceeding, we must point out an *important distinction* between the practical SQL model and the formal relational model discussed in Chapter 5: SQL allows a table (relation) to have two or more tuples that are identical in all their attribute values. Hence, in general, an **SQL** table is not a *set of tuples*, because a set does not allow two identical members; rather, it is a **multiset** (sometimes called a *bag*) of tuples. Some SQL relations are *constrained to be sets* because a key constraint has been declared or because the DISTINCT option has been used with the SELECT statement (described later in this section). We should be aware of this distinction as we discuss the examples.

The SELECT-FROM-WHERE Structure of Basic SQL Queries

Queries in SQL can be very complex. We will start with simple queries, and then progress to more complex ones in a step-by-step manner. The basic form of the SELECT statement, sometimes called a **mapping** or a **select-from-where block**, is formed of the three clauses SELECT, FROM, and WHERE and has the following form:9

SELECT <attribute list>
FROM <table list>
WHERE <condition>;
where

- <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.

In SQL, the basic logical comparison operators for comparing attribute values with one another and with literal constants are =, <, <=, >, >=, and <>. These correspond to the relational algebra operators =, <, ≤, >, ≥, and ≠, respectively, and to the C/C++ programming language operators =, <, <=, >, >=, and !=. The main syntactic difference is the *not equal* operator. SQL has additional comparison operators that we will present gradually. We illustrate the basic SELECT statement in SQL with some sample queries. The queries are labeled here with the same query numbers used in Chapter 8 for easy cross-reference.

Query 0. Retrieve the birth date and address of the employee(s) whose name is 'John B. Smith'.

Q0: SELECT Bdate, Address **FROM** EMPLOYEE **WHERE** Fname = 'John' **AND** Minit = 'B' **AND** Lname = 'Smith';

This query involves only the EMPLOYEE relation listed in the FROM clause. The query *selects* the individual EMPLOYEE tuples that satisfy the condition of the WHERE clause, then *projects* the result on the Bdate and Address attributes listed in the SELECT clause. The SELECT clause of SQL specifies the attributes whose values are to be retrieved, which are called the **projection attributes** in relational algebra (see Chapter 8) and the WHERE clause specifies the Boolean condition that must be true for any retrieved tuple, which is known as the **selection condition** in relational algebra. Figure 6.3(a) shows the result of query Q0 on the database of Figure 5.6. We can think of an implicit **tuple variable** or *iterator* in the SQL query ranging or *looping* over each individual tuple in the EMPLOYEE table and evaluating the condition in the WHERE clause. Only those tuples that satisfy the condition—that is, those tuples for which the condition evaluates to TRUE after substituting their corresponding attribute values—are selected. **Query 1.** Retrieve the name and address of all employees who work for the 'Research' department.

Q1: SELECT Fname, Lname, Address **FROM** EMPLOYEE, DEPARTMENT **WHERE** Dname = 'Research' **AND** Dnumber = Dno;

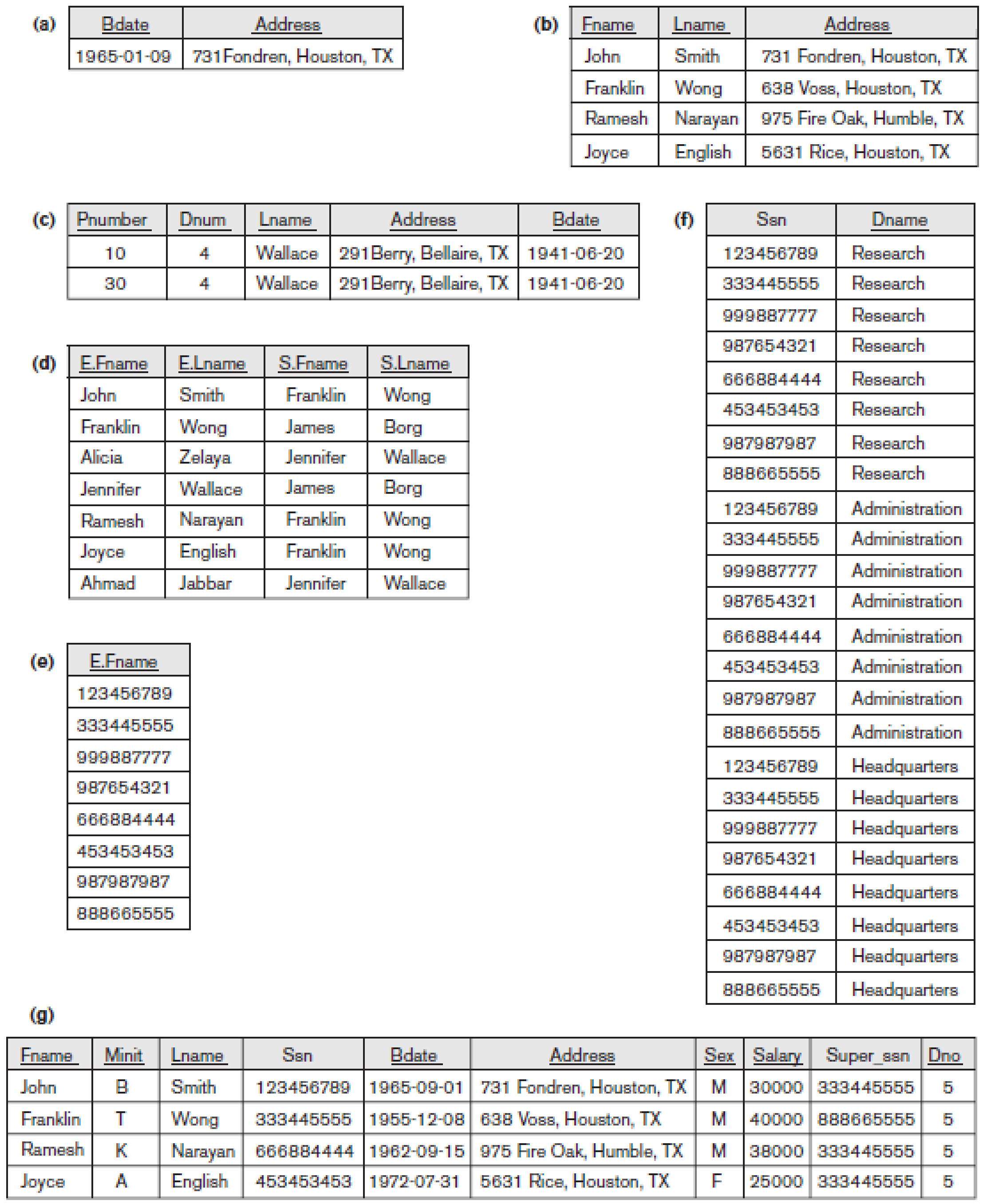
In the WHERE clause of Q1, the condition Dname = 'Research' is a **selection condition** that chooses the particular tuple of interest in the DEPARTMENT table, because Dname is an attribute of DEPARTMENT. The condition Dnumber = Dno is called a **join condition**, because it combines two tuples: one from DEPARTMENT and one from EMPLOYEE, whenever the value of Dnumber in DEPARTMENT is equal to the value of Dno in EMPLOYEE. The result of query Q1 is shown in Figure 6.3(b). In general, any number of selection and join conditions may be specified in a single SQL query.

A query that involves only selection and join conditions plus projection attributes is known as a **select-project-join** query. The next example is a select-project-join query with *two* join conditions.

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

Q2: SELECT Pnumber, Dnum, Lname, Address, Bdate **FROM** PROJECT, DEPARTMENT, EMPLOYEE **WHERE** Dnum = Dnumber **AND** Mgr_ssn = Ssn **AND** Plocation = 'Stafford'

Figure 6.3
Results of SQL queries when applied to the COMPANY database state shown in Figure 5.6. (a) Q0. (b) Q1. (c) Q2. (d) Q8. (e) Q9. (f) Q10. (g) Q1C.



(a)

Bdate	Address
1965-01-09	731Fondren, Houston, TX

(b)

Fname	Lname	Address
John	Smith	731 Fondren, Houston, TX
Franklin	Wong	638 Voss, Houston, TX
Ramesh	Narayan	975 Fire Oak, Humble, TX
Joyce	English	5631 Rice, Houston, TX

(c)

Pnumber	Dnum	Lname	Address	Bdate
10	4	Wallace	291Berry, Bellaire, TX	1941-06-20
30	4	Wallace	291Berry, Bellaire, TX	1941-06-20

(d)

E.Fname	E.Lname	S.Fname	S.Lname
John	Smith	Franklin	Wong
Franklin	Wong	James	Borg
Alicia	Zelaya	Jennifer	Wallace
Jennifer	Wallace	James	Borg
Ramesh	Narayan	Franklin	Wong
Joyce	English	Franklin	Wong
Ahmad	Jabbar	Jennifer	Wallace

(e)

E.Fname
123456789
333445555
999887777
987654321
666884444
453453453
987987987
888665555

(f)

Ssn	Dname
123456789	Research
333445555	Research
999887777	Research
987654321	Research
666884444	Research
453453453	Research
987987987	Research
888665555	Research
123456789	Administration
333445555	Administration
999887777	Administration
987654321	Administration
666884444	Administration
453453453	Administration
987987987	Administration
888665555	Administration
123456789	Headquarters
333445555	Headquarters
999887777	Headquarters
987654321	Headquarters
666884444	Headquarters
453453453	Headquarters
987987987	Headquarters
888665555	Headquarters

(g)

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-09-01	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5

The join condition Dnum = Dnumber relates a project tuple to its controlling department tuple, whereas the join condition Mgr_ssn = Ssn relates the controlling department tuple to the employee tuple who manages that department. Each tuple in the result will be a combination of one project, one department (that controls the project), and one employee (that manages the department). The projection attributes are used to choose the attributes to be displayed from each combined tuple. The result of query Q2 is shown in Figure 6.3(c).

Ambiguous Attribute Names, Aliasing, Renaming, and Tuple Variables

In SQL, the same name can be used for two (or more) attributes as long as the attributes are in *different tables.* If this is the case, and a multitable query refers to two or more attributes with the same name, we *must* **qualify** the attribute name with the relation name to prevent ambiguity. This is done by *prefixing* the relation name to the attribute name and separating the two by a period. To illustrate this, suppose that in Figures 5.5 and 5.6 the Dno and Lname attributes of the EMPLOYEE relation were called Dnumber and Name, and the Dname attribute of DEPARTMENT was also called Name; then, to prevent ambiguity, query Q1 would be rephrased as shown in Q1A. We must prefix the attributes Name and Dnumber in Q1A to specify which ones we are referring to, because the same attribute names are used in both relations:

Q1A: SELECT Fname, EMPLOYEE.Name, Address **FROM** EMPLOYEE, DEPARTMENT **WHERE** DEPARTMENT.Name = 'Research' **AND** DEPARTMENT.Dnumber = EMPLOYEE.Dnumber;

Fully qualified attribute names can be used for clarity even if there is no ambiguity in attribute names. Q1 can be rewritten as Q12 below with fully qualified attribute names. We can also rename the table names to shorter names by creating an *alias* for each table name to avoid repeated typing of long table names

(see Q8 below).

Q12: SELECT EMPLOYEE.Fname, EMPLOYEE.LName, EMPLOYEE.Address

FROM EMPLOYEE, DEPARTMENT **WHERE** DEPARTMENT.DName = 'Research'

ANDDEPARTMENT.Dnumber = EMPLOYEE.Dno;

The ambiguity of attribute names also arises in the case of queries that refer to the same relation twice, as in the following example. **Query 8.** For each employee, retrieve the employee's first and last name and the first and last name of his or her immediate supervisor.

Q8: SELECT E.Fname, E.Lname, S.Fname, S.Lname **FROM** EMPLOYEE **AS** E, EMPLOYEE **AS** S

WHERE E.Super_ssn = S.Ssn;

In this case, we are required to declare alternative relation names E and S, called **aliases** or **tuple variables**, for the EMPLOYEE relation. An alias can follow the keyword **AS**, as shown in Q8, or it can directly follow the relation name—for example, by writing EMPLOYEE E, EMPLOYEE S in the FROM clause of Q8. It is also possible to **rename** the relation attributes within the query in SQL by giving them aliases. For example, if we write

EMPLOYEE **AS** E(Fn, Mi, Ln, Ssn, Bd, Addr, Sex, Sal, Sssn, Dno) in the FROM clause, Fn becomes an alias for Fname, Mi for Minit, Ln for Lname, and so on. In Q8, we can think of E and S as two *different copies* of the EMPLOYEE relation; the first, E, represents employees in the role of supervisees or subordinates; the second, S, represents employees in the role of supervisors. We can now join the two copies. Of course, in reality there is *only one* EMPLOYEE relation, and the join condition is meant to join the relation with itself by matching the tuples that satisfy the join condition E.Super_ssn = S.Ssn. Notice that this is an example of a one-level recursive query, as we will discuss in Section 8.4.2. In earlier versions of SQL, it was not possible to specify a general recursive query, with an unknown number of levels, in a single SQL statement. A construct for specifying recursive queries has been incorporated into SQL:1999 (see Chapter 7).

The result of query Q8 is shown in Figure 6.3(d). Whenever one or more aliases are given to a relation, we can use these names to represent different references to that same relation. This permits multiple references to the same relation within a query. We can use this alias-naming or **renaming** mechanism in any SQL query to specify tuple variables for every table in the WHERE clause, whether or not the same relation needs to be referenced more than once. In fact, this practice is recommended since it results in queries that are easier to comprehend. For example, we could specify query Q1 as in Q1B:

Q1B: SELECT E.Fname, E.LName, E.Address **FROM** EMPLOYEE **AS** E, DEPARTMENT **AS** D

WHERE D.DName = 'Research' **AND** D.Dnumber = E.Dno;

Unspecified WHERE Clause and Use of the Asterisk

We discuss two more features of SQL here. A *missing* WHERE clause indicates no condition on tuple selection; hence, *all tuples* of the relation specified in the FROM clause qualify and are selected for the query result. If more than one relation is specified in the FROM clause and there is no WHERE clause, then the CROSS PRODUCT—*all possible tuple combinations*—of these relations is selected. For example, Query 9 selects all EMPLOYEE Ssns (Figure 6.3(e)), and Query 10 selects all combinations of an EMPLOYEE Ssn and a DEPARTMENT Dname, regardless of whether the employee works for the department or not (Figure 6.3(f)).**Queries 9 and 10.** Select all EMPLOYEE Ssns (Q9) and all combinations of EMPLOYEE Ssn and DEPARTMENT Dname (Q10) in the database.

Q9: SELECT Ssn **FROM** EMPLOYEE;

Q10: SELECT Ssn, Dname **FROM** EMPLOYEE, DEPARTMENT;

It is extremely important to specify every selection and join condition in the WHERE clause; if any such condition is overlooked, incorrect and very large relations may result. Notice that Q10 is similar to a CROSS PRODUCT operation followed by a PROJECT operation in relational algebra (see Chapter 8). If we specify all the attributes of EMPLOYEE and DEPARTMENT in Q10, we get the actual CROSS PRODUCT (except for duplicate elimination, if any).

To retrieve all the attribute values of the selected tuples, we do not have to list the attribute names explicitly in SQL; we just specify an *asterisk* (*), which stands for *all the attributes.* The * can also be prefixed by the relation name or alias; for example, EMPLOYEE.* refers to all attributes of the EMPLOYEE table. Query Q1C retrieves all the attribute values of any EMPLOYEE who works in DEPARTMENT number 5 (Figure 6.3(g)), query Q1D retrieves all the attributes of an EMPLOYEE and the attributes of the DEPARTMENT in which he or she works for every employee of the 'Research' department, and Q10A specifies the CROSS PRODUCT of the EMPLOYEE and DEPARTMENT relations.

Q1C: SELECT * **FROM** EMPLOYEE **WHERE** Dno = 5;

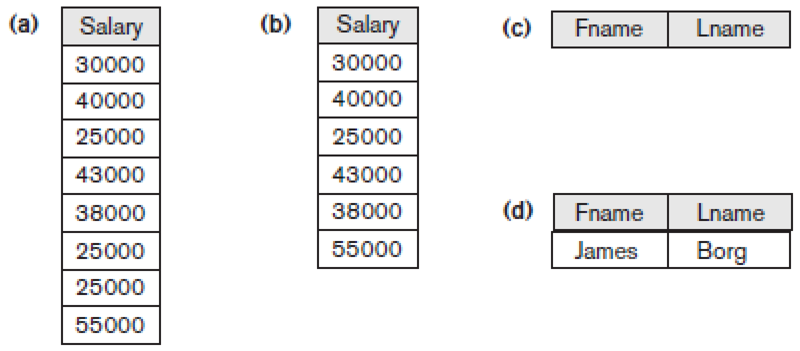
Q1D: SELECT * **FROM** EMPLOYEE, DEPARTMENT **WHERE** Dname = 'Research' **AND** Dno = Dnumber;

Q10A: SELECT * **FROM** EMPLOYEE, DEPARTMENT;

Tables as Sets in SQL

As we mentioned earlier, SQL usually treats a table not as a set but rather as a **multiset**; *duplicate tuples can appear more than once* in a table, and in the result of a query. SQL does not automatically eliminate duplicate tuples in the results of queries, for the following reasons:

- Duplicate elimination is an expensive operation. One way to implement it is to sort the tuples first and then eliminate duplicates.
- The user may want to see duplicate tuples in the result of a query.
- When an aggregate function (see Section 7.1.7) is applied to tuples, in most cases we do not want to eliminate duplicates.



(a)

Salary
30000
40000
25000
43000
38000
25000
25000
55000

(b)

Salary
30000
40000
25000
43000
38000
55000

(c)

Fname	Lname

(d)

Fname	Lname
James	Borg

Figure 6.4
Results of additional SQL queries when applied to the COMPANY database state shown in Figure 5.6. (a) Q11. (b) Q11A. (c) Q16. (d) Q18.

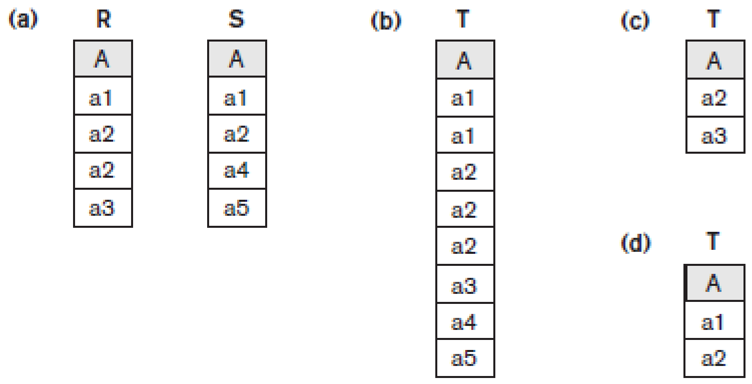
An SQL table with a key is restricted to being a set, since the key value must be distinct in each tuple.[10] If we *do want* to eliminate duplicate tuples from the result of an SQL query, we use the keyword **DISTINCT** in the SELECT clause, meaning that only distinct tuples should remain in the result. In general, a query with SELECT DISTINCT eliminates duplicates, whereas a query with SELECT ALL does not. Specifying SELECT with neither ALL nor DISTINCT—as in our previous examples—is equivalent to SELECT ALL. For example, Q11 retrieves the salary of every employee; if several employees have the same salary, that salary value will appear as many times in the result of the query, as shown in Figure 6.4(a). If we are interested only in distinct salary values, we want each value to appear only once, regardless of how many employees earn that salary. By using the keyword **DISTINCT** as in Q11A, we accomplish this, as shown in Figure 6.4(b).

Query 11. Retrieve the salary of every employee (Q11) and all distinct salary values (Q11A).

Q11: SELECT ALL Salary **FROM** EMPLOYEE;

Q11A: SELECT DISTINCT Salary **FROM** EMPLOYEE;

SQL has directly incorporated some of the set operations from mathematical *set theory*, which are also part of relational algebra (see Chapter 8). There are set union (**UNION**), set difference (**EXCEPT**),[11] and set intersection (**INTERSECT**) operations. The relations resulting from these set operations are sets of tuples; that is, *duplicate tuples are eliminated from the result.* These set operations apply only to *type compatible relations*, so we must make sure that the two relations on which we apply the operation have the same attributes and that the attributes appear in the same order in both relations. The next example illustrates the use of UNION.


(a) R

A
a1
a2
a2
a3

S

A
a1
a2
a4
a5

(b) T

A
a1
a1
a2
a2
a2
a3
a4
a5

(c) T

A
a2
a3

(d) T

A
a1
a2

Figure 6.5
The results of SQL multiset operations. (a) Two tables, R(A) and S(A).
(b) R(A)UNION ALL S(A).
(c) R(A) EXCEPT ALL S(A).
(d) R(A) INTERSECT ALL S(A).

Query 4. Make a list of all project numbers for projects that involve an employee whose last name is 'Smith', either as a worker or as a manager of the department that controls the project.

Q4A: (**SELECT DISTINCT** Pnumber
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE Dnum = Dnumber **AND** Mgr_ssn = Ssn
AND Lname = 'Smith')
UNION
(**SELECT DISTINCT** Pnumber
FROM PROJECT, WORKS_ON, EMPLOYEE
WHERE Pnumber = Pno **AND** Essn = Ssn
AND Lname = 'Smith');

The first SELECT query retrieves the projects that involve a 'Smith' as manager of the department that controls the project, and the second retrieves the projects that involve a 'Smith' as a worker on the project. Notice that if several employees have the last name 'Smith', the project names involving any of them will be retrieved. Applying the UNION operation to the two SELECT queries gives the desired result. SQL also has corresponding multiset operations, which are followed by the keyword **ALL** (UNION ALL, EXCEPT ALL, INTERSECT ALL). Their results are multisets (duplicates are not eliminated). The behavior of these operations is illustrated by the examples in Figure 6.5. Basically, each tuple—whether it is a duplicate or not— is considered as a different tuple when applying these operations.

Substring Pattern Matching and Arithmetic Operators

In this section we discuss several more features of SQL. The first feature allows comparison conditions on only parts of a character string, using the **LIKE** comparison operator. This can be used for string **pattern matching**. Partial strings are specified using two reserved characters: % replaces an arbitrary number of zero or more characters, and the underscore (_) replaces a single character. For example, consider the following query.

Query 12. Retrieve all employees whose address is in Houston, Texas.

Q12: SELECT Fname, Lname **FROM** EMPLOYEE **WHERE** Address **LIKE** '%Houston,TX%';

To retrieve all employees who were born during the 1970s, we can use Query Q12A. Here, '7' must be the third character of the string (according to our format for date), so we use the value '_ _ 5 _ _ _ _ _ _ _', with each underscore serving as a placeholder for an arbitrary character.

Query 12A. Find all employees who were born during the 1950s.

Q12: SELECT Fname, Lname **FROM** EMPLOYEE **WHERE** Bdate **LIKE** '_ _ 7 _ _ _ _ _ _ _';

If an underscore or % is needed as a literal character in the string, the character should be preceded by an *escape character*, which is specified after the string using the keyword ESCAPE. For example, 'AB_CD\%EF' ESCAPE '\' represents the literal string 'AB_CD%EF' because \ is specified as the escape character. Any character not used in the string can be chosen as the escape character. Also, we need a rule to specify apostrophes or single quotation marks (' ') if they are to be included in a string because they are used to begin and end strings. If an apostrophe (') is needed, it is represented as two consecutive apostrophes (") so that it will not be interpreted as ending the string. Notice that substring comparison implies that attribute values are not atomic (indivisible) values, as we had assumed in the formal relational model (see Section 5.1).

Another feature allows the use of arithmetic in queries. The standard arithmetic operators for addition (+), subtraction (−), multiplication (*), and division (/) can be applied to numeric values or attributes with numeric domains. For example, suppose that we want to see the effect of giving all employees who work on the 'ProductX' project a 10% raise; we can issue Query 13 to see what their salaries would become. This example also shows how we can rename an attribute in the query result using AS in the SELECT clause.

Query 13. Show the resulting salaries if every employee working on the 'ProductX' project is given a 10% raise.

Q13: SELECT E.Fname, E.Lname, 1.1 * E.Salary **AS** Increased_sal **FROM** EMPLOYEE **AS** E, WORKS_ON **AS** W, PROJECT **AS** P

WHERE E.Ssn = W.Essn **AND** W.Pno = P.Pnumber **AND** P.Pname = 'ProductX';

For string data types, the concatenate operator || can be used in a query to append two string values. For date, time, timestamp, and interval data types, operators include incrementing (+) or decrementing (−) a date, time, or timestamp by an interval. In addition, an interval value is the result of the difference between two date, time, or timestamp values. Another comparison operator, which can be used for convenience, is **BETWEEN**, which is illustrated in Query 14.

Query 14. Retrieve all employees in department 5 whose salary is between $30,000 and $40,000.

Q14: SELECT * **FROM** EMPLOYEE **WHERE** (Salary **BETWEEN** 30000 **AND** 40000) **AND** Dno = 5;

The condition (Salary **BETWEEN** 30000 **AND** 40000) in Q14 is equivalent to the condition ((Salary >= 30000) **AND** (Salary <= 40000)).

Ordering of Query Results

SQL allows the user to order the tuples in the result of a query by the values of one or more of the attributes that appear in the query result, by using the **ORDER BY** clause. This is illustrated by Query 15.

Query 15. Retrieve a list of employees and the projects they are working on, ordered by department and, within each department, ordered alphabetically by last name, then first name.

Q15: SELECT D.Dname, E.Lname, E.Fname, P.Pname **FROM** DEPARTMENT **AS** D, EMPLOYEE **AS** E, WORKS_ON **AS** W, PROJECT **AS** P **WHERE** D.Dnumber = E.Dno **AND** E.Ssn = W.Essn **AND** W.Pno = P.Pnumber **ORDER BY** D.Dname, E.Lname, E.Fname;

The default order is in ascending order of values. We can specify the keyword **DESC** if we want to see the result in a descending order of values. The keyword **ASC** can be used to specify ascending order explicitly. For example, if we want descending alphabetical order on Dname and ascending order on Lname, Fname, the ORDER BY clause of Q15 can be written as **ORDER BY** D.Dname **DESC**, E.Lname **ASC**, E.Fname **ASC**

Discussion and Summary of Basic SQL Retrieval Queries

A *simple* retrieval query in SQL can consist of up to four clauses, but only the first two—SELECT and FROM—are mandatory. The clauses are specified in the following order, with the clauses between square brackets […] being optional:

SELECT <attribute list> **FROM** <table list> [**WHERE** <condition>] [**ORDER BY** <attribute list>];

The SELECT clause lists the attributes to be retrieved, and the FROM clause specifies all relations (tables) needed in the simple query. The WHERE clause identifies the conditions for selecting the tuples from these relations, including join conditions if needed. ORDER BY specifies an order for displaying the results of a query. Two additional clauses GROUP BY and HAVING will be described in Section 7.1.8.

In Chapter 7, we will present more complex features of SQL retrieval queries. These include the following: nested queries that allow one query to be included as part of another query; aggregate functions that are used to provide summaries of the information in the tables; two additional clauses (GROUP BY and HAVING) that can be used to provide additional power to aggregate functions; and various types of joins that can combine records from various tables in different ways.

INSERT, DELETE, and UPDATE Statements in SQL

In SQL, three commands can be used to modify the database: INSERT, DELETE, and UPDATE. We discuss each of these in turn.

The INSERT Command

In its simplest form, INSERT is used to add a single tuple (row) to a relation (table). We must specify the relation name and a list of values for the tuple. The values should be listed *in the same order* in which the corresponding attributes were specified in the CREATE TABLE command. For example, to add a new tuple to the EMPLOYEE relation shown in Figure 5.5 and specified in the CREATE TABLE EMPLOYEE … command in Figure 6.1, we can use U1:

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

A second form of the INSERT statement allows the user to specify explicit attribute names that correspond to the values provided in the INSERT command. This is useful if a relation has many attributes but only a few of those attributes are assigned values in the new tuple. However, the values must include all attributes with NOT NULL specification *and* no default value. Attributes with NULL allowed or DEFAULT values are the ones that can be *left out.* For example, to enter a tuple for a new EMPLOYEE for whom we know only the Fname, Lname, Dno, and Ssn attributes, we can use U1A:

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

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

A DBMS that fully implements SQL should support and enforce all the integrity constraints that can be specified in the DDL. For example, if we issue the command in U2 on the database shown in Figure 5.6, the DBMS should *reject* the operation because no DEPARTMENT tuple exists in the database with Dnumber = 2. Similarly, U2A would be *rejected* because no Ssn value is provided and it is the primary key, which cannot be NULL.

U2: INSERT INTO EMPLOYEE (Fname, Lname, Ssn, Dno) **VALUES** ('Robert', 'Hatcher', '980760540', 2);

(U2 is rejected if referential integrity checking is provided by DBMS.)

U2A: INSERT INTO EMPLOYEE (Fname, Lname, Dno) **VALUES** ('Robert', 'Hatcher', 5);

(U2A is rejected if NOT NULL checking is provided by DBMS.)

A variation of the INSERT command inserts multiple tuples into a relation in conjunction with creating the relation and loading it with the *result of a query.* For example, to create a temporary table that has the employee last name, project name, and hours per week for each employee working on a project, we can write the statements in U3A and U3B:

U3A: CREATE TABLE WORKS_ON_INFO (Emp_name VARCHAR(15), Proj_name VARCHAR(15),

Hours_per_week DECIMAL(3,1));

U3B: INSERT INTO WORKS_ON_INFO (Emp_name, Proj_name, Hours_per_week)

SELECT E.Lname, P.Pname, W.Hours **FROM** PROJECT P, WORKS_ON W, EMPLOYEE E **WHERE** P.Pnumber = W.Pno **AND** W.Essn = E.Ssn;

A table WORKS_ON_INFO is created by U3A and is loaded with the joined information retrieved from the database by the query in U3B. We can now query WORKS_ON_INFO as we would any other relation; when we do not need it anymore, we can remove it by using the DROP TABLE command (see Chapter 7). Notice that the WORKS_ON_INFO table may not be up to date; that is, if we update any of the PROJECT,WORKS_ON, or EMPLOYEE relations after issuing U3B, the information in WORKS_ON_INFO *may become outdated.* We have to create a view (see Chapter 7) to keep such a table up to date.

Most DBMSs have *bulk loading* tools that allow a user to load formatted data from a file into a table without having to write a large number of INSERT commands. The user can also write a program to read each record in the file, format it as a row in the table, and insert it using the looping constructs of a programming language (see Chapters 10 and 11, where we discuss database programming techniques).

Another variation for loading data is to create a new table TNEW that has the same attributes as an existing table T, and load some of the data currently in T into TNEW. The syntax for doing this uses the LIKE clause. For example, if we want to create a table D5EMPS with a similar structure to the EMPLOYEE table and load it with the rows of employees who work in department 5, we can write the following SQL:

CREATE TABLE D5EMPS **LIKE** EMPLOYEE (**SELECT** E.* **FROM** EMPLOYEE **AS** E **WHERE** E.Dno = 5) **WITH DATA**;

The clause WITH DATA specifies that the table will be created and loaded with the data specified in the query, although in some implementations it may be left out.

The DELETE Command

The DELETE command removes tuples from a relation. It includes a WHERE clause, similar to that used in an SQL query, to select the tuples to be deleted.

Tuples are explicitly deleted from only one table at a time. However, the deletion may propagate to tuples in other relations if *referential triggered actions* are specified in the referential integrity constraints of the DDL (see Section 6.2.2).12 Depending on the number of tuples selected by the condition in the WHERE clause, zero, one, or several tuples can be deleted by a single DELETE command. A missing WHERE clause specifies that all tuples in the relation are to be deleted; however, the table remains in the database as an empty table. We must use the DROP TABLE command to remove the table definition (see Chapter 7). The DELETE commands in U4A to U4D, if applied independently to the database state shown in Figure 5.6, will delete zero, one, four, and all tuples, respectively, from the EMPLOYEE relation:

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

The UPDATE Command

The **UPDATE** command is used to modify attribute values of one or more selected tuples. As in the DELETE command, a WHERE clause in the UPDATE command selects the tuples to be modified from a single relation. However, updating a primary key value may propagate to the foreign key values of tuples in other relations if such a *referential triggered action* is specified in the referential integrity constraints of the DDL (see Section 6.2.2). An additional **SET** clause in the UPDATE command specifies the attributes to be modified and their new values. For example, to change the location and controlling department number of project number 10 to 'Bellaire' and 5, respectively, we use U5:

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

Several tuples can be modified with a single UPDATE command. An example is to give all employees in the 'Research' department a 10% raise in salary, as shown in U6. In this request, the modified Salary value depends on the original Salary value in each tuple, so two references to the Salary attribute are needed. In the SET clause, the reference to the Salary attribute on the right refers to the old Salary value *before modification*, and the one on the left refers to the new Salary value *after modification*:

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

It is also possible to specify NULL or DEFAULT as the new attribute value. Notice that each UPDATE command explicitly refers to a single relation only. To modify multiple relations, we must issue several UPDATE commands.

Additional Features of SQL

SQL has a number of additional features that we have not described in this chapter but that we discuss elsewhere in the book. These are as follows:

- In Chapter 7, which is a continuation of this chapter, we will present the following SQL features: various techniques for specifying complex retrieval queries, including nested queries, aggregate functions, grouping, joined tables, outer joins, case statements, and recursive queries; SQL views, triggers, and assertions; and commands for schema modification.

- SQL has various techniques for writing programs in various programming languages that include SQL statements to access one or more databases. These include embedded (and dynamic) SQL, SQL/CLI (Call Level Interface) and its predecessor ODBC (Open Data Base Connectivity), and SQL/PSM (Persistent Stored Modules). We discuss these techniques in Chapter 10. We also describe how to access SQL databases through the Java programming language using JDBC and SQLJ.
- Each commercial RDBMS will have, in addition to the SQL commands, a set of commands for specifying physical database design parameters, file structures for relations, and access paths such as indexes. We called these commands a *storage definition language* (*SDL*) in Chapter 2. Earlier versions of SQL had commands for **creating indexes**, but these were removed from the systems still have the CREATE INDEX commands; but they require a special privilege. We describe this in Chapter 17.
- SQL has transaction control commands. These are used to specify units of database processing for concurrency control and recovery purposes. We discuss these commands in Chapter 20 after we discuss the concept of transactions in more detail.
- SQL has language constructs for specifying the *granting and revoking of privileges* to users. Privileges typically correspond to the right to use certain SQL commands to access certain relations. Each relation is assigned an owner, and either the owner or the DBA staff can grant to selected users the privilege to use an SQL statement—such as SELECT, INSERT, DELETE, or UPDATE—to access the relation. In addition, the DBA staff can grant the privileges to create schemas, tables, or views to certain users. These SQL commands—called **GRANT** and **REVOKE**—are discussed in Chapter 20, where we discuss database security and authorization.
- SQL has language constructs for creating triggers. These are generally referred to as **active database** techniques, since they specify actions that are automatically triggered by events such as database updates. We discuss these features in Section 26.1, where we discuss active database concepts.
- SQL has incorporated many features from object-oriented models to have more powerful capabilities, leading to enhanced relational systems known as **object-relational**. Capabilities such as creating complex-structured attributes, specifying abstract data types (called **UDT**s or user-defined types) for attributes and tables, creating **object identifiers** for referencing tuples, and specifying **operations** on types are discussed in Chapter 12.
- SQL and relational databases can interact with new technologies such as XML (see Chapter 13) and OLAP/data warehouses (Chapter 29).

Summary

In this chapter, we introduced the SQL database language. This language and its variations have been implemented as interfaces to many commercial relational DBMSs, including Oracle's Oracle; ibm's DB2; Microsoft's SQL Server; and many other systems including Sybase and INGRES. Some open source systems also provide SQL, such as MySQL and PostgreSQL. The original version of SQL was implemented in the experimental DBMS called SYSTEM R, which was developed at IBM Research. SQL is designed to be a comprehensive language that includes statements for data definition, queries, updates, constraint specification, and view definition.

We discussed the following features of SQL in this chapter: the data definition commands for creating tables, SQL basic data types, commands for constraint specification, simple retrieval queries, and database update commands. In the next chapter, we will present the following features of SQL: complex retrieval queries; views; triggers and assertions; and schema modification commands.