SQL: Advanced Queries

This Module describes more advanced features of the SQL language standard for relational databases.

5.1 More Complex SQL Retrieval Queries

We described some basic types of retrieval queries in SQL. Because of the generality and expressive power of the language, there are many additional features that allow users to specify more complex retrievals from the database.

5.1.1 Comparisons Involving NULL and Three-Valued Logic

SQL has various rules for dealing with NULL values. NULL is used to represent a missing value, but that it usually has one of three different interpretations—value unknown (exists but is not known),value not available (exists but is purposely withheld),or value not applicable (the attribute is undefined for this tuple).

Consider the following examples to illustrate each of the meanings of NULL.

1. **Unknown value**. A person’s date of birth is not known, so it is represented by NULL in the database.
2. **Unavailable or withheld value**. A person has a home phone but does not want it to be listed, so it is withheld and represented as NULL in the database.
3. **Not applicable attribute.** An attribute LastCollegeDegree would be NULL for a person who has no college degrees because it does not apply to that person.

It is often not possible to determine which of the meanings is intended; for example, a NULL for the home phone of a person can have any of the three meanings. Hence, SQL does not distinguish between the different meanings of NULL.

In general, each individual NULL value is considered to be different from every other NULL value in the various database records .When a NULL is involved in a comparison operation, the result is considered to be UNKNOWN (it may be TRUE or it may be FALSE). Hence, SQL uses a three- valued logic with values TRUE, FALSE, and UNKNOWN instead of the standard two-valued (Boolean) logic with values TRUE or FALSE.I t is therefore necessary to define the results (or truth values) of three- valued logical expressions when the logical connectives AND, OR, and NOT are used. Table 5.1 shows the resulting values.

Table 5.1 Logical Connectives in Three-Valued Logic

(a)

AND	TRUE	FALSE	UNKNOWN
TRUE	TRUE	FALSE	UNKNOWN
FALSE	FALSE	FALSE	FALSE
UNKNOWN	UNKNOWN	FALSE	UNKNOWN

(b)

OR	TRUE	FALSE	UNKNOWN
TRUE	TRUE	TRUE	TRUE
FALSE	TRUE	FALSE	UNKNOWN
UNKNOWN	TRUE	UNKNOWN	UNKNOWN

(c)

NOT	
TRUE	FALSE
FALSE	TRUE
UNKNOWN	UNKNOWN

In Tables 5.1(a) and 5.1(b), the rows and columns represent the values of the results of comparison conditions, which would typically appear in the WHERE clause of an SQL query. Each expression result would have a value of TRUE, FALSE, or UNKNOWN. The result of combining the two values using the AND logical connective is shown by the entries in Table 5.1(a).Table 5.1(b) shows the result of using the OR logical connective. For example, the result of (FALSE AND UNKNOWN) is FALSE, whereas the result of (FALSE OR UNKNOWN) is UNKNOWN. Table 5.1(c) shows the result of the NOT logical operation. Notice that in standard Boolean logic, only Truer FALSE values are permitted; there is no UNKNOWN value.

SQL allows queries that check whether an attribute value is NULL. Rather than using = or <> to compare an attribute value to NULL, SQL uses the comparison operators **IS** or **IS NOT**. This is because SQL considers each NULL value as being distinct from every other NULL value, so equality comparison is not appropriate.

Query 18. Retrieve the names of all employees who do not have supervisors.

```
SELECT Fname, Lname
FROM EMPLOYEE WHERE Super_ssn IS  NULL;
```

5.1.2 Nested Queries, Tuples, and Set/Multiset Comparisons

Some queries require that existing values in the database be fetched and then used in a comparison condition. Such queries can be conveniently formulated by using **nested queries,** which are complete select-from-where blocks within the WHERE clause of another query. That other query is called the **outer query**.

IN operator:

IN operator is a comparison operator that compares a value v with a set (or multiset) of values V and evaluates to TRUE if v is one of the elements in V.

ex: Query 17. Retrieve the Social Security numbers of all employees who work on project numbers 1,2,or 3.

```
SELECT DISTINCT Essn
FROM WORKS_ON WHERE Pno IN (1, 2, 3);
```

SQL allows the use of tuples of values in comparisons by placing them within parentheses. To illustrate this, consider the following query:

```
SELECT DISTINCT Essn
FROM WORKS_ON WHERE (Pno, Hours) IN ( SELECT Pno, Hours FROM WORKS_ON
                                      WHERE Essn='123456789');
```

This query will select the Essns of all employees who work the same (project,hours) combination on some project that employee 'John Smith' (whose Ssn = '123456789') works on. In this example, the IN operator compares the subtuple of values in parentheses (Pno, Hours) within each tuple in WORKS_ON with the set of type-compatible tuples produced by the nested query.

In addition to the IN operator ,a number of other comparison operators can be used to compare a single value v (typically an attribute name) to a set or multiset v (typically a nested query).The = ANY (or = SOME) operator returns TRUE if the value v is equal to some value in the set V and is hence equivalent to IN. The two keywords ANY and SOME have the same effect. Other operators that can be combined with ANY (or SOME) include >, >=, <, <=, and <>. The keyword ALL can also be combined with each of these operators. For example,the comparison condition (v>ALL V) returns TRUE if the value v is greater than all the values in the set (or multiset) V.

An example is the following query, which returns the names of employees whose salary is greater than the salary of all the employees in department 5:

```
SELECT Lname, Fname
FROM EMPLOYEE WHERE Salary > ALL ( SELECT Salary FROM EMPLOYEE
                                    WHERE      Dno=5 );
```

Query 16. Retrieve the name of each employee who has a dependent with the same first name and is the same sex as the employee.

```
Q16:  SELECT   E.Fname, E.Lname
      FROM     EMPLOYEE AS E
      WHERE    E.Ssn IN  ( SELECT   Essn
                           FROM     DEPENDENT AS D
                           WHERE    E.Fname=D.Dependent_name
                                    AND E.Sex=D.Sex );
```

In the nested query of Q16, we must qualify E.Sex because it refers to the Sex attribute of EMPLOYEE from the outer query, and DEPENDENT also has an attribute called Sex. If there were any unqualified references to Sex in the nested query, they would refer to the Sex attribute of DEPENDENT. However, we would not *have to* qualify the attributes Fname and Ssn of EMPLOYEE if they appeared in the nested query because the DEPENDENT relation does not have attributes called Fname and Ssn, so there is no ambiguity.

5.1.3 Correlated Nested Queries

Whenever a condition in the WHERE clause of a nested query references some attribute of a relation declared in the outer query, the **two queries are said to be correlated.** We can understand a correlated query better by considering that the nested query is evaluated once for each tuple (or combination of tuples) in the outer query.

Example for Correlated Nested Queries:

Retrieve the name of each employee who has a dependent with the same first name and is the same sex as the employee.

```
Q16: SELECT E.Fname, E.Lname FROM EMPLOYEE AS E
 WHERE E.Ssn IN ( SELECT Essn FROM DEPENDENT AS D
                  WHERE E.Fname=D.Dependent_name AND E.Sex=D.Sex );
```

For example, we can think of Q16 as follows: For each EMPLOYEE tuple, evaluate the nested query, which retrieves the Essn values for all DEPENDENT tuples with the same sex and name as that EMPLOYEE tuple; if the Ssn value of the EMPLOYEE tuple is in the result of the nested query, then select that EMPLOYEE tuple.

In general 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, Q16 may be written as in Q16A:

Q16A: SELECT E.Fname, E.Lname
FROM EMPLOYEE AS E, DEPENDENT AS D

WHERE E.Ssn=D.Essn AND E.Sex=D.Sex AND E.Fname=D.Dependent_name;

The EXISTS and UNIQUE Functions in SQL

The EXISTS function in SQL is used to check whether the result of a correlated nested query is *empty* (contains no tuples) or not. The result of EXISTS is a Boolean value **TRUE** if the nested query result contains at least one tuple, or **FALSE** if the nested query result contains no tuples. We illustrate the use of EXISTS—and NOT EXISTS—with some examples. First, we formulate Query 16 in an alternative form that uses EXISTS as in Q16B:

```
Q16B:  SELECT    E.Fname, E.Lname
       FROM      EMPLOYEE AS E
       WHERE     EXISTS ( SELECT   *
                          FROM     DEPENDENT AS D
                          WHERE    E.Ssn=D.Essn AND E.Sex=D.Sex
                                   AND E.Fname=D.Dependent_name);
```

EXISTS and NOT EXISTS are typically used in conjunction with a correlated nested query. In Q16B,the nested query references the Ssn,Fname,and Sex attributes of the EMPLOYEE relation from the outer query. We can think of Q16Bas follows: For each EMPLOYEE tuple, evaluate the nested query, which retrieves all DEPENDENT tuples with the same Essn, Sex, and Dependent_name as the EMPLOYEE tuple; if at least one tuple EXISTS in the result of the nested query, then select that EMPLOYEE tuple.

In general, **EXISTS(Q)** returns TRUE if there is at least one tuple in the result of the nested query Q, and it returns FALSE otherwise.

On the other hand**, NOT EXISTS(Q)** returns TRUE if there are no tuples in the result of nested query Q, and it returns FALSE otherwise. Next, we illustrate the use of NOT EXISTS.

Query 6. Retrieve the names of employees who have no dependents.

```
SELECT Fname, Lname
FROM    EMPLOYEE
WHERE NOT EXISTS ( SELECT * FROM DEPENDENT
                             WHERE Ssn=Essn );
```

In Q6, the correlated nested query retrieves all DEPENDENT tuples related to a particular EMPLOYEE tuple. If none exist, the EMPLOYEE tuple is selected because the WHERE-clause condition will evaluate to TRUE in this case. We can explain Q6 as follows: For each EMPLOYEE tuple, the correlated nested query selects all DEPENDENT tuples whose Essn value matches the EMPLOYEE Ssn; if the result is empty, no dependents are related to the employee, so we select that EMPLOYEE tuple and retrieve its Fname and Lname.

5.1.4 Explicit Sets and Renaming of Attributes in SQL

Explicit Sets

We have seen several queries with a nested query in the WHERE clause. It is also possible to use an explicit set of values in the WHERE clause, rather than a nested query.Such a set is enclosed in parentheses in SQL.

Query 17. Retrieve the Social Security numbers of all employees who work on project numbers 1,2,or 3.

SELECT DISTINCT Essn FROM WORKS_ON WHERE Pno IN (1, 2, 3);

Renaming of Attributes

In SQL, it is possible to rename any attribute that appears in the result of a query by adding the qualifier **AS** followed by the desired new name. Hence, the AS construct can be used to alias both attribute and relation names, and it can be used in both the SELECT and FROM clauses.

For example, to retrieve the last name of each employee and his or her supervisor,while renaming the resulting attribute names as Employee_name and Supervisor_name.The new names will appear as column headers in the query result.

SELECT E.Lname **AS** Employee_name, S.Lname **AS** Supervisor_name
FROM EMPLOYEE AS E, EMPLOYEE AS S
WHERE E.Super_ssn=S.Ssn;

5.1.5 Joined Tables in SQL and Outer Joins

The concept of a joined table (or joined relation) was incorporated into SQL to permit users to specify a table resulting from a join operation in the FROM clause of a query. This construct may be easier to comprehend than mixing together all the select and join conditions in the WHERE clause.

For example, consider query Q1, which retrieves the name and address of every employee who works for the 'Research' department. It may be easier to specify the join of the EMPLOYEE and DEPARTMENT relations first, and then to select the desired tuples and attributes. This can be written in SQL as in Q1A:

Q1A**: SELECT** Fname, Lname, Address
FROM (EMPLOYEE **JOIN** DEPARTMENT ON **Dno=Dnumber**)
WHERE Dname='Research';

The FROM clause in Q1A contains a single joined table. The attributes of such a table are all the attributes of the first table, EMPLOYEE, followed by all the attributes of the second table, DEPARTMENT.

The concept of a joined table also allows the user to specify different types of join, such as **NATURAL JOIN** and various types of **OUTER JOIN**.

In a **NATURAL JOIN** on two relations R and S, no join condition is specified; an implicit **EQUIJOIN** condition for each pair of attributes with the same name from R and S is created. Each such pair of attributes is included only once in the resulting relation.

If the names of the join attributes are not the same in the base relations, it is possible to rename the attributes so that they match, and then to apply NATURAL JOIN. In this case, the AS construct can be used to rename a relation and all its attributes in the FROM clause. This is illustrated in Q1B, where the DEPARTMENT relation is renamed as DEPT and its attributes are renamed as Dname, Dno (to match the name of the desired join attribute Dno in the EMPLOYEE table), Mssn, and Msdate. The implied join condition for this NATURAL JOIN is EMPLOYEE.Dno=DEPT.Dno, because this is the only pair of attributes with the same name after renaming:

Q1B: SELECT Fname, Lname, Address FROM
(EMPLOYEE **NATURAL JOIN** (DEPARTMENT AS DEPT (Dname, Dno, Mssn,Msdate)))
WHERE Dname='Research';

The default type of join in a joined table is called an **inner join**, where a tuple is included in the result only if a matching tuple exists in the other relation

There are a variety **<u>of outer join</u>** operations.

1) **LEFT OUTER JOIN** (every tuple in the left table must appear in the result; if it does not have a matching tuple, it is padded with NULL values for the attributes of the right table).

2) **RIGHT OUTER JOIN** (every tuple in the right table must appear in the result;if it does not have a matching tuple,it is padded with NULLvalues for the attributes of the left table).
3) **FULL OUTER JOIN :** It is a combination of left and right outer joins .

In the latter three options, the keyword OUTER may be omitted. If the join attributes have the same name,one can also specify the natural join variation of outer joins by using the keyword NATURAL before the operation (for example, NATURAL LEFT OUTER JOIN).

The keyword **CROSS JOIN** is used to specify the **CARTESIAN PRODUCT** operation although this should be used only with the utmost care because it generates all possible tuple combinations.

It is also possible to nest join specifications; that is, one of the tables in a join may itself be a joined table. This allows the specification of the join of three or more tables as a single joined table, which is called a **multiway join**.

EX: SELECT Pnumber, Dnum, Lname, Address, Bdate
FROM ((PROJECT **JOIN** DEPARTMENT ON Dnum=Dnumber)
JOIN EMPLOYEE ON Mgr_ssn=Ssn) WHERE Plocation='Stafford';

Not all SQL implementations have implemented the new syntax of joined tables.In some systems, a different syntax was used to specify outer joins by using the comparison operators **+=, =+, and +=+** for left, right, and full outer join, respectively, when specifying the join condition. For example, this syntax is available in **Oracle.** To specify the **left outer join** using this syntax, we could write the query as follows:

```
SELECT E.Lname, S.Lname
FROM EMPLOYEE E, EMPLOYEE S
WHERE E.Super_ssn += S.Ssn;
```

5.1.6 Aggregate Functions in SQL

Aggregate functions are used to summarize information from multiple tuples into a single-tuple summary. **Grouping** is used to create subgroups of tuples before summarization. **Grouping and aggregation** are required in many database applications, and we will introduce their use in SQL through examples.

A number of built-in **aggregate** functions exist: **COUNT, SUM, MAX, MIN, and AVG.** The COUNT function returns the number of tuples or values as specified in a query. The functions SUM,MAX,MIN, and AVG can be applied to a set or multiset of numeric values and return, respectively, the sum, maximum value, minimum value, and average (mean) of those values.

Query 19. Find the sum of the salaries of all employees,the maximum salary, the minimum salary,and the average salary.

```
SELECT SUM (Salary), MAX (Salary), MIN (Salary), AVG (Salary)
FROM EMPLOYEE;
```

If we want to get the preceding function values for employees of a specific department—say, the 'Research' department—we can write Query 20, where the EMPLOYEE tuples are restricted by the WHERE clause to those employees who work for the 'Research' department.

Query 20. Find the sum of the salaries of all employees of the 'Research' department, as well as the maximum salary,the minimum salary,and the average salary in this department.

```
SELECT SUM (Salary), MAX (Salary), MIN (Salary), AVG (Salary)
FROM (EMPLOYEE JOIN DEPARTMENT ON Dno=Dnumber)
WHERE Dname='Research';
```

Queries 21 and 22. Retrieve the total number of employees in the company (Q21) and the number of employees in the 'Research' department (Q22).

```
Q21:    SELECT     COUNT (*)
        FROM       EMPLOYEE;

Q22:    SELECT     COUNT (*)
        FROM       EMPLOYEE, DEPARTMENT
        WHERE      DNO=DNUMBER AND DNAME='Research';
```

Here the asterisk (*) refers to the *rows* (tuples), so COUNT (*) returns the number of rows in the result of the query. We may also use the COUNT function to count values in a column rather than tuples, as in the next example.

Query 23. Count the number of distinct salary values in the database.

```
Q23:    SELECT     COUNT (DISTINCT Salary)
        FROM       EMPLOYEE;
```

If we write COUNT(SALARY) instead of COUNT(DISTINCT SALARY) in Q23, then duplicate values will not be eliminated. However, any tuples with NULL for SALARY will not be counted. In general, NULL values are discarded when aggregate functions are applied to a particular column (attribute).

5.1.7 Grouping: The GROUP BY and HAVING Clauses

GROUP BY clause

SQL has a GROUP BY clause. The GROUP BY clause specifies the grouping attributes, which should also appear in the SELECT clause, so that the value resulting from applying each aggregate function to a group of tuples appears along with the value of the grouping attribute(s).

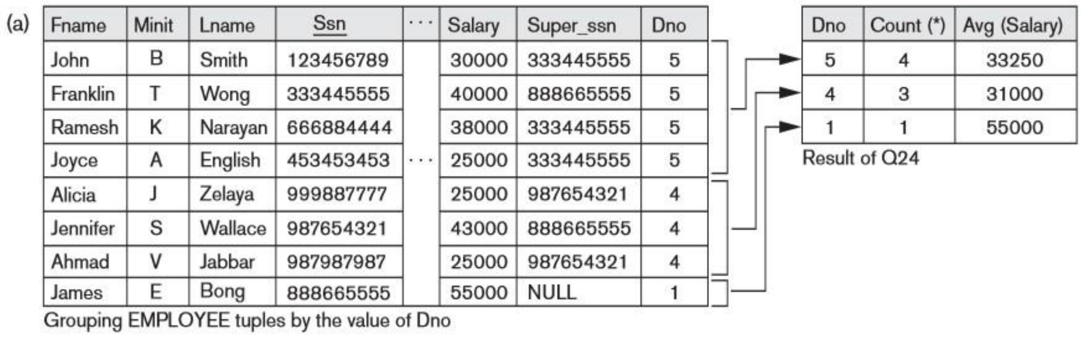
In many cases we want to apply the aggregate functions to subgroups of tuples in a relation, where the subgroups are based on some attribute values. For example, we may want to find the average salary of employees in each department or the number of employees who work on each project. In these cases we need to partition the relation into non overlapping subsets (or groups) of tuples. Each group (partition) will consist of the tuples that have the same value of some attribute(s), called the grouping attribute(s). We can then apply the function to each such group independently to produce summary information about each group.

Query 24. For each department, retrieve the department number, the number of employees in the department, and their average salary.

```
Q24:    SELECT     Dno, COUNT (*), AVG (Salary)
        FROM       EMPLOYEE
        GROUP BY   Dno;
```

In Q24, the EMPLOYEE tuples are partitioned into groups—each group having the same value for the grouping attribute Dno. Hence, each group contains the employees who work in the same department. The COUNT and AVG functions are applied to each such group of tuples. Notice that the SELECT clause includes only the grouping attribute and the aggregate functions to be applied on each group of tuples. Figure 5.1(a) illustrates how grouping works on Q24; it also shows the result of Q24.

Figure 5.1
Results of GROUP BY and HAVING. (a) Q24. (b) Q26.


(a)
Grouping EMPLOYEE tuples by the value of Dno
Result of Q24

Fname	Minit	Lname	Ssn	...	Salary	Super_ssn	Dno
John	B	Smith	123456789		30000	333445555	5
Franklin	T	Wong	333445555		40000	888665555	5
Ramesh	K	Narayan	666884444		38000	333445555	5
Joyce	A	English	453453453	...	25000	333445555	5
Alicia	J	Zelaya	999887777		25000	987654321	4
Jennifer	S	Wallace	987654321		43000	888665555	4
Ahmad	V	Jabbar	987987987		25000	987654321	4
James	E	Bong	888665555		55000	NULL	1

Dno	Count (*)	Avg (Salary)
5	4	33250
4	3	31000
1	1	55000

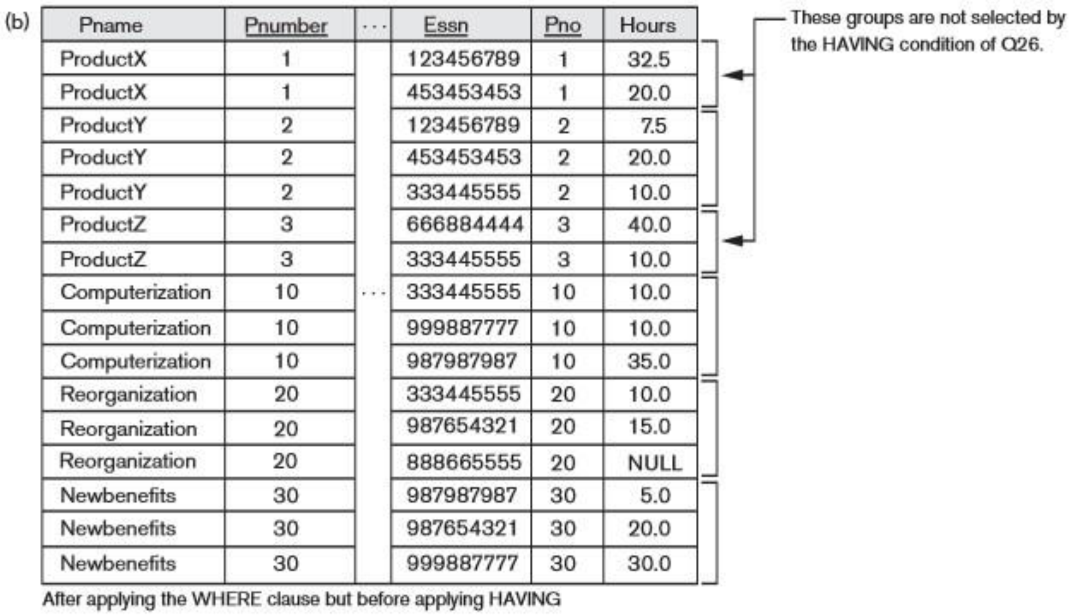
HAVING clause

SQL provides a **HAVING** clause,which can appear in conjunction with a **GROUP BY** clause. HAVING provides a condition on the summary information regarding the **group** of tuples associated with each value of the grouping attributes. Only the groups that satisfy the condition are retrieved in the result of the query.This is illustrated by Query 26.

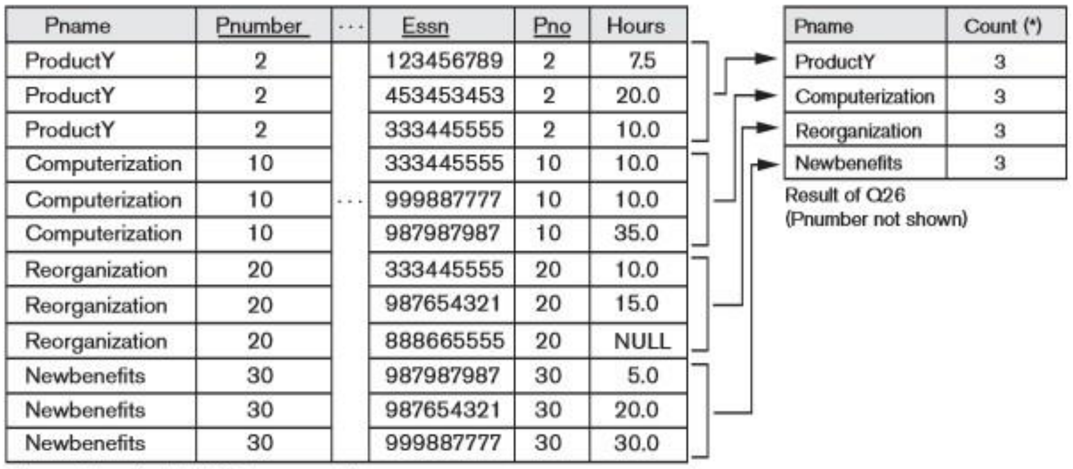
Query 26. For each project *on which more than two employees work,* retrieve the project number, the project name, and the number of employees who work on the project.

```
Q26:  SELECT     Pnumber, Pname, COUNT (*)
      FROM       PROJECT, WORKS_ON
      WHERE      Pnumber=Pno
      GROUP BY   Pnumber, Pname
      HAVING     COUNT (*) > 2;
```

Notice that while selection conditions in the WHERE clause limit the *tuples* to which functions are applied, the HAVING clause serves to choose *whole groups.* Figure 5.1(b) illustrates the use of HAVING and displays the result of Q26.


(b)
These groups are not selected by the HAVING condition of Q26.
After applying the WHERE clause but before applying HAVING

Pname	Pnumber	...	Essn	Pno	Hours
ProductX	1		123456789	1	32.5
ProductX	1		453453453	1	20.0
ProductY	2		123456789	2	7.5
ProductY	2		453453453	2	20.0
ProductY	2		333445555	2	10.0
ProductZ	3		666884444	3	40.0
ProductZ	3		333445555	3	10.0
Computerization	10	...	333445555	10	10.0
Computerization	10		999887777	10	10.0
Computerization	10		987987987	10	35.0
Reorganization	20		333445555	20	10.0
Reorganization	20		987654321	20	15.0
Reorganization	20		888665555	20	NULL
Newbenefits	30		987987987	30	5.0
Newbenefits	30		987654321	30	20.0
Newbenefits	30		999887777	30	30.0



Pname	Pnumber	...	Essn	Pno	Hours
ProductY	2		123456789	2	7.5
ProductY	2		453453453	2	20.0
ProductY	2		333445555	2	10.0
Computerization	10		333445555	10	10.0
Computerization	10	...	999887777	10	10.0
Computerization	10		987987987	10	35.0
Reorganization	20		333445555	20	10.0
Reorganization	20		987654321	20	15.0
Reorganization	20		888665555	20	NULL
Newbenefits	30		987987987	30	5.0
Newbenefits	30		987654321	30	20.0
Newbenefits	30		999887777	30	30.0

Pname	Count (*)
ProductY	3
Computerization	3
Reorganization	3
Newbenefits	3

Result of Q26
(Pnumber not shown)

After applying the HAVING clause condition

5.1.8 Discussion and Summary of SQL Queries

A retrieval query in SQL can consist of up to six clauses, but only the first two—SELECT and FROM—are mandatory. The query can span several lines, and is ended by a semicolon. Query terms are separated by spaces, and parentheses can be used to group relevant parts of a query in the standard way. The clauses are specified in the following order, with the clauses between square brackets [...] being optional:

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

The SELECT clause lists the attributes or functions to be retrieved. The FROM clause specifies all relations (tables) needed in the query, including joined relations, but not those in nested queries. The WHERE clause specifies the conditions for selecting the tuples from these relations, including join conditions if needed. GROUP BY

specifies grouping attributes, whereas HAVING specifies a condition on the groups being selected rather than on the individual tuples. The built-in aggregate functions COUNT, SUM, MIN, MAX, and AVG are used in conjunction with grouping, but they can also be applied to all the selected tuples in a query without a GROUP BY clause. Finally, ORDER BY specifies an order for displaying the result of a query.

In order to formulate queries correctly, it is useful to consider the steps that define the meaning or semantics of each query. A **query is evaluated** conceptually by first applying the FROM clause (to identify all tables involved in the query or to materialize any joined tables), followed by the WHERE clause to select and join tuples, and then by GROUP BY and HAVING. Conceptually, ORDER BY is applied at the end to sort the query result.

5.2 *Specifying Constraints as Assertions and Actions as Triggers*

In this section, we introduce two additional features of SQL: the **CREATE ASSERTION** statement and the **CREATE TRIGGER** statement.

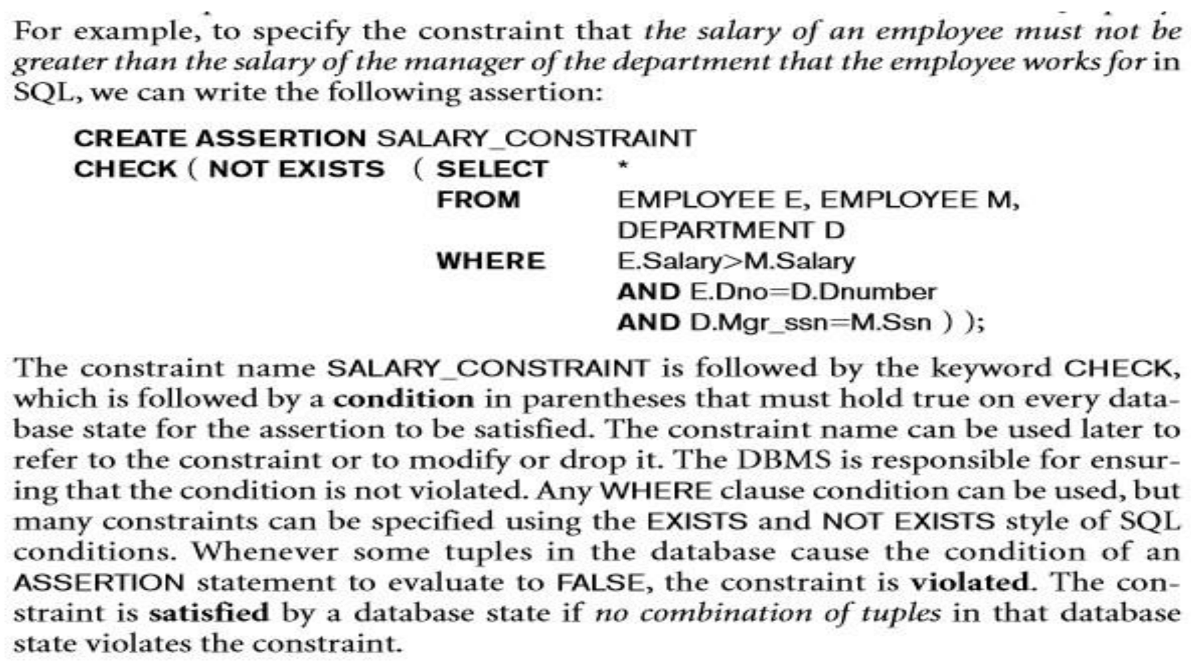
CREATE ASSERTION, which can be used to specify additional types of constraints that are outside the scope of the built-in relational model constraints (primary and unique keys, entity integrity, and referential integrity) that we presented early.

CREATE TRIGGER, which can be used to specify automatic actions that the database system will perform when certain events and conditions occur. This type of functionality is generally referred to as active databases.

5.2.1 Specifying General Constraints as Assertions in SQL

ASSERTIONS

In SQL, users can specify general constraints—those that do not fall into any of the categories described via declarative assertions, using the CREATE ASSERTION statement of the DDL. Each assertion is given a constraint name and is specified via a condition similar to the WHERE clause of an SQL query.


For example, to specify the constraint that *the salary of an employee must not be greater than the salary of the manager of the department that the employee works for* in SQL, we can write the following assertion:

```
CREATE ASSERTION SALARY_CONSTRAINT
CHECK ( NOT EXISTS  ( SELECT    *
                      FROM      EMPLOYEE E, EMPLOYEE M,
                                DEPARTMENT D
                      WHERE     E.Salary>M.Salary
                                AND E.Dno=D.Dnumber
                                AND D.Mgr_ssn=M.Ssn ) );
```

The constraint name SALARY_CONSTRAINT is followed by the keyword CHECK, which is followed by a **condition** in parentheses that must hold true on every database state for the assertion to be satisfied. The constraint name can be used later to refer to the constraint or to modify or drop it. The DBMS is responsible for ensuring that the condition is not violated. Any WHERE clause condition can be used, but many constraints can be specified using the EXISTS and NOT EXISTS style of SQL conditions. Whenever some tuples in the database cause the condition of an ASSERTION statement to evaluate to FALSE, the constraint is **violated.** The constraint is **satisfied** by a database state if *no combination of tuples* in that database state violates the constraint.

The basic technique for writing such assertions is to specify a query that selects any tuples that violate the desired condition. By including this query inside a NOT EXISTS clause, the assertion will specify that the result of this query must be empty so that the condition will always be TRUE. Thus ,the assertion is violated if the result of the query is not empty. In the preceding example, the query selects all employees whose salaries are greater than the salary of the manager of their department. If the result of the query is not empty, the assertion is violated.

5.2.2 Introduction to Triggers in SQL

Another important statement in SQL is CREATE TRIGGER. In many cases it is convenient to specify the type of action to be taken when certain events occur and when certain conditions are satisfied. For example,it may be useful to specify a condition that, if violated, causes some user to be informed of the violation. The CREATE TRIGGER statement is used to implement such actions in SQL.

A typical trigger has **three components:**

- ***Event:*** When this event happens, the trigger is activated
- ***Condition (optional):*** If the condition is true, the trigger executes, otherwise skipped
- ***Action:*** The actions performed by the trigger

➢ The **action** is to be executed **automatically** if the **condition** is satisfied when **event** occurs**.**

Trigger: Events

Three event types

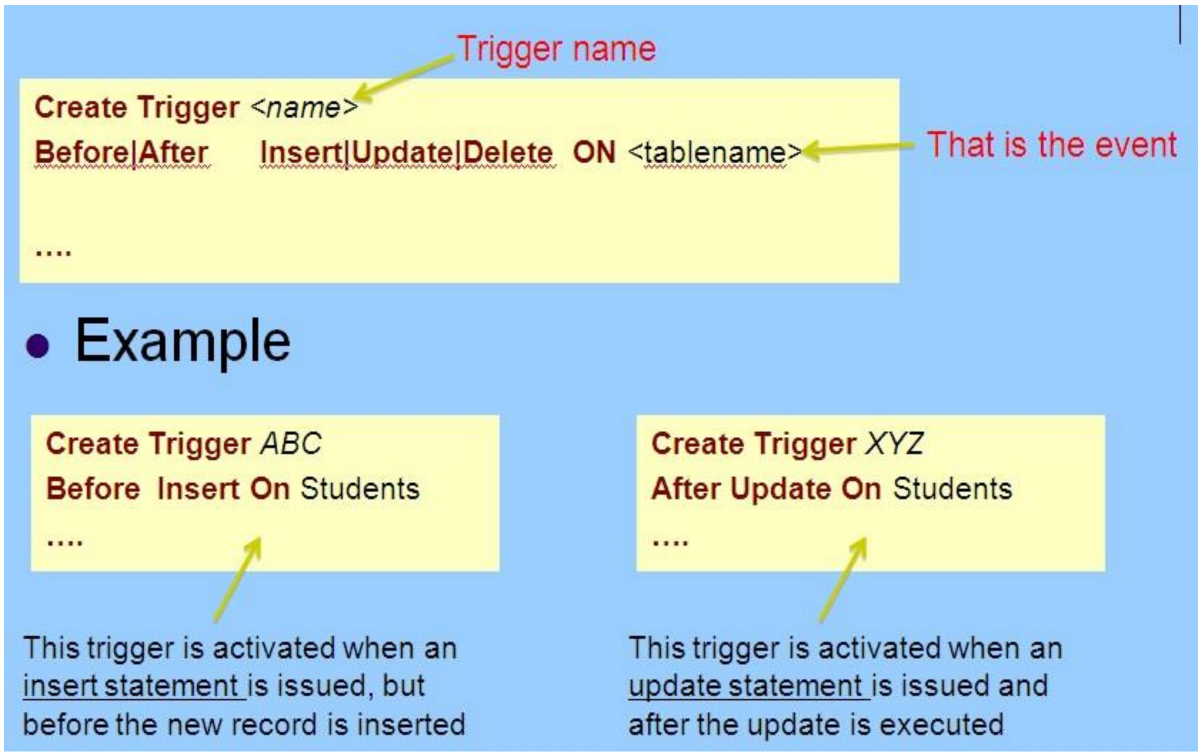
- Insert
- Update
- Delete

Two triggering times

- Before the event
- After the event

Two granularities

- Execute for each row
- Execute for each statement



```
Create Trigger <name>
Before|After    Insert|Update|Delete  ON <tablename>

....
```

Trigger name
That is the event

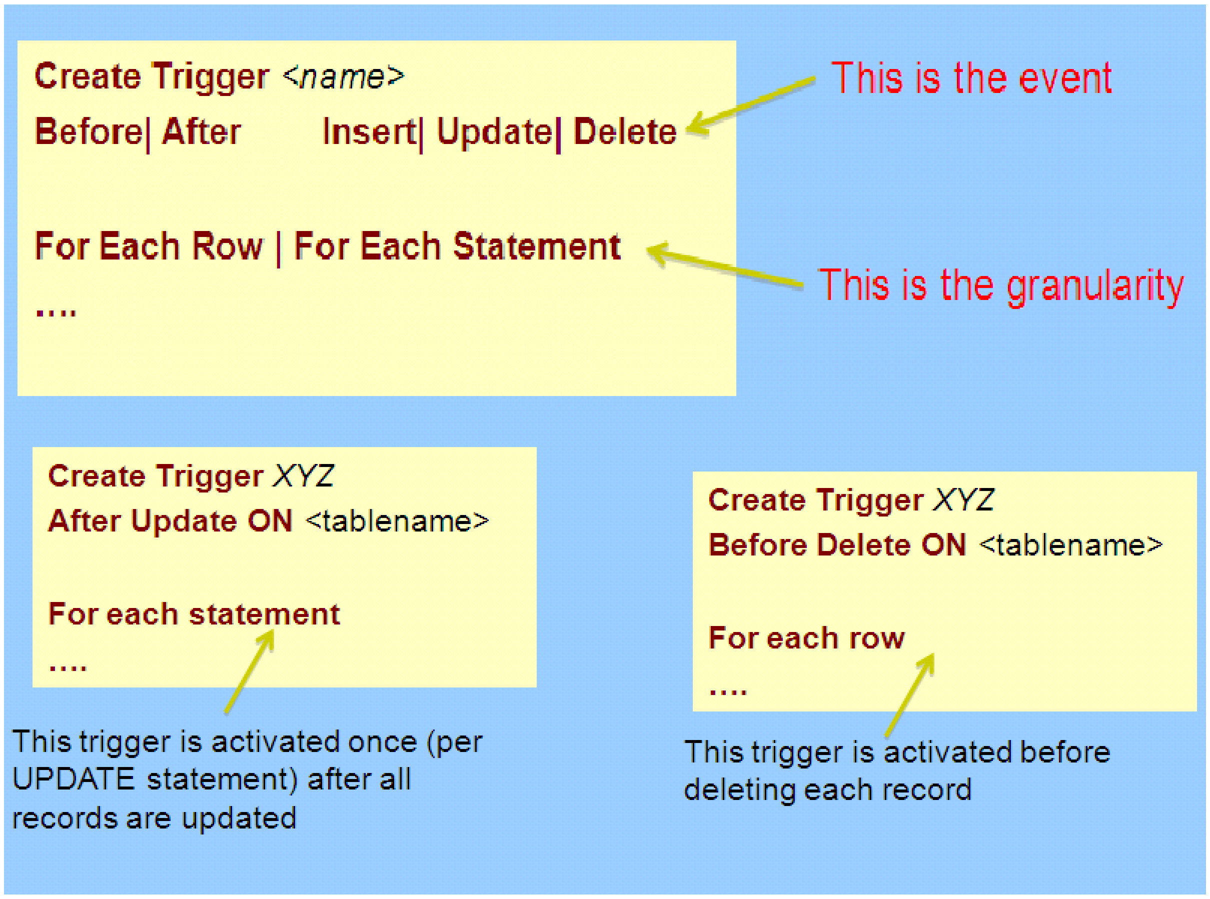
• Example

```
Create Trigger ABC
Before  Insert On Students
....
```

This trigger is activated when an insert statement is issued, but before the new record is inserted

```
Create Trigger XYZ
After Update On Students
....
```

This trigger is activated when an update statement is issued and after the update is executed



```
Create Trigger <name>
Before| After     Insert| Update| Delete

For Each Row | For Each Statement
....
```

This is the event

This is the granularity

```
Create Trigger XYZ
After Update ON <tablename>

For each statement
....
```

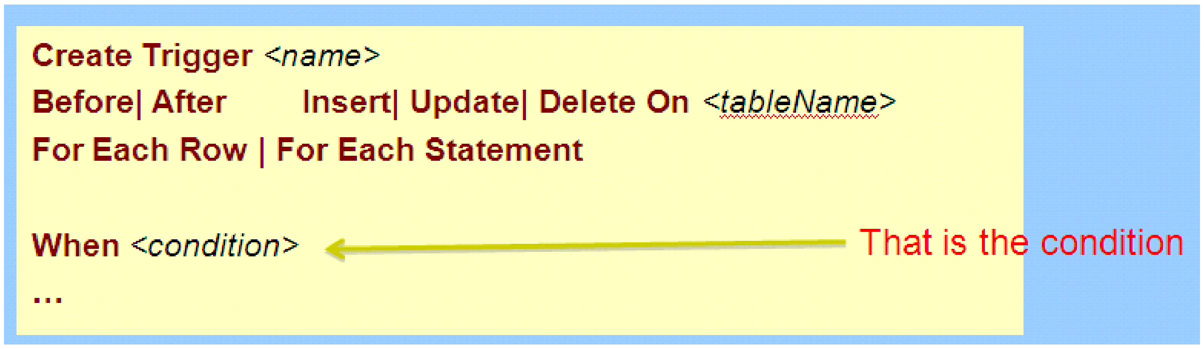
This trigger is activated once (per UPDATE statement) after all records are updated

```
Create Trigger XYZ
Before Delete ON <tablename>

For each row
....
```

This trigger is activated before deleting each record

Trigger: Condition

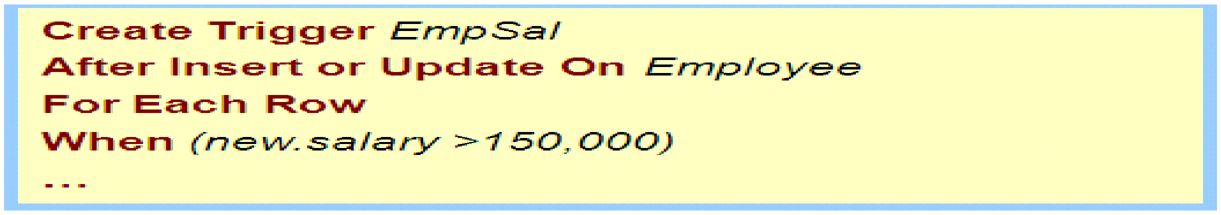


```
Create Trigger <name>
Before| After     Insert| Update| Delete On <tableName>
For Each Row | For Each Statement

When <condition>
...
```

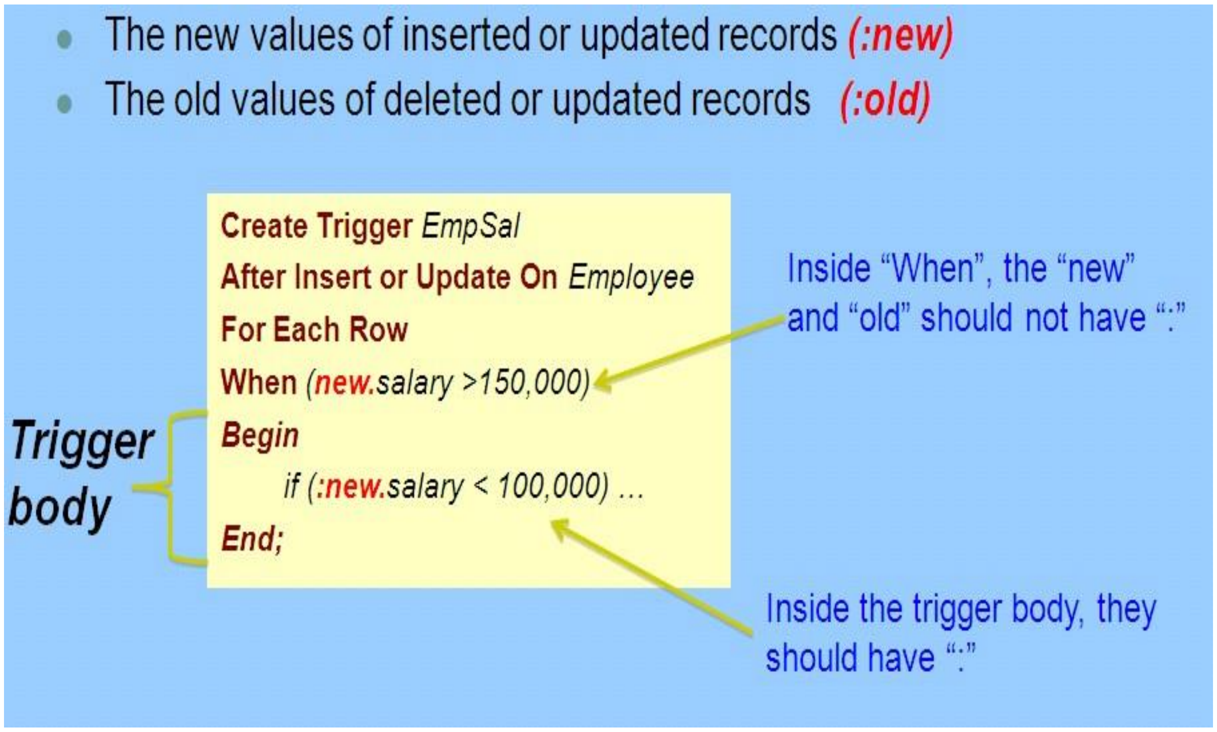
That is the condition

If the employee salary > 150,000 then some actions will be taken



```
Create Trigger EmpSal
After Insert or Update On Employee
For Each Row
When (new.salary >150,000)
...
```

Trigger: Action

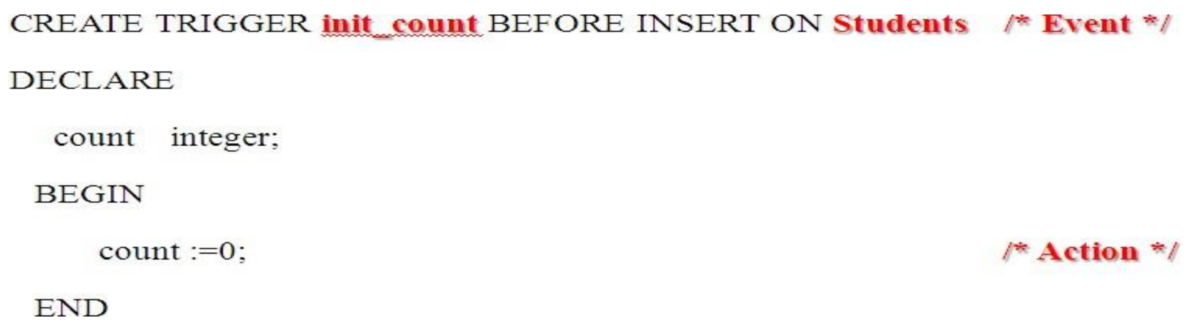


- The new values of inserted or updated records (:new)
- The old values of deleted or updated records (:old)

```
Create Trigger EmpSal
After Insert or Update On Employee
For Each Row
When (new.salary >150,000)
Begin
    if (:new.salary < 100,000) ...
End;
```

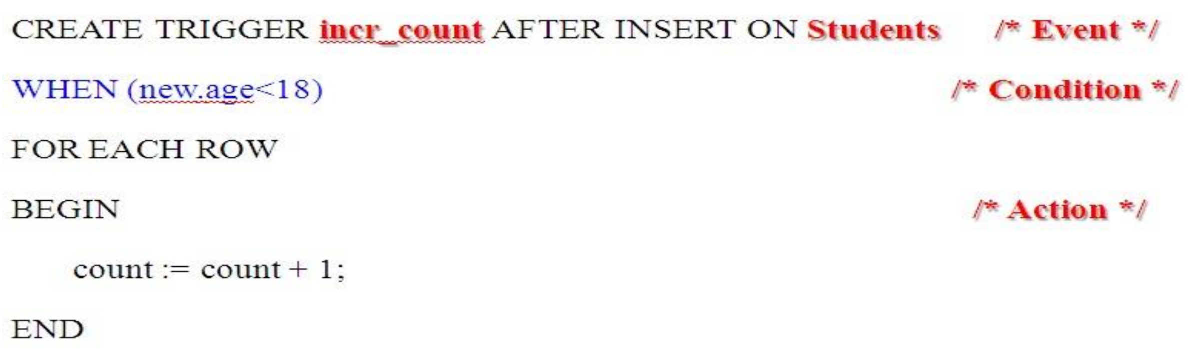
Trigger body
Inside "When", the "new" and "old" should not have ":"
Inside the trigger body, they should have ":"

Example 1



```
CREATE TRIGGER init_count BEFORE INSERT ON Students   /* Event */
DECLARE
   count   integer;
  BEGIN
       count :=0;                                      /* Action */
  END
```

<u>Example 2</u>



```
CREATE TRIGGER incr_count AFTER INSERT ON Students      /* Event */
WHEN (new.age<18)                                       /* Condition */
FOR EACH ROW
BEGIN                                                   /* Action */
    count := count + 1;
END
```

5.3 <u>Views (virtual table) in SQL</u>

1.1 <u>Concept of a View in SQL</u>

- A view is a single table that is derived from one or more base tables or other views
- Views neither exist physically nor contain data itself, it depends on the base tables for its existence
- A view contains rows and columns, just like a real table. The fields in a view are fields from one or more real tables in the database.

1.2 <u>Specification of Views in SQL</u>

<u>**Syntax:**</u>

```
CREATE VIEW view_name AS
SELECT column_name(s)
FROM table_name
WHERE condition
```

Example

```
CREATE VIEW  WORKS_ON1
AS SELECT    Fname, Lname, Pname, Hours
FROM     EMPLOYEE, PROJECT, WORKS_ON
WHERE Ssn=Essn AND Pno=Pnumber ;
```

- We can specify SQL queries on view

  <u>**Example #**</u>
- Retrieve the Last name and First name of all employees who work on ‘ProductX’

```
SELECT    Fname, Lname
FROM    WORKS_ON1
WHERE    Pname=‘ProductX’ ;
```

- A view always shows **up-to-date**
- If we **modify** the tuples in the **base tables** on which the view is defined, the view must **automatically reflect** these **changes**
- If we do not need a view any more, we can use the DROP VIEW command

  DROP VIEW WORKS_ON1;

1.3 View Implementation and View Update

View Implementation

- ➢ The problem of efficiently implementing a view for quering is complex
  Two main approaches have been suggested

Query Modification

- ➢ Modifying the view query into a query on the underlying base tables
- ➢ Disadvantage: inefficient for views defined via complex queries that are time-consuming to execute , especially if multiple queries are applied to the view within a short period of time.

Example

- ❖ The query example# would be automatically modified to the following query by the DBMS

```
SELECT   Fname, Lname
FROM     EMPLOYEE, PROJECT, WORKS_ON
WHERE Ssn=Essn AND Pno=Pnumber
AND Pname=”ProductX’;
```

View Materialization

- ➢ Physically create a temporary view table when the view is first queried
- ➢ Keep that table on the assumption that other queries on the view will follow
- ➢ Requires efficient strategy for automatically updating the view table when the base tables are updated, that is **Incremental Update**
- ➢ **Incremental Update** determines what new tuples must be inserted, deleted, or modified in a materialized view table when a change is applied to one of the defining base table

View Update

- ➢ Updating of views is complicated and can be ambiguous
- ➢ An update on view defined on a single table without any aggregate functions can be mapped to an update on the underlying base table under certain conditions.
- ➢ View involving joins, an update operation may be mapped to update operations on the underlying base relations in multiple ways.

Example

- ❖ **Update the Pname attribute of ‘john smith’ from ‘ProductX’ to ‘ProductY’**

```
UPDATE  WORKS_ON1
SET     Pname= ‘ProductY’
WHERE Lname=‘smith’ AND Fname=‘john’
AND Pname= ‘ProductX’
```

- ❖ This query can be mapped into several updates on the base relations to give the desired effect on the view.
- ❖ Two possible **updates (a) and (b)** on the base relations corresponding to above query .

```
(a)     UPDATE     WORKS_ON
                SET   Pno=     (SELECT   Pnumber
                                FROM    PROJECT
                                        WHERE    Pname= ‘ProductY’)
                                        WHERE   Essn IN (SELECT Ssn
                                        FROM  EMPLOYEE
                          WHERE Lname=‘smith’ AND Fname=‘john’)
            AND
                          Pno=  (SELECT   Pnumber
                          FROM  PROJECT
                          WHERE   Pname='ProductX' );

(b)             UPDATE    PROJECT
                          SET  Pname='ProductY'
                          WHERE Pname= 'ProductX' ;
```

- Update (a) relates 'john smith' to the 'ProductY' PROJECT tuple in place of the 'ProductX' PROJECT tuple and is the most likely update.
- Update (b) would also give the desired update effect on the view, but it accomplishes this by changing the name of the 'ProductX' tuple in the PROJECT relation to 'ProductY'

OBSERVATIONS ON VIEWS

- A view with a single defining table is updatable if the view attributes contain the primary key of the base relation, as well as all attributes with the NOT NULL constraint that do not have default values specified
- Views defined on multiple tables using joins are generally not updatable
- Views defined using grouping and aggregate functions are not updatable
- In SQL, the clause WITH HECK OPTION must be added at the end of the view definition if a view is to be updated.

Advantages of Views

- Data independence
- Currency
- Improved security
- Reduced complexity
- Convenience
- Customization
- Data integrity

5.4 Schema Change Statements in SQL

In this section, we give an overview of the schema evolution commands available in SQL, which can be used to alter a schema by adding or dropping tables, attributes, constraints, and other schema elements. This can be done while the database is operational and does not require recompilation of the database schema. Certain checks must be done by the DBMS to ensure that the changes do not affect the rest of the database and make it inconsistent.

5.4.1 The DROP Command

The DROP command can be used to drop named schema elements, such as tables, domains, or constraints.

One can also drop a schema. For example, if a whole schema is no longer needed, the DROP SCHEMA command can be used. There are two drop behavior options: **CASCADE and RESTRICT**. For example, to remove the COMPANY database schema and all its tables, domains, and other elements, the CASCADE option is used as follows:

DROP SCHEMA COMPANY **CASCADE**;

If the RESTRICT option is chosen in place of CASCADE, the schema is dropped only if it has no elements in it; otherwise, the DROP command will not be executed. To use the RESTRICT option, the user must first individually drop each element in the schema, then drop the schema itself.

DROP TABLE COMMAND :
If a base relation within a schema is no longer needed, the relation and its definition can be deleted by using the DROP TABLE command. For example, if we no longer wish to keep track of dependents of employees in the COMPANY .we can get rid of the DEPENDENT relation by issuing the following command:

DROP TABLE DEPENDENT **CASCADE**;

If the RESTRICT option is chosen instead of CASCADE, a table is dropped only if it is not referenced in any constraints (for example, by foreign key definitions in another relation) or views or by any other elements. With the CASCADE option, all such constraints, views, and other elements that reference the table being dropped are also dropped automatically from the schema, along with the table itself.
Notice that the DROP TABLE command not only deletes all the records in the table if successful, but also removes the table definition from the catalog.

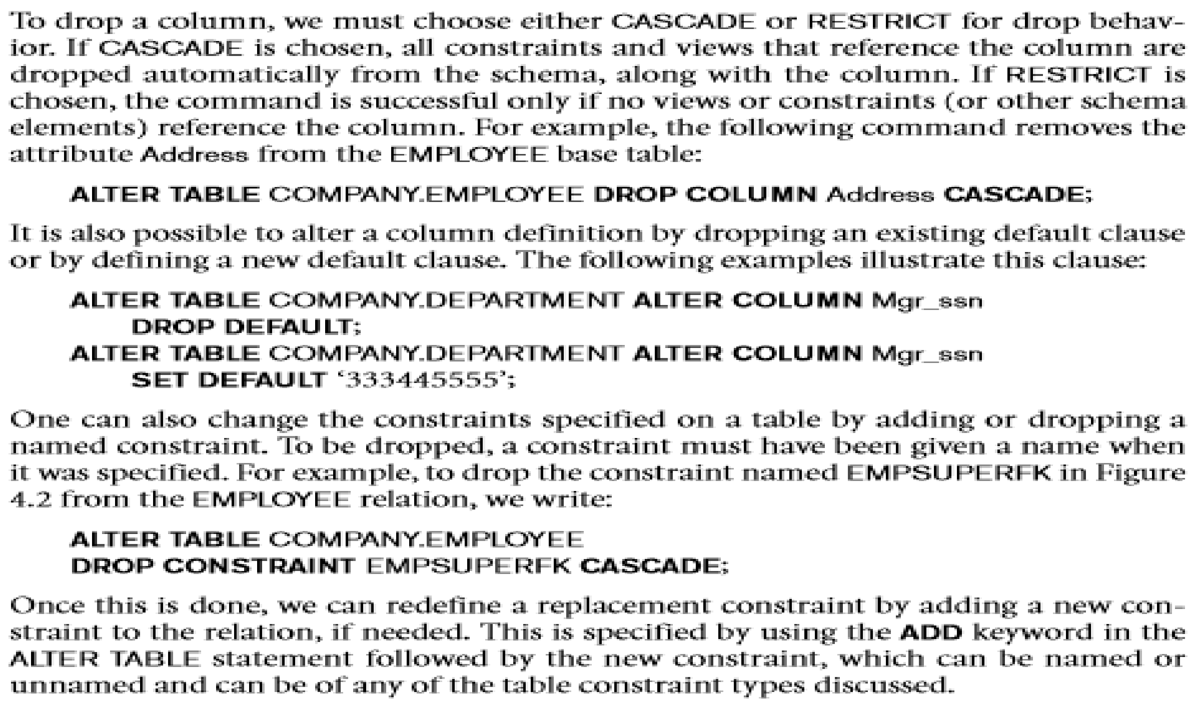
5.4.2 The ALTER Command

The definition of a base table or of other named schema elements can be changed by using the ALTER command. For base tables, the possible alter table actions include adding or dropping a column (attribute),changing a column definition, and adding or dropping table constraints.

For example, to add an attribute for keeping track of jobs of employees to the EMPLOYEE base relation in the COMPANY schema , we can use the command.

ALTER TABLE COMPANY.EMPLOYEE **ADD COLUMN** Job VARCHAR(12);

We must still enter a value for the new attribute Job for each individual EMPLOYEE tuple. This can be done either by specifying a default clause or by using the UPDATE command individually on each tuple. .If no default clause is specified, the new attribute will have NULLs in all the tuples of the relation immediately after the command is executed; hence, the NOT NULL constraint is not allowed in this case.



To drop a column, we must choose either CASCADE or RESTRICT for drop behavior. If CASCADE is chosen, all constraints and views that reference the column are dropped automatically from the schema, along with the column. If RESTRICT is chosen, the command is successful only if no views or constraints (or other schema elements) reference the column. For example, the following command removes the attribute Address from the EMPLOYEE base table:

ALTER TABLE COMPANY.EMPLOYEE **DROP COLUMN** Address **CASCADE**;

It is also possible to alter a column definition by dropping an existing default clause or by defining a new default clause. The following examples illustrate this clause:

ALTER TABLE COMPANY.DEPARTMENT **ALTER COLUMN** Mgr_ssn
    DROP DEFAULT;
ALTER TABLE COMPANY.DEPARTMENT **ALTER COLUMN** Mgr_ssn
    SET DEFAULT '333445555';

One can also change the constraints specified on a table by adding or dropping a named constraint. To be dropped, a constraint must have been given a name when it was specified. For example, to drop the constraint named EMPSUPERFK in Figure 4.2 from the EMPLOYEE relation, we write:

ALTER TABLE COMPANY.EMPLOYEE
DROP CONSTRAINT EMPSUPERFK **CASCADE**;

Once this is done, we can redefine a replacement constraint by adding a new constraint to the relation, if needed. This is specified by using the **ADD** keyword in the ALTER TABLE statement followed by the new constraint, which can be named or unnamed and can be of any of the table constraint types discussed.

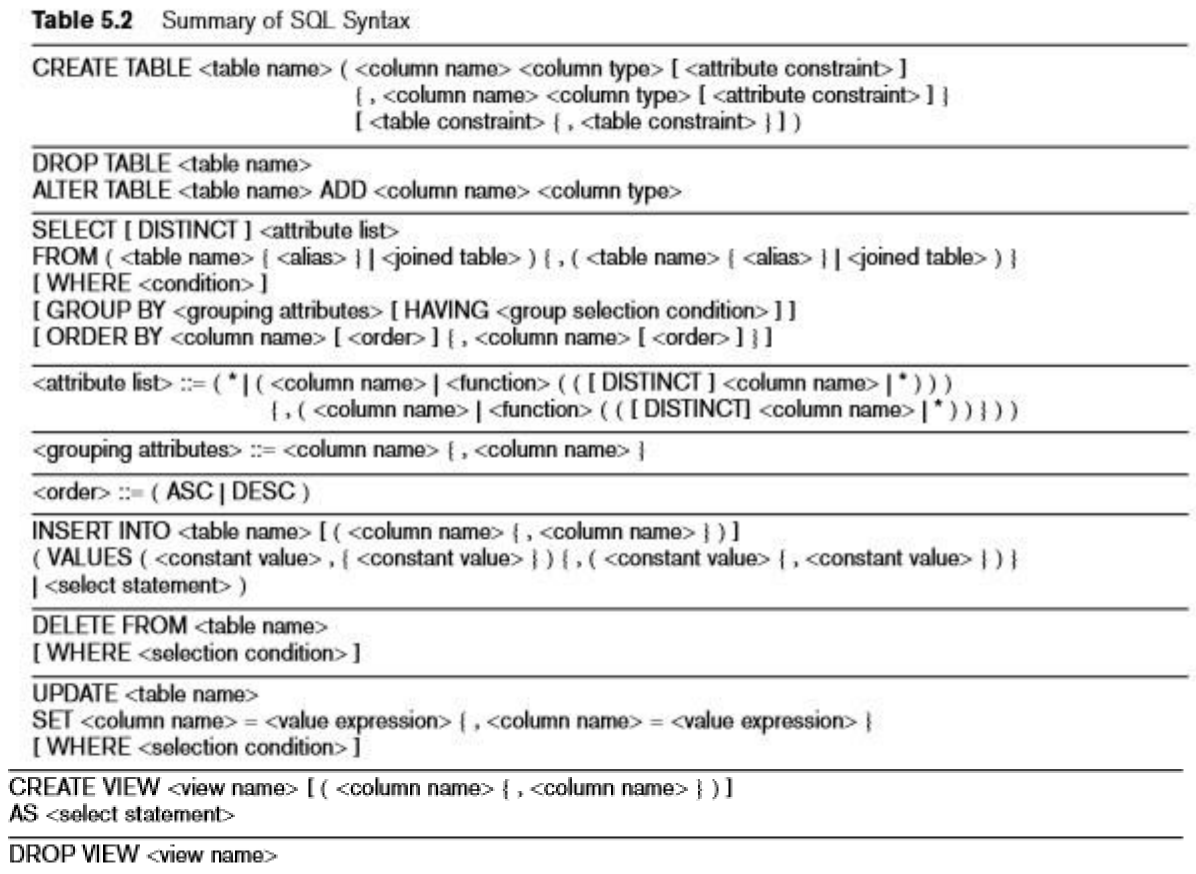


Table 5.2 Summary of SQL Syntax

```
CREATE TABLE <table name> ( <column name> <column type> [ <attribute constraint> ]
                          { , <column name> <column type> [ <attribute constraint> ] }
                          [ <table constraint> { , <table constraint> } ] )

DROP TABLE <table name>
ALTER TABLE <table name> ADD <column name> <column type>

SELECT [ DISTINCT ] <attribute list>
FROM ( <table name> { <alias> } | <joined table> ) { , ( <table name> { <alias> } | <joined table> ) }
[ WHERE <condition> ]
[ GROUP BY <grouping attributes> [ HAVING <group selection condition> ] ]
[ ORDER BY <column name> [ <order> ] { , <column name> [ <order> ] } ]

<attribute list> ::= ( * | ( <column name> | <function> ( ( [ DISTINCT ] <column name> | * ) ) )
                     { , ( <column name> | <function> ( ( [ DISTINCT] <column name> | * ) ) } ) )

<grouping attributes> ::= <column name> { , <column name> }

<order> ::= ( ASC | DESC )

INSERT INTO <table name> [ ( <column name> { , <column name> } ) ]
( VALUES ( <constant value> , { <constant value> } ) { , ( <constant value> { , <constant value> } ) }
| <select statement> )

DELETE FROM <table name>
[ WHERE <selection condition> ]

UPDATE <table name>
SET <column name> = <value expression> { , <column name> = <value expression> }
[ WHERE <selection condition> ]

CREATE VIEW <view name> [ ( <column name> { , <column name> } ) ]
AS <select statement>

DROP VIEW <view name>
```

Database Application Development

Applications that rely on the DBMS to manage data run as separate processes that connect to the DBMS to interact with it. Once a connection is established, SQL commands can be used to insert, delete, and modify data. SQL queries can be used to retrieve desired data. but we need to bridge an important difference in how a database system sees data and how an application program in a language like Java or C sees data: The result of a database query is a set (or multiset) or records, hut Java has no set or multiset data type. This mismatch is resolved through additional SQL constructs that allow applications to obtain
a handle on a collection and iterate over the records one at a time.

6.1 ACCESSING DATABASES FROM APPLICATIONS

In this section, we cover how SQL commands can be executed from within a program in a host language such as C or Java. The use of SQL commands within a host language program is called **Embedded SQL**. Details of Embedded SQL also depend on the host language. Although similar capabilities are supported for a variety of host languages, the syntax sometimes varies.

6.1.1 Embedded SQL

Conceptually, embedding SQL commands in a host language program is straightforward.SQL statements (i.e., not declarations) can be used wherever a statement in the host language is allowed (with a few restrictions). SQL statements must be clearly marked so that a preprocessor can deal with them before invoking the compiler for the host language. Also, any host language variables used to pass arguments into an SQL command must be declared in SQL. In particular, some special host language variables *must* be declared in SQL (so that, for example, any error conditions arising during SQL execution can be communicated back to the main application program in the host language).

There are, however, two complications to bear in mind. First, the **data types** recognized by SQL may not be recognized by the host language and vice versa. This mismatch is typically addressed by **casting** data values appropriately before passing them to or from SQL commands. The second complication haste do with SQL being set-oriented, and is addressed using **cursors**.

Declaring Variables and Exceptions

SQL statements can refer to variables defined in the host program. Such host language variables must be prefixed by a colon (:) in SQL statements and be declared between the commands EXEC SQL BEGIN DECLARE SECTION and EXEC SQL END DECLARE SECTION. The declarations are similar to how they would look in a C program and, as usual in C. are separated by semicolons. For example.we can declare variables *c-sname, c_sid, c_rating,* and *c_age* (with the initial *c* used as a naming convention to emphasize that these are host language variables) as follows:

```
EXEC SQL BEGIN DECLARE SECTION
char c_sname[20];
long c_sid;
short c_rating;
float c_age;
EXEC SQL END DECLARE SECTION
```

The SQL-92 standard defines a correspondence between the host language types and SQL types for a number of host languages. In our example, c_snam c has the type CHARACTER(20) when referred to in an SQL statement, c_sid has the type INTEGER, crating has the type SMALLINT, and cage has the type REAL.

The SQL-92 standard recognizes two special variables for reporting errors, SQLCODE and SQLSTATE.

Embedding SQL Statements

All SQL statements embedded within a host program must be clearly marked, with the details dependent on the host language; in C, SQL statements must be prefixed by EXEC SQL.

As a simple example, the following Embedded SQL statement inserts a row, whose column values are based on the values of the host language variables contained in it, into the Sailors relation:

```
EXEC SQL
 INSERT INTO Sailors VALUES (:c_sname, :c_sid, :c_rating, :c_age);
```

The SQLSTATE variable should be checked for errors and exceptions after each Embedded SQL statement. SQL provides the WHENEVER command to simplify this tedious task:

```
EXEC SQL WHENEVER [SQLERROR IF NOT FOUND] [ CONTINUE I GOTO stmt ]
```

The intent is that the value of SQLSTATE should be checked after each Embedded SQL statement is executed. If SQLERROR is specified and the value of SQLSTATE indicates an exception, control is transferred to stmt, which is presumably responsible for error and exception handling. Control is also transferred to stmt if NOT FOUND is specified and the value of SQLSTATE is **02000**, which denotes NO DATA.

<u>6.1.2</u> <u>Cursors</u>

A major problem in embedding SQL statements in a host language like C is that an impedance mismatch occurs because SQL operates on set of records, whereas languages like C do not cleanly support a set-of-records abstraction. The solution is to essentially provide a mechanism that allows us to retrieve rows one at a time from a relation.This **mechanism is called a cursor.**

We can declare a cursor on any relation or on any SQL query (because every query returns a set of rows). Once a cursor is declared, we can open it (which positions the cursor just before the first row); fetch the next row; move the cursor (to the next row, to the row after the next n, to the first row, or to the previous row, etc., by specifying additional parameters for the FETCH command); or close the cursor. Thus, a cursor essentially allows us to retrieve the rows in a table by positioning the cursor at a particular row and reading its contents.

Basic Cursor Definition and Usage

Cursors enable us to examine, in the host language program, a collection of rows computed by an Embedded SQL statement:

We usually need to open a cursor if the embedded statement is a SELECT query. However, we can avoid opening a cursor if the answer contains a single row.

INSERT, DELETE, and UPDATE statements typically require no cursor, although some variants of DELETE and UPDATE use a cursor.

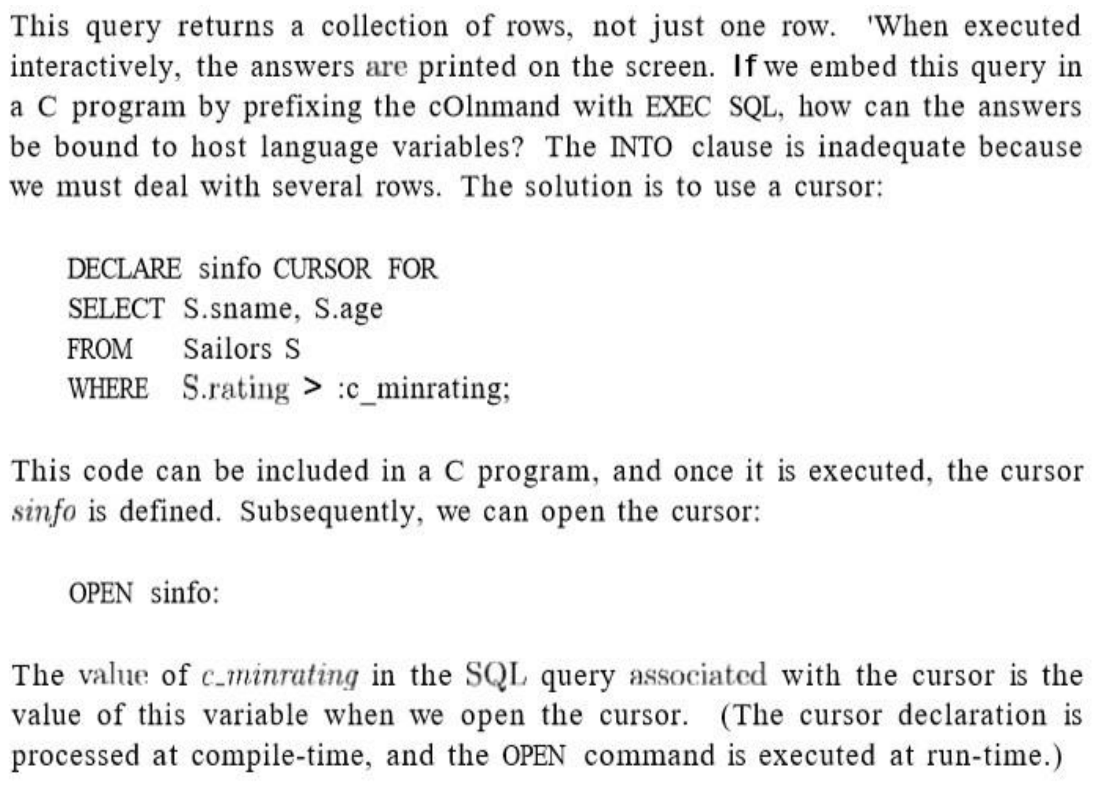
As an example, we can find the name and age of a sailor, specified by assigning a value to the host variable c_sid, declared earlier, as follows:

```
EXEC SQL
 SELECTS.sname, S.age
INTO :c_sname, :c_age
FROM Sailors S WHERES.sid = :c_sid;
```

The INTO clause allows us to assign the columns of the single answer row to the host variables c_sname and c_age. Therefore, we do not need a cursor to embed this query in a host language program.

But what about the following query, which computes the names and ages of all sailors with a rating greater than the current value of the host variable c_minrating?

```
SELECT S.sname, S.age
FROM Sailors S
WHERE S.rating> :c_minrating
```



This query returns a collection of rows, not just one row. 'When executed interactively, the answers are printed on the screen. If we embed this query in a C program by prefixing the cOlnmand with EXEC SQL, how can the answers be bound to host language variables? The INTO clause is inadequate because we must deal with several rows. The solution is to use a cursor:

```
DECLARE sinfo CURSOR FOR
SELECT  S.sname, S.age
FROM    Sailors S
WHERE   S.rating > :c_minrating;
```

This code can be included in a C program, and once it is executed, the cursor *sinfo* is defined. Subsequently, we can open the cursor:

```
OPEN sinfo:
```

The value of *c_minrating* in the SQL query associated with the cursor is the value of this variable when we open the cursor. (The cursor declaration is processed at compile-time, and the OPEN command is executed at run-time.)

A cursor can be thought of as 'pointing' to a row in the collection of answers to the query associated with it. When a cursor is opened, it is positioned just before the first row. We can use the FETCH command to read the first row of cursor sinfo into host language variables:

FETCH sinfo INTO :c_sname, :c_age;

When the FETCH statement is executed, the cursor is positioned to point at the next row (which is the first row in the table when FETCH is executed for the first time after opening the cursor) and the column values in the row are copied into the corresponding host variables. By repeatedly executing this FETCH statement (say, in a while-loop in the C program), we can read all the rows computed by the query, one row at a time. Additional parameters to the FETCH command allow us to position a cursor in very flexible ways.

How do we know when we have looked at all the rows associated with the cursor? By looking at the special variables SQLCODE or SQLSTATE, of course. SQLSTATE, for example, is set to the value 02000, which denotes NO DATA, to indicate that there are no more rows ifthe FETCH statement positions the cursor after the last row.

When we are done with a cursor, we can close it:

```
CLOSE sinfo;
```

It can be opened again if needed and the value of :c_minrating in the SQL query associated with the cursor would be the value of the host variable c_minrating at that time.

Properties of Cursors

The general form of a cursor declaration is:

```
DECLARE cursorname [INSENSITIVE] [SCROLL] CURSOR
        [WITH HOLD]
        FOR some query
        [ ORDER BY order-item-list ]
        [ FOR READ ONLY | FOR UPDATE ]
```

A cursor can be declared to be a read-only cursor (FOR READ ONLY) or, if it is a cursor on a base relation or an updatable view, to be an updatable cursor (FOR UPDATE). If it is IIpdatable, simple variants of the UPDATE and

DELETE commands allow us to update or delete the row on which the cursor is positioned. If the keyword SCROLL is specified, the cursor is scrollable, which means that variants of the FETCH command can be used to position the cursor in very flexible ways; If the keyword INSENSITIVE is specified, the cursor behaves as if it is ranging over a private copy of the collection of answer rows. A holdable cursor is specified using the WITH HOLD clause, and is not closed when the transaction is committed. Finally, in what order do FETCH commands retrieve rows? In general this order is unspecified, but the optional ORDER BY clause can be used to specify a sort order. Note that columns mentioned in the ORDER BY clause cannot be updated through the cursor!

6.1.3 Dynamic SQL

Consider an application such as a spreadsheet or a graphical front-end that needs to access data from a DBMS. Such an application must accept commands from a user and, based on what the user needs, generate appropriate SQL statements to retrieve the necessary data. In such situations, we may not be able to predict in advance just what SQL statements need to be executed, even though there is (presumably) some algorithm by which the application can construct the necessary SQL statements once a user's command is issued.

SQL provides some facilities to deal with such situations; these are referred to as Dynamic SQL. We illustrate the two main commands, PREPARE and EXECUTE, through a simple example:

```
char c_sqlstring[] = {"DELETE FROM Sailors WHERE rating>5"};
EXEC SQL PREPARE readytogo FROM :c_sqlstring;
EXEC SQL EXECUTE readytogo;
```

The first statement declares the C variable c_sqlstring and initializes its value to the string representation of an SQL command. The second statement results in this string being parsed and compiled as an SQL command, with the resulting executable bound to the SQL variable readytogo. (Since readytogo is an SQL variable, just like a cursor name, it is not prefixed by a colon.) The third statement executes the command.

6.2 AN INTRODUCTION TO JDBC

ODBC and JDBC, short for Open DataBase Connectivity and Java DataBase Connectivity, also enable the integration of SQL with a general-purpose programming language. Both ODBC and JDBC expose database capabilities in a standardized way to the application programmer through an application programming interface (API).

An application that interacts with a data source through ODBC or JDBC selects a data source, dynamically loads the corresponding driver, and establishes a connection with the data source.

6.2.1 JDBC Architecture

The architecture of JDBC has four main components: the **application**, the **driver manager**, several data source specific **drivers**, and the corresponding data **Sources**.

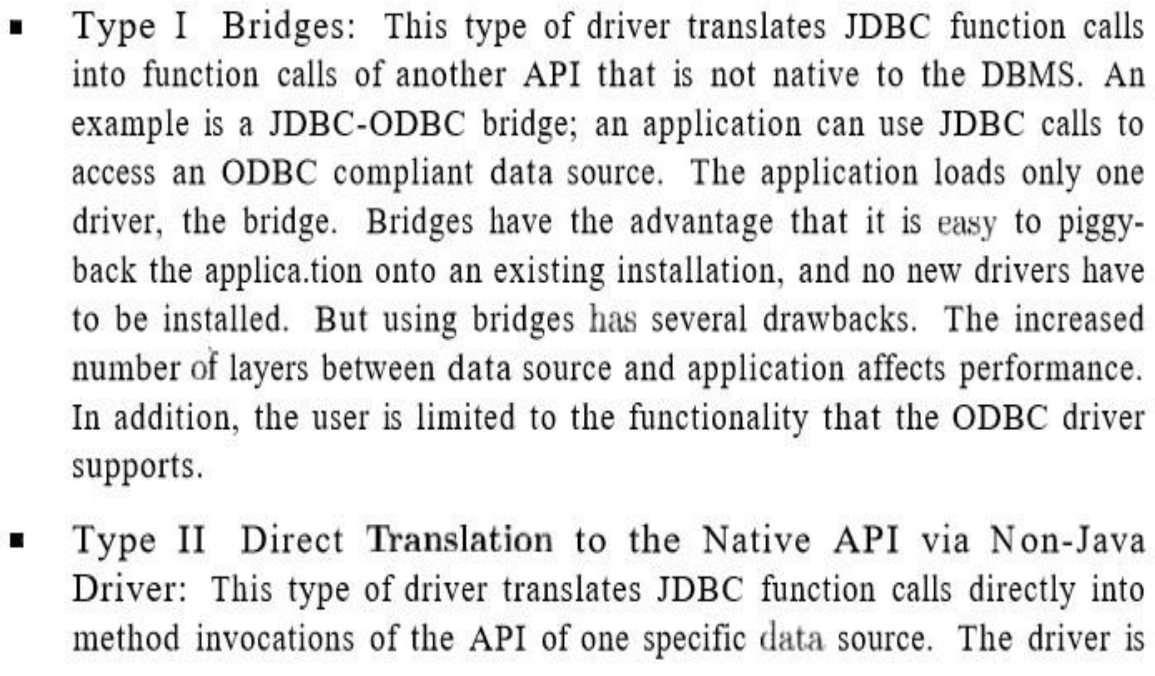
The **application** initiates and terminates the connection with a data source. It sets transaction boundaries, submits SQL statements, and retrieves the results-----all through a well-defined interface as specified by the JDBC API.

The primary goal of the **driver manager** is to load JDBC drivers and pass JDBC function calls from the application to the correct driver.

The **driver** establishes the connection with the data source.

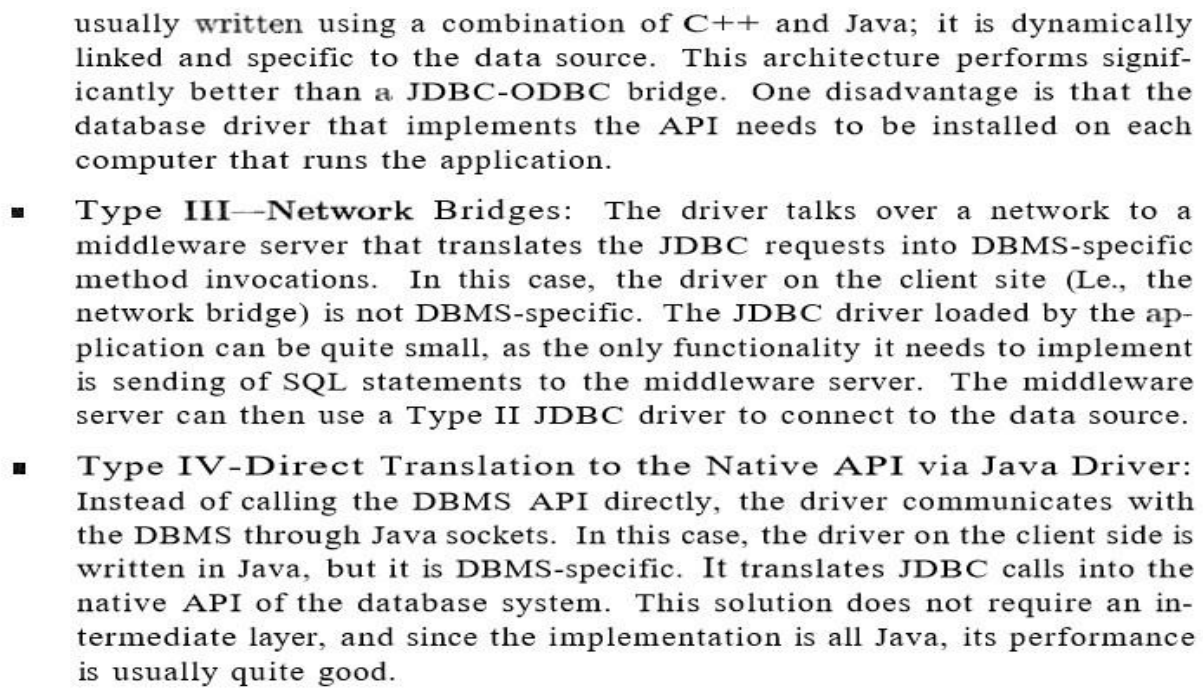
The **data source** processes commands from the driver and returns the results.

Drivers in JDBC are classified into **four types** depending on the architectural relationship between the application and the data source:



- Type I Bridges: This type of driver translates JDBC function calls into function calls of another API that is not native to the DBMS. An example is a JDBC-ODBC bridge; an application can use JDBC calls to access an ODBC compliant data source. The application loads only one driver, the bridge. Bridges have the advantage that it is easy to piggy-back the applica.tion onto an existing installation, and no new drivers have to be installed. But using bridges has several drawbacks. The increased number of layers between data source and application affects performance. In addition, the user is limited to the functionality that the ODBC driver supports.

- Type II Direct Translation to the Native API via Non-Java Driver: This type of driver translates JDBC function calls directly into method invocations of the API of one specific data source. The driver is


usually written using a combination of C++ and Java; it is dynamically linked and specific to the data source. This architecture performs significantly better than a JDBC-ODBC bridge. One disadvantage is that the database driver that implements the API needs to be installed on each computer that runs the application.

- Type III—Network Bridges: The driver talks over a network to a middleware server that translates the JDBC requests into DBMS-specific method invocations. In this case, the driver on the client site (Le., the network bridge) is not DBMS-specific. The JDBC driver loaded by the application can be quite small, as the only functionality it needs to implement is sending of SQL statements to the middleware server. The middleware server can then use a Type II JDBC driver to connect to the data source.
- Type IV-Direct Translation to the Native API via Java Driver: Instead of calling the DBMS API directly, the driver communicates with the DBMS through Java sockets. In this case, the driver on the client side is written in Java, but it is DBMS-specific. It translates JDBC calls into the native API of the database system. This solution does not require an intermediate layer, and since the implementation is all Java, its performance is usually quite good.

6.3 JDBC CLASSES AND INTERFACES

JDBC is a collection of Java classes and interfaces that enables database access from programs written in the Java language. It contains methods for connecting to a remote data source, executing SQL statements, examining sets of results from SQL statements, transaction management, and exception handling. The classes and interfaces are part of the java.sql package. Thus, all code fragments in the remainder of this section should include the statement import java. sql .* at the beginning of the code;

6.3.1 JDBC Driver Management

In JDBC, data source drivers are managed by the Drivermanager class, which maintains a list of all currently loaded drivers. The Driver manager class has methods register Driver, deregister Driver, and get Drivers to enable dynamic addition and deletion of drivers.

The first step in connecting to a data source is to load the corresponding JDBC driver. This is accomplished by using the Java mechanism for dynamically loading classes. The static method for Name in the Class class returns the Java class as specified in the argument string and executes its static constructor. The static constructor of the dynamically loaded class loads an instance of the Driver class, and this Driver object registers itself with the DriverManager class.

The following Java example code explicitly loads a JDBC driver:

Class.forName("oracle/jdbc.driver.OracleDriver");

6.3.2 Connections

A session with a data source is started through creation of a Connection object; A connection identifies a logical session with a data source; multiple connections within the same Java program can refer to different data sources or the same data source. Connections are specified through a JDBC URL, a URL that uses the jdbc protocol. Such a URL has the form

jdbc:<subprotocol>:<otherParameters>

The code example shown in Figure 6.2 establishes a connection to an Oracle database assuming that the strings userld and password are set to valid values.

```
String uri = "jdbc:oracle:www.bookstore.com:3083"
Connection connection;
try {
    Connection connection =
        DriverManager.getConnection(urI,userId,password);
}
catch(SQLException excpt) {
    System.out.println(excpt.getMessageO);
    return;
}
```

Figure 6.2 Establishing a Connection with JDBC

JDBC Connections: Remember to close connections to data sources and return shared connections to the connection pool. Database systems have a limited number of resources available for connections, and orphan connections can often only be detected through time-outs-and while the database system is waiting for the connection to time-out, the resources used by the orphan connection are wasted.

Establishing a connection to a data source is a costly operation since it involves several steps, such as establishing a network connection to the data source, authentication, and allocation of resources such as memory. In case an application establishes many different connections from different parties (such as a Web server), connections are often pooled to avoid this overhead. A connection pool is a set of established connections to a data source. Whenever a new connection is needed, one of the connections from the pool is used, instead of creating a new connection to the data source.

6.3.3 Executing SQL Statements

We now discuss how to create and execute SQL statements using JDBC. In the JDBC code examples in this section, we assume that we have a Connection object named con. JDBC supports three different ways ofexecuting statements: Statement, PreparedStatement, and CallableStatement. The Statement class is the base class for the other two statment classes. It allows us to query the data source with any static or dynamically generated SQL query.

The PreparedStatement class is dynamically generates precompiled SQL statements that can be used several times; these SQL statements can have parameters, but their structure is fixed when the PreparedStatement object (representing the SQL statement) is created.

Consider the sample code using a PreparedStatement object shown in Figure 6.3. The SQL query specifies the query string, but uses "?' for the values of the parameters, which are set later using methods setString,setFloat, and setlnt. The "?' placeholders can be used anywhere in SQL statements where they can be replaced with a value. Examples of places where they can appear include the WHERE clause (e.g., 'WHERE author=?'), or in SQL UPDATE and INSERT staternents, as in Figure 6.3.

The method setString is one wayto set a parameter value; analogous methods are available for int, float, and date. It is good style to always use clearParameters() before setting parameter values in order to remove any old data.

```
// initial quantity is always zero
String sql = "INSERT INTO Books VALUES('?, 7, '?, ?, 0, 7)";
PreparedStatement pstmt = con.prepareStatement(sql);

// now instantiate the parameters with values
// assume that isbn, title, etc. are Java variables that
// contain the values to be inserted
pstmt.clearParameters();
pstmt.setString(1, isbn);
pstmt.setString(2, title);
pstmt.setString(3, author);
pstmt.setFloat(5, price);
pstmt.setInt(6, year);

int numRows = pstmt.executeUpdate();
```

Figure 6.3 SQL Update Using a PreparedStatement Object

The executeUpdate method returns an integer indicating the number of rows the SQL statement modified; it returns 0 for successful execution without modifying any rows.

The executeQuery method is used if the SQL statement returns data, such &"l in a regular SELECT query.JDBC has its own cursor mechanism in the form of a ResultSet object, which we discuss next. The execute method is more general than executeQuery and executeUpdate.

6.3.4 ResultSets

The statement executeQuery returns a, ResultSet object, which is similar to a cursor. ResultSet cursors in JDBC 2.0 are very powerful; they allow forward and reverse scrolling and in-place editing and insertions**.**

In its most basic form, the ResultSet object allows us to read one row of the output of the query at a time. Initially, the ResultSet is positioned before the first row, and we have to retrieve the first row with an explicit call to the next0 method. The next method returns false if there are no more rows in the query answer, and true other\vise. The code fragment shown in Figure 6.4 illustrates the basic usage of a ResultSet object.

```
ResultSet rs=stmt.executeQuery(sqlQuery);
// rs is now a cursor
// first call to rs.nextO moves to the first record
// rs.nextO moves to the next row
String sqlQuery;
ResultSet rs = stmt.executeQuery(sqlQuery)
while (rs.next()) {
    // process the data
}
```

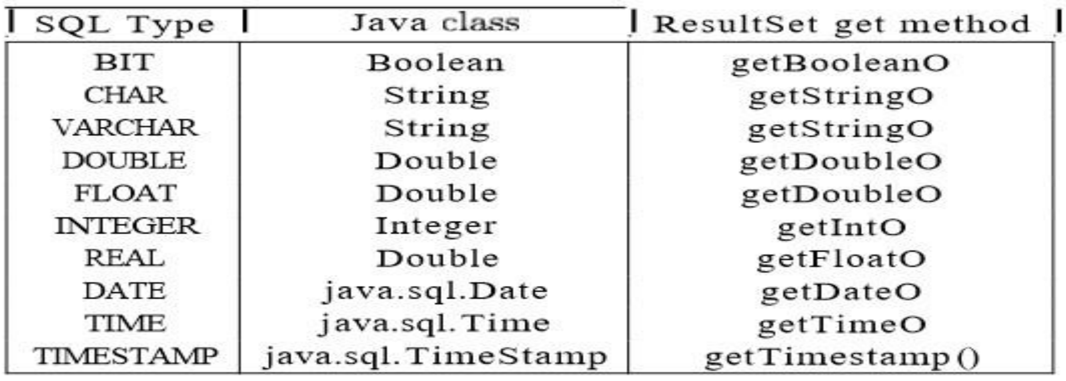
Figure 6.4 Using a ResultSet Object

While next() allows us to retrieve the logically next row in the query answer, we can move about in the query answer in other ways too:

- previous 0 moves back one row.
- absolute (int num) moves to the row with the specified number.
- relative (int num) moves forward or backward (if num is negative) relative to the current position. relative (-1) has the same effect as previous.
- first 0 moves to the first row, and last 0 moves to the last row.

Matching Java and SQL Data Types

JDBC provides special data types and specifies their relationship to corresponding SQL data types. Figure 6.5 shows the accessor methods in a ResultSet object for the most common SQL datatypes. With these accessor methods, we can retrieve values from the current row of the query result referenced by the ResultSet object. There are two forms for each accessor method: One method retrieves values by column index, starting at one, and the other retrieves values by column name. The following example shows how to access fields of the current ResultSet row using accesssor methods.



SQL Type	Java class	ResultSet get method
BIT	Boolean	getBooleanO
CHAR	String	getStringO
VARCHAR	String	getStringO
DOUBLE	Double	getDoubleO
FLOAT	Double	getDoubleO
INTEGER	Integer	getIntO
REAL	Double	getFloatO
DATE	java.sql.Date	getDateO
TIME	java.sql.Time	getTimeO
TIMESTAMP	java.sql.TimeStamp	getTimestamp()

Figure 6.5 Reading SQL Datatypes from a ResultSet Object

```
ResultSet rs=stmt.executeQuery(sqIQuery);
String sqlQuerYi
ResultSet rs = stmt.executeQuery(sqIQuery)
while (rs.nextO) {
     isbn = rs.getString(l);
     title = rs.getString("TITLE");
     // process isbn and title
}
```

6.3.5 Exceptions and Warnings

Similar to the SQLSTATE variable, most of the methods in java.sql can throw an exception of the type SQLException if an error occurs. The information includes SQLState, a string that describes the error (e.g., whether the statement contained an SQL syntax error). In addition to the standard getMessage0 method inherited from Throwable, SQLException has two additional methods that provide further information, and a method to get (or chain) additional exceptions:

- public String getSQLState0 returns an SQLState identifier based on the SQL:1999 specification, as discussed in Section 6.1.1.
- public int getErrorCode() retrieves a vendor-specific error code.
- public SQLException getNextExceptionO gets the next exception in a chain of exceptions associated with the current SQLException object.

An SQL Warning is a subclass of SQLException. Warnings are not severe as errors and the program can usually proceed without special handling of warnings. Warnings are not thrown like other exceptions, and they are not caught as part of the try"-catch block around a java.sql statement. We Heed to specifically test whether warnings exist. Connection, Statement, and ResultSet objects all have a getWarnings 0 method with which we can retrieve SQL warnings if they exist. Statement objects clear warnings automatically on execution of the next statement; ResultSet objects clear warnings every time a new tuple is accessed.

Typical code for obtaining SQLWarnings looks similar to the code shown in Figure 6.6.

```
    try {
        stmt = con.createStatement();
        warning = con.getWarnings();
        while( warning != null) {
            // handleSQLWarnings                //code to process warning
            warning = warning.getNextWarningO;        //get next warning
        }
        con.clear\Varnings();

     stmt.executeUpdate( queryString );
     warning =  stmt.getWarnings();
     while( warning != null) {
          // handleSQLWarnings                //code to process warning
          warning =  warning.getNextWarningO;        //get next warning
     }
  } // end try
  catch ( SQLException SQLe) {
     // code to handle exception
  } // end catch
```

Figure 6.6 Processing JDBC Warnings and Exceptions

<u>6.3.6</u> <u>Examining Database Metadata</u>

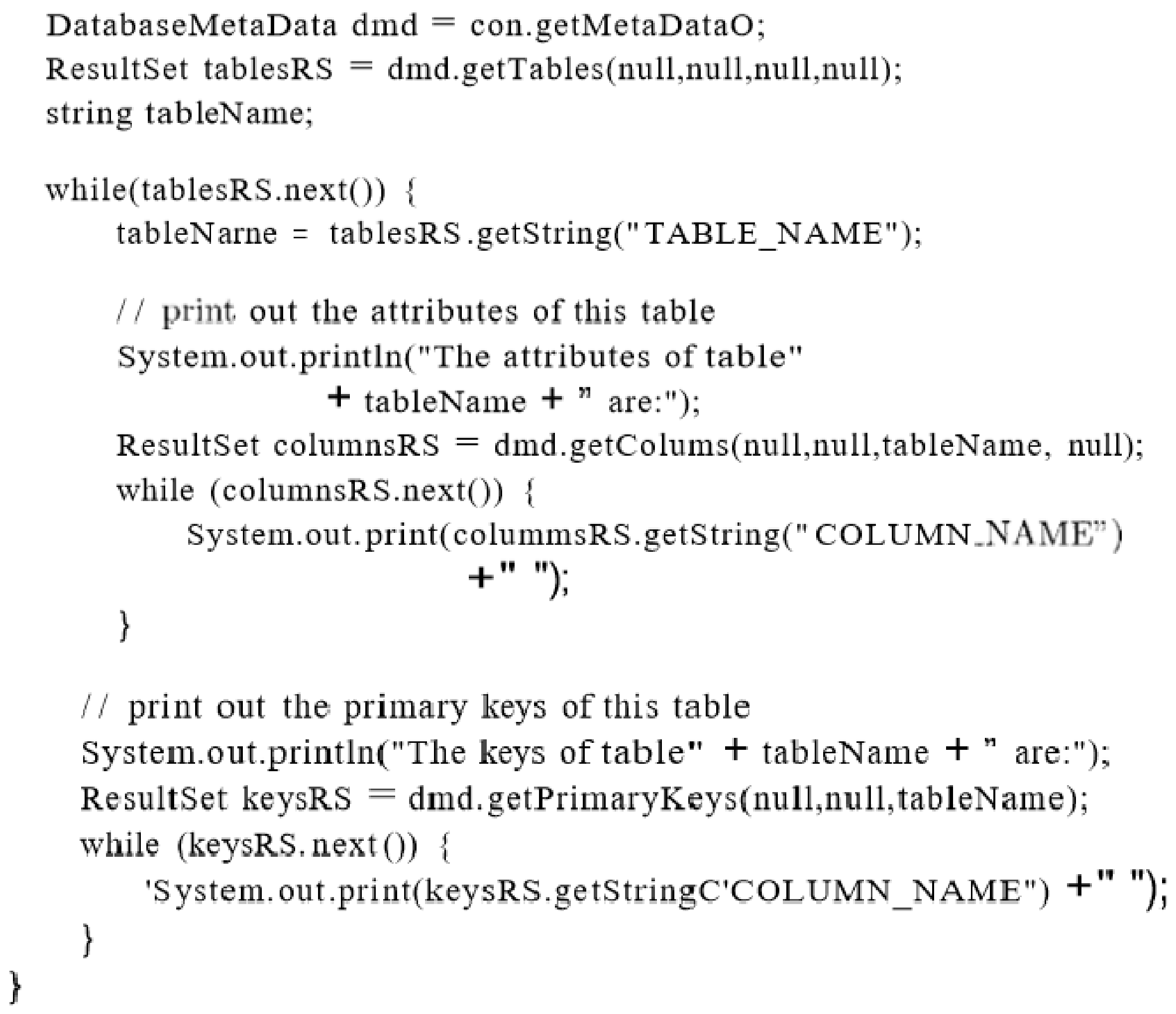
we can use the Database MetaData object to obtain information about the database system itself, as well as information from the database catalog. For example, the following code fragment shows how to obtain the name and driver version of the JDBC driver:

```
DatabaseMetaData md = con.getMetaD<Lta():
System.out.println("Driver Information:");
System.out.println("Name:" + md.getDriverNameO + "; version:" + mcl.getDriverVersion());
```

The DatabaseMetaData object has many more methods.we list some methods here:
1) public **ResultSet getCatalogs0** throws SqLException. This function returns a ResultSet that can be used to iterate over all the catalog relations. The functions getIndexInfo0 and getTables0 work analogously.

2) public **int getMaxConnections0** throws SqLException. This function returns the ma.ximum number of connections possible.

We will conclude our discussion of JDBC with an example code fragment that examines all database metadata shown in Figure 6.7.



```
DatabaseMetaData dmd = con.getMetaDataO;
ResultSet tablesRS = dmd.getTables(null,null,null,null);
string tableName;

while(tablesRS.next()) {
    tableNarne = tablesRS.getString("TABLE_NAME");

    // print out the attributes of this table
    System.out.println("The attributes of table"
                  + tableName + " are:");
    ResultSet columnsRS = dmd.getColums(null,null,tableName, null);
    while (columnsRS.next()) {
        System.out.print(colummsRS.getString("COLUMN_NAME")
                          +" ");
    }

  // print out the primary keys of this table
  System.out.println("The keys of table" + tableName + " are:");
  ResultSet keysRS = dmd.getPrimaryKeys(null,null,tableName);
  while (keysRS.next()) {
      'System.out.print(keysRS.getStringC'COLUMN_NAME") +" ");
  }
}
```

Figure 6.7 Obtaining Infon-nation about a Data Source

6.4 SQLJ

SQLJ (short for 'SQL-Java') was developed by the SQLJ Group, a group of database vendors and Sun. SQLJ was developed to complement the dynamic way of creating queries in JDBC with a static model. It is therefore very close to Embedded SQL. Unlike JDBC, having semi-static SQL queries allows the compiler to perform SQL syntax checks, strong type checks of the compatibility of the host variables with the respective SQL attributes, and consistency of the query with the database schema-tables, attributes, views, and stored procedures--all at compilation time. For example, in both SQLJ and Embedded SQL, variables in the host language always are bound statically to the same arguments, whereas in JDBC, we need separate statements to bind each variable to an argument and to retrieve the

result. For example, the following SQLJ statement binds host language variables title, price, and author to the return values of the cursor books.

```
        #sql books = {
                        SELECT title, price INTO :title, :price
                         FROM Books WHERE author = :author
};
```

In JDBC, we can dynamically decide which host language variables will hold the query result. In the following example, we read the title of the book into variable ftitle if the book was written by Feynman, and into variable otitle otherwise:

```
        / / assume we have a ResultSet cursor rs
        author = rs.getString(3);
        if (author=="Feynman")
                { ftitle = rs.getString(2):
                 }
        else { otitle = rs.getString(2);
        }
```

When writing SQLJ applications, we just write regular Java code and embed SQL statements according to a set of rules. SQLJ applications are pre-processed through an SQLJ translation program that replaces the embedded SQLJ code with calls to an SQLJ Java library. The modified program code can then be compiled by any Java compiler. Usually the SQLJ Java library makes calls to a JDBC driver, which handles the connection to the database system.

6.4.1 Writing SQLJ Code

We will introduce SQLJ by means of examples. Let us start with an SQLJ code fragment that selects records from the Books table that match a given author.

```
String title; Float price; String atithor;
#sql iterator Books (String title, Float price);
Books books;

// the application sets the author
// execute the query and open the cursor
#sql books = {
     SELECT title, price INTO :titIe, :price
     FROM Books WHERE author = :author
};

// retrieve results
while (books.next()) {
     System.out.println(books.titleO + ", " + books.price());
}
books.close();
```

The corresponding JDBC code fragment looks as follows (assuming we also declared price, name, and author:

```
PrcparcdStatcment stmt = connection.prepareStatement(
"SELECT title, price FROM Books WHERE author = ?");

// set the parameter in the query ancl execute it
stmt.setString(1, author);
ResultSet 1'8 = stmt.executeQuery();

// retrieve the results
while (rs.next()) {
```

```
System.out.println(rs.getString(l) + ", " + rs.getFloat(2));
}
```

Comparing the JDBC and SQLJ code, we see that the SQLJ code is much easier to read than the JDBC code. Thus, SQLJ reduces software development and maintenance costs.

Let us consider the individual components of the SQLJ code in more detail. All SQLJ statements have the special prefix #sql. In SQLJ, we retrieve the results of SQL queries with iterator objects, which are basically cursors. An iterator is an instance of an iterator class. Usage of an iterator in SQLJ goes through five steps:

- Declare the Iterator Class: In the preceding code, this happened through the statement
  `#sql iterator Books (String title, Float price);`
  This statement creates a new Java class that we can use to instantiate objects.
- Instantiate an Iterator Object from the New Iterator Class: We instantiated our iterator in the statement Books books;.
- Initialize the Iterator Using a SQL Statement: In our example, this happens through the statement #sql books = ...
- Iteratively, Read the Rows From the Iterator Object: This step is very similar to reading rows through a ResultSet object in JDBC.
- Close the Iterator Object.

There are two types of iterator classes: **named iterators** and **positional iterators.** For named iterators, we specify both the variable type and the name of each column of the iterator. This allows us to retrieve individual columns by name as in our previous example where we could retrieve the title column from the Books table using the expression books.titIe(). For positional iterators, we need to specify only the variable type for each column of the iterator. To access the individual columns of the iterator, we use a FETCH ... INTO construct, similar to Embedded SQL. Both iterator types have the same performance; which iterator to use depends on the programmer's taste.

6.5 STORED PROCEDURES

It is often important to execute some parts of the application logic directly in the process space of the database system. Running application logic directly at the database has the advantage that the amount of data that is transferred between the database server and the client issuing the SQL statement can be minimized, while at the same time utilizing the full power of the databa.se server.

When SQL statements are issued from a remote application, the records in the result of the query need to be transferred from the database system back to the application. If we use a cursor to remotely access the results of an SQL statement, the DBMS has resources such as locks and memory tied up while the application is processing the records retrieved through the cursor.

In contrast, a **stored procedure** is a program that is executed through a single SQL statement that can be locally executed and completed within the process space of the database server. The results can be packaged into one big result and returned to the application, or the application logic can be performed directly at the server, without having to transmit the results to the client at all.

Once a stored procedure is registered with the database server, different users can re-use the stored procedure, eliminating duplication of efforts in writing SQL queries or application logic, and making code maintenance easy. In addition, application programmers do not need to know the the databa.se schema if we encapsulate all databa.'3e access into stored procedures.

Although they are called stored procedures, they do not have to be procedures in a programming language sense; they can be functions.

6.5.1 Creating a Simple Stored Procedure

Let us look at the example stored procedure written in SQL shown in Figure 6.8 see that stored procedures must have a name; this stored procedure has the name 'ShowNumberOfOrders.' Otherwise, it just contains an SQL statement that is precompiled and stored at the server.

```
CREATE  PROCEDURE ShowNumberOfOrders
SELECT  C.cid, C.cname, COUNT(*)
        FROM      Customers C, Orders a
        WHERE     C.cid = O.cid
        GROUP BY  C.cid, C.cname
```

Figure 6.8 A Stored Procedure in SQL

Stored procedures can also have parameters. These parameters have to be valid SQL types, and have one of three different modes: IN, OUT, or INOUT. IN parameters are arguments to' the stored procedure. OUT parameters are returned from the stored procedure; it assigns values to all OUT parameters that the user can process. INOUT parameters combine the properties of IN and OUT parameters: They contain values to be passed to the stored procedures, and the stored procedure can set their values as return values. Stored procedures enforce strict type conformance: If a parameter is of type INTEGER, it cannot be called with an argument of type VARCHAR.

Let us look at an example of a stored procedure with arguments. The stored procedure shown in Figure 6.9 has two arguments: book_isbn and addedQty. It updates the available number of copies of a book with the quantity from a new shipment.

```
CREATE  PROCEDURE AddInventory (
                  IN book_isbn CHAR(lO),
                  IN addedQty INTEGER)
UPDATE  Books
        SET     qty_in_stock =  qtyjn_stock + addedQty
        WHERE   bookjsbn =  isbn
```

Figure 6.9 A Stored Procedure with Arguments

Stored procedures do not have to be written in SQL; they can be written in any host language. As an example, the stored procedure shown in Figure 6.10 is a Java function that is dynamically executed by the database server whenever it is called by the client:

```
CREATE PROCEDURE RallkCustomers(IN number INTEGER)
 LANGUAGE Java
EXTERNAL NAME 'file:// /c:/storedProcedures/rank.jar'
```

Figure 6.10 A Stored Procedure in Java

6.5.2 Calling Stored Procedures

Stored procedures can be called in interactive SQL with the CALL statement:

CALL storedProcedureName(argumentl, argument2, ... , argumentN);

In Embedded SQL, the arguments to a stored procedure are usually variables in the host language. For example, the stored procedure AddInventory would be called as follows:

```
EXEC  SQL  BEGIN  DECLARE  SECTION
char isbn[lO];
long qty;
EXEC  SQL  END  DECLARE  SECTION

// set isbn and qty to some values
EXEC  SQL  CALL AddInventory(:isbn,:qty);
```

Calling Stored Procedures from JDBC

We can call stored procedures from JDBC using the CallableStatment class. CallableStatement is a subclass of PreparedStatement and provides the same functionality. A stored procedure could contain multiple SQL staternents or a series of SQL statements-thus, the result could be many different ResultSet objects. We illustrate the case when the stored procedure result is a single ResultSet.

```
CallableStatement cstmt=
                coll.prepareCall(" {call ShowNumberOfOrders}");
ResultSet rs = cstmt.executeQueryO
while (rs.next())
```

Calling Stored Procedures from SQLJ

The stored procedure 'ShowNumberOfOrders' is called as follows using SQLJ:

```
    // create the cursor class
    #sql !terator CustomerInfo(int cid, String cname, int count);

    // create the cursor

  CustomerInfo customerinfo;

  // call the stored procedure
  #sql customerinfo = {CALL ShowNumberOfOrders};
  while (customerinfo.nextO) {
       System.out.println(customerinfo.cid() + "," +
                    customerinfo.count());
  }
```

6.5.3 SQL/PSM

All major database systems provide ways for users to write stored procedures in a simple, general purpose language closely aligned with SQL. In this section, we briefly discuss the SQL/PSM standard, which is representative of most vendor specific languages. In PSM, we define **modules, which are collections of stored procedures, temporary relations, and other declarations.**

In SQL/PSM, we declare a stored procedure as follows:

```
    CREATE PROCEDURE name (parameter1,..., parameterN)
         local variable declarations
         procedure code;
```

We can declare a function similarly as follows:

```
    CREATE FUNCTION name (parameterl,..., parameterN)
                 RETURNS sqIDataType
         local variable declarations
         function code;
```

Each parameter is a triple consisting of the mode (IN, OUT, or INOUT as discussed in the previous section), the parameter name, and the SQL data type of the parameter.

We start out with an example of a SQL/PSM function that illustrates the main SQL/PSM constructs. The function takes as input a customer identified by her cid and a year. The function returns the rating of the customer, which is defined a...'3 follows: Customers who have bought more than ten books during the year are rated 'two'; customer who have purchased between 5 and 10 books are rated 'one', otherwise the customer is rated 'zero'. The following SQL/PSM code computes the rating for a given customer and year.

```
CREATE PROCEDURE RateCustomer(IN custId INTEGER, IN year INTEGER)
RETURNS INTEGER
DECLARE rating INTEGER;
 DECLARE numOrders INTEGER;
 SET numOrders = (SELECT COUNT(*) FROM Orders 0 WHERE O.tid = custId);
IF (numOrders>10) THEN rating=2;
ELSEIF (numOrders>5) THEN rating=1;
 ELSE rating=O;
END IF;
RETURN rating;
```

Let us use this example to give a short overview of some SQL/PSM constructs:

- We can declare local variables using the DECLARE statement. In our example, we declare two local variables: 'rating', and 'numOrders'.
- PSM/SQL functions return values via the RETURN statement. In our example, we return the value of the local variable 'rating'.
- We can assign values to variables with the SET statement. In our example, we assigned the return value of a query to the variable 'numOrders'.
- SQL/PSM has branches and loops. Branches have the following form:

  ```
  IF (condition) THEN statements;
  ELSEIF statements;

  ELSEIF statements;
  ELSE statements; END IF
  ```

  Loops are of the form

  ```
  LOOP
          staternents:
  END LOOP
  ```

6.6 CASE STUDY: THE INTERNET BOOK SHOP

DBDudes finished logical database design, as discussed in Section 3.8, and now consider the queries that they have to support. They expect that the application logic will be implemented in Java, and so they consider JDBC and SQLJ as possible candidates for interfacing the database system with application code.

Recall that DBDudes settled on the following schema:

Books(isbn: CHAR(10), title: CHAR(8), author: CHAR(80), qty_in_stock: INTEGER, price: REAL, year_published: INTEGER)

Customers(cid: INTEGER, cname: CHAR(80), address: CHAR(200))

Orders(ordernum: INTEGER, isbn: CHAR(lO), cid: INTEGER, cardnum: CHAR(l6), qty: INTEGER, order_date: DATE, ship_date: DATE)

Now, DBDudes considers the types of queries and updates that will arise. They first create a list of tasks that will be performed in the application. Tasks performed by customers include the following.

- Customers search books by author name, title, or ISBN.
- Customers register with the website. Registered customers might want to change their contact information. DBDudes realize that they have to augment the Customers table with additional information to capture login and password information for each customer; we do not discuss this aspect any further.
- Customers check out a final shopping basket to complete a sale.
- Customers add and delete books from a 'shopping basket' at the website.
- Customers check the status of existing orders and look at old orders.

Administrative tasks performed by employees of B&N are listed next.

- Employees look up customer contact information.
- Employees add new books to the inventory.
- Employees fulfill orders, and need to update the shipping date of individual books.
- Employees analyze the data to find profitable customers and customers likely to respond to special marketing campaigns.

Next, DBDudes consider the types of queries that will arise out of these tasks. To support searching for books by name, author, title, or ISBN, DBDudes decide to write a stored procedure as follows:

```
CREATE PROCEDURE SearchByISBN (IN book.isbn CHAR (10) )
SELECT B.title, B.author, B.qty_in_stock,B.price, B.yeaLpublished
FROM Books B
WHERE B.isbn = book.isbn
```

Placing an order involves inserting one or more records into the Orders table.Since DBDudes has not yet chosen the Java-based technology to program the application logic, they assume for now that the individual books in the order are stored at the application layer in a Java array. To finalize the order, they write the following JDBC code shown in Figure 6.11, which inserts the elements from the array into the Orders table. Note that this code fragment assumes several Java variables have been set beforehand.

```
String sql = "INSERT INTO Orders VALUES(7, 7, 7, 7, 7, 7)";
PreparedStatement pstmt = con.prepareStatement(sql);
con.setAutoCommit(false);

try {
     // orderList is a vector of Order objects
     // ordernum is the current order number
     // dd is the ID of the customer, cardnum is the credit card number
     for (int i=O; iiorderList.lengthO; i++)
          // now instantiate the parameters with values
          Order currentOrder = orderList[i];
          pstmt.clearParameters();
          pstmt.setInt(1, ordernum);
          pstmt.setString(2, Order.getIsbnO);
          pstmt.setInt(3, dd);
          pstmt.setString(4, creditCardNum);
          pstmt.setlnt(5, Order.getQtyO);
          pstmt.setDate(6, null);
```

```
            pstmt.executeUpdate();
        }
        con.commit();
    catch (SqLException e){
        con.rollbackO;
        System.out.println(e.getMessage());
    }
```

Figure 6.11 Inserting a Completed Order into the Database

DBDudes writes other JDBC code and stored procedures for all of the remaining tasks. They use code similar to some of the fragments that we have seen in this chapter.

- Establishing a connection to a database, as shown in Figure 6.2.
- Adding new books to the inventory, as shown in Figure 6.3.
- Processing results from SQL queries as shown in Figure 6.4-
- For each customer, showing how many orders he or she has placed. We showed a sample stored procedure for this query in Figure 6.8.
- Increasing the available number of copies of a book by adding inventory, as shown in Figure 6.9.
- Ranking customers according to their purchases, as shown in Figure 6.10.

DBDudcs takes care to make the application robust by processing exceptions and warnings, as shown in Figure 6.6.

DBDudes also decide to write a trigger, which is shown in Figure 6.12. Whenever a new order is entered into the Orders table, it is inserted with ship~date set to NULL. The trigger processes each row in the order and calls the stored procedure 'UpdateShipDate'. This stored procedure (whose code is not shown here) updates the (anticipated) ship_date of the new order to 'tomorrow', in case qtyjlLstock of the corresponding book in the Books table is greater than zero. Otherwise, the stored procedme sets the ship_date to two weeks.

```
CREATE  TRIGGER update_ShipDate
            AFTER  INSERT  ON Orders                        1* Event *j
    FOR  EACH  ROW
    BEGIN CALL  UpdatcShipDate(new);  END                  1* Action *j
```

Figure 6.12 Trigger to Update the Shipping Date of New Orders

INTERNET APPLICATIONS:

7.5 *THE THREE-TIER APPLICATION ARCHITECTURE*

In this section, we discuss the overall architecture of data-intensive Internet applications. Data-intensive Internet applications can be understood in terms of **three different functional** components: **data management, application logic, and presentation.** The component that handles data management usually utilizes a DBMS for data storage, but application logic and presentation involve much more than just the DBMS itself.

7.5.1 Single-Tier

In this section, we provide some perspective on the three-tier architecture by discussing single- tier and client-server architectures, the predecessors of the three-tier architecture. Initially, data-intensive applications were combined into a single tier, including the DBMS, application logic, and user interface, as illustrated in Figure 7.5. The application typically ran on a mainframe, and users accessed it through dumb terminals that could perform only data input and display. This approach has the benefit of being easily maintained by a central administrator.

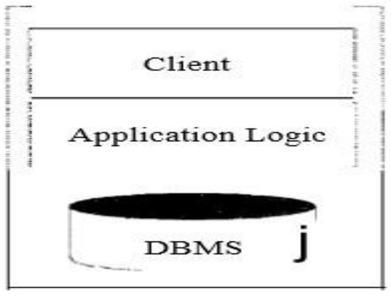


Figure 7.5 A Single-Tier Architecture

Single-tier architectures have an important drawback: Users expect graphical interfaces that require much more computational power than simple dumb terminals. Centralized computation of the graphical displays of such interfaces requires much more computational power than a single server has available, and thus single-tier architectures do not scale to thousands of users.

Two Tier or Client-Server Architectures

The commoditization of the PC and the availability of cheap client computers led to the development of the two-tier architecture.

Two-tier architectures, often also referred to as client-server architectures, consist of a client computer and a server computer, which interact through a well-defined protocol. What part of the functionality the client implements, and what part is left to the server, can vary. In the traditional client server architecture, the client implements just the graphical user interface, and the server. Implements both the business logic and the data management; such clients are often called thin clients, and this architecture

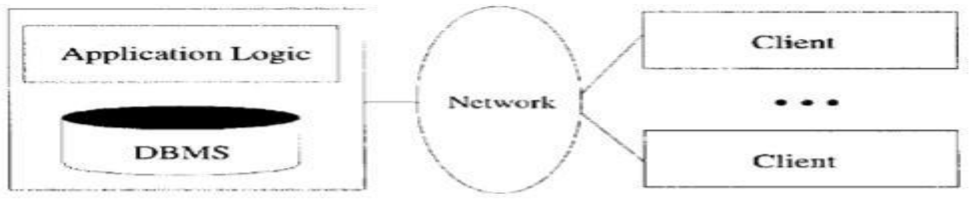


Figure 7.6 A Two-Server Architecture: Thin Clients

is illustrated in Figure 7.6.

Other divisions are possible, such as more powerful clients that implement both user interface and business logic, or clients that implement user interface and part of the business logic, with the remaining part being implemented at the server level; such clients are often called thick clients, and this architecture is illustrated in Figure 7.7

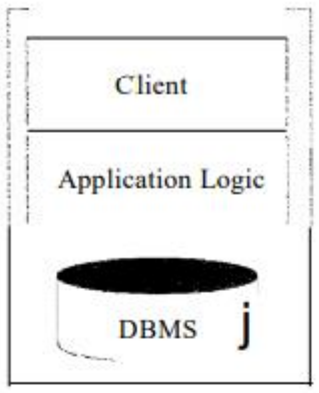


Figure 7.5 A Single-Tier Architecture

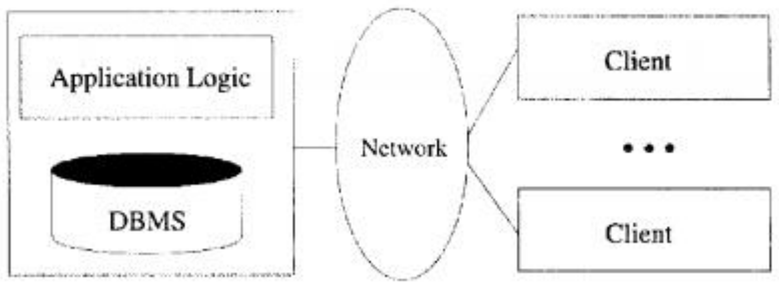


Figure 7.6 A Two-Server Architecture: Thin Clients

The thick-client model has several disadvantages when compared to the thinclient model. First, there is no central place to update and maintain the business logic, since the application code runs at many client sites. Second, a large amount of trust is required between the server and the clients.A third disadvantage of the thick-client architecture is that it does not scale with the number of clients; it typically cannot handle more than a few hundred clients.

7.5.2 Three Tier Architectures

The thin-client two-tier architecture essentially separates presentation issues from the rest of the application. The three-tier architecture goes one step further, and also separates application logic from data management:

- **Presentation Tier:** Users require a natural interface to make requests, provide input, and to see results. The widespread use of the Internet has made Web-based interfaces increasingly popular.
- **Middle Tier:** The application logic executes here. An enterprise-class application reflects complex business processes, and is coded in a general purpose language such as C++ or Java.
- **Data Management Tier:** Data-intensive Web applications involve DBMSs, which are the subject of this book.

Figure 7.8 shows a basic three-tier architecture.

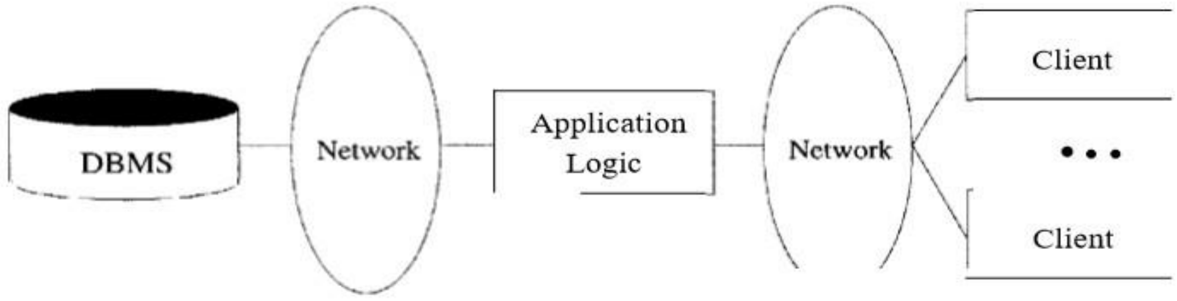


Figure 7.8 A Standard Three-Tier Architecture

Different technologies have been developed to enable distribution of the three tiers of an application across multiple hardware platforms and different physical sites. Figure 7.9 shows the technologies relevant to each tier.

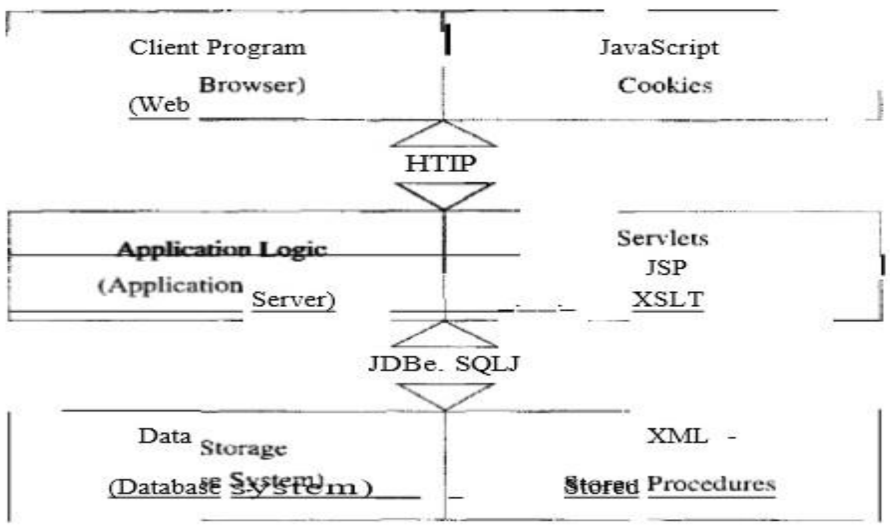

Client Program (Web Browser)
JavaScript
Cookies
HTTP
Application Logic (Application Server)
Servlets
JSP
XSLT
JDBe. SQLJ
Data Storage (Database System)
XML
Stored Procedures

Figure 7.9 Technologies for the Three Tiers

<u>7.5.3</u> <u>Advantages ofthe Three-Tier Architecture</u>

The three-tier architecture has the following advantages:

1)**Heterogeneous Systems:** Applications can utilize the strengths of different platforms and different software components at the different tiers. It is easy to modify or replace the code at any tier without affecting the other tiers.

2) **Thin Clients**: Clients only need enough computation power for the presentation layer. Typically, clients are Web browsers.

3) **Integrated Data Access:** In many applications, the data must be accessed from several sources. This can be handled transparently at the middle tier, where we can centrally manage connections to all database systems involved.

4) **Scalability to Many Clients:** Each client is lightweight and all access to the system is through the middle tier. The middle tier can share database connections across clients, and if the middle tier becomes the bottle-neck, we can deploy several servers executing the middle tier code; clients can connect to anyone of these servers, if the logic is designed appropriately. This is illustrated in Figure 7.10

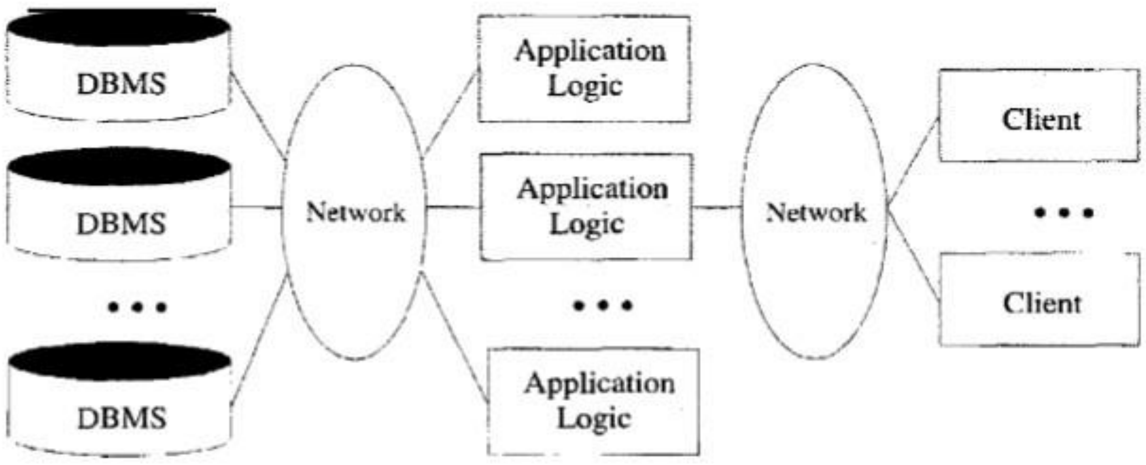


Figure 7.10 Middle-Tier Replication and Access to Multiple Data Sources

5) **Software Development Benefits:** By dividing the application cleanly into parts that address presentation, data access, and business logic, we gain many advantages. The business logic is centralized, and is therefore easy to maintain, debug, and change. Interaction between tiers occurs through well- defined, standardized APls. Therefore, each application tier can be built out of reusable components that can be individually developed, debugged, and tested.

7.6 THE PRESENTATION LAYER

In this section, we describe technologies for the client side of the three-tier architecture. we discuss HTML forms as a special means of passing arguments from the client to the middle tier.

7.6.1 HTML Forms

HTML forms are a common way of communicating data from the client tier to the middle tier. The general format of a form is the following:

<FORM ACTION="page.jsp" METHOD="GET" NAME="LoginForm">
</FORM>

A single HTML document can contain more than one form. Inside an HTML form, we can have any HTML tags except another FORM element.

The FORM tag has three important attributes:

a) ACTION: Specifies the URI of the page to which the form contents are submitted; if the ACTION attribute is absent, then the URI of the current page is used.

b) METHOD: The HTTP/1.0 method used to submit the user input from the filled-out form to the webserver. There are two choices, GET and POST

c) NAME: This attribute gives the form a name. Although not necessary, naming forms is good style

Inside HTML forms, the INPUT, SELECT, and TEXTAREA tags are used to specify user input elements; a form can have many elements of each type. The simplest user input element is an INPUT field, a standalone tag with no terminating tag. An example of an INPUT tag is the following:

```
<INPUT TYPE=ltext" NAME="title">
```

The INPUT tag has several attributes. The three most important ones are TYPE, NAME, and VALUE. The TYPE attribute determines the type of the input field. If the TYPE attribute has value text, then the field is a text input field. If the TYPE attribute has value password, then the input field is a text field where the entered characters are displayed as stars on the screen. If the TYPE attribute has value reset, it is a simple button that resets all input fields within the form to their default values. If the TYPE attribute has value submit, then it is a button that sends the values of the different inputfields in the form to the server. Note that reset and submit input fields affect the entire form.

The NAME attribute of the INPUT tag specifies the symbolic name for this field and is used to identify the value of this input field when it is sent to the server.

The VALUE attribute of an input tag can be used for text or password fields to specify the default contents of the field. For submit or reset buttons, VALUE determines the label of the button.

The form in Figure 7.11 shows two text fields, one regular text input field and one password field. It also contains two buttons, a reset button labeled 'Reset Values' and a submit button labeled 'Log on.' Note that the two input fields are named, whereas the reset and submit button have no NAME attributes.

```
<FORM ACTION="page.jsp" METHoD="GET" NAME="LoginForm">
    <INPUT TYPE="text" NAME="username" VALUE=" Joe"><P>
    <INPUT TYPE="password" NAME="password"><P>
    <INPUT TYPE="reset" VALUE="Reset Values"><P>
    <INPUT TYPE="submit" VALUE="Log on">
    </FoRM>
```

Figure 7.11 HTML Form with Two Text Fields and Two Buttons

Passing Arguments to Server Side Scripts

There are two different ways to submit HTML Form data to the webserver. If the method GET is used, then the contents of the form are assembled into a query URI (as discussed next) and sent to the server. If the method POST is used, then the contents of the form are encoded as in the GET method, but the contents are sent in a separate data block instead of appending them directly to the URI. Thus, in the GET method the form contents are directly visible to the user as the constructed URI, whereas in the POST method, the form contents are sent inside the HTTP request message body and are not visible to the user.

Let us look at the encoding of the URI when the GET method is used. The encoded URI has the following form:

```
action?name1=value1&name2=value2&name3=value3
```

7.6.2 JavaScript

JavaScript is a scripting language at the client tier with which we can add programs to webpages that run directly at the client (ie., at the machine running the Web browser). JavaScript is often used for the following types of computation at the client:

1) Browser Detection: JavaScript can be used to detect the browser type and load a browser-specific page.

2) Form Validation: JavaScript is used to perform simple consistency checks on form fields. For example, a JavaScript program might check whether aform input that asks for an email address contains the character '@,' or if all required fields have been input by the user.

3) **Browser Control:** This includes opening pages in customized windows; examples include the annoying pop-up advertisements that you see at many websites, which are programmed using JavaScript.

JavaScript is usually embedded into an HTML document with a special tag, the SCRIPT tag. The SCRIPT tag has the attribute LANGUAGE, which indicates the language in which the script is written.
Another attribute of the SCRIPT tag is the SRC attribute, which specifies an external file with JavaScript code that is automatically embedded into the HTML document. Usually JavaScript source code files use a '.js' extension. The following fragment shows a JavaScript file included in an HTML document:

```
<SCRIPT LANGUAGE=" JavaScript" SRC="validateForm.js"></SCRIPT>
```

We enclose the JavaScipt code inside HTML comments for the reasons just mentioned.

```
<SCRIPT LANGUAGE=" JavaScript">
<I--
alert (" Welcome to our bookstore");
//-->
</SCRIPT>
```

JavaScript provides two different commenting styles: single-line comments that start with the '//' character, and multi-line comments starting with '/*' and ending with ,*/' characters.

JavaScript allows us to create functions using the function keyword: function f (argl, arg2) {statements;}. We can call functions from JavaScript code, and functions can return values using the keyword return.

We conclude this introduction to JavaScript with a larger example of a JavaScript function that tests whether the login and password fields of a HTML form are not empty. Figure 7.12 shows the JavaScript function and the HTML form. The JavaScript code is a function called testLoginEmptyO that tests whether either of the two input fields in the form named LoginForm is empty. In the function testLoginEmpty, we first use variable loginForm to refer to the form LoginForm using the implicitly defined variable document, which refers to the current HTML page. (JavaScript has a library of objects that are implicitly defined.) We then check whether either of the strings loginForm.userif.value or loginForm.password.value is empty.

```
<SCRIPT LANGUAGE="JavaScript">
<!--
function testLoginEmpty()
{
    10ginForm = document.LoginForm
    if ((loginForm.userid.value == "") ||
            (loginFonn.password.value == |.I)) {
        alert(,Please enter values for userid and password.');
        return false;
    }
    else
        return true;
}
//-->
</SCRIPT>
<Hi ALIGN = "CENTER">Barns and Nobble Internet Bookstore</Hi>
<H3 ALIGN = "CENTER">Please enter your userid and password:</H3>
<FORM NAME = "LoginForm" METHOD="POST"
        ACTION=„TableOfContents.jsp"
        onSubmit="return testLoginEmptyO">
    Userid: <INPUT TYPE="TEXT" NAME=‖userid"><P>
    Password: <INPUT TYPE="PASSWORD" NAME="password"><P>
    <INPUT TYPE="SUBMIT" VALUE="Login" NAME="SUBMIT">
    <INPUT TYPE="RESET" VALUE=‖Clear Input" NAME="RESET">
</FORM>
```

Figure 7.12 Form Validation with JavaScript

<u>7.6.3</u> <u>Style Sheets</u>

Different clients have different displays, and we need correspondingly different ways of displaying the same information. For example, in the simplest ca.se, we might need to use different font sizes or colors that provide high-contrast on a black-and-white screen.

A style sheet is a method to adapt the same document contents to different presentation formats. A style sheet contains instructions that tell a 'Web browser (or whatever the client uses to display the webpage) how to translate the data of a document into a presentation that is suitable for the client's display.

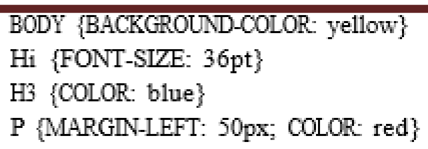
There are two style sheet languages: XSL and ess. ess was created for HTML with the goal of separating the display characteristics of different formatting tags from the tags themselves. XSL is an extension of ess to arbitrary XML docurnents; besides allowing us to define ways of formatting objects, XSL contains a transformation language that enables us to rearrange objects. The target files for ess are HTML files, whereas the target files for XSL are XML files.

Cascading Style Sheets

A Cascading Style Sheet (CSS) defines how to display HTML elements. Styles are normally stored in style sheets, which are files that contain style definitions. Many different HTML documents, such as all documents in a website, can refer to the same ess. Thus, we can change the format of a website by changing a single file. This is a very convenient way of changing the layout of many webpages at the seune time, and a first step toward the separation of content from presentation.

An example style sheet is shown in Figure 7.13. It is included into an HTML file with the following line:

<LINK REL="style sheet" TYPE="text/css" HREF="books.css" />



```
BODY {BACKGROUND-COLOR: yellow}
Hi {FONT-SIZE: 36pt}
H3 {COLOR: blue}
P {MARGIN-LEFT: 50px; COLOR: red}
```

Figure 7.13 An Example Style sheet

Each line in a CSS sheet consists of three parts; a selector, a property, and a value. They are syntactically arranged in the following way:

selector {property: value}

The selector is the element or tag whose format we are defining. The property indicates the tag's attribute whose value we want to set in the style sheet, and the property is the actual value of the attribute. As an example, consider the first line of the example style sheet shown in Figure 7.13:

BODY {BACKGROUND-COLOR: yellow}

XSL

XSL is a language for expressing style sheets. An XSL style sheet is, like CSS, a file that describes how to display an XML document of a given type. XSL shares the functionality of CSS and is compatible with it (although it uses a different syntax).

XSL contains the XSL Transformation language, or XSLT, a language that allows 11S to transform the input XML document into a XML document with another structure.

XSL also contains the XML Path Language (XPath), a language that allows us to refer to parts of an XML document.

7.7 THE MIDDLE TIER

In this section, we discuss technologies for the middle tier. The first generation of middle-tier applications were stand-alone programs written in a general-purpose programming language such as C, C++, and Perl. Programmers quickly realized that interaction with a stand-alone application was quite costly; the overheads include starting the application every time it is invoked and switching processes between the webserver and the application. Therefore, such interactions do not scale to large numbers of concurrent users. This led to the development of the application server, which provides the run-time environment for several technologies that can be used to program middle-tier application components. Most oftoday's large-scale websites use an application server to run application code at the middle tier.

7.7.1 CGI: The Common Gateway Interface

The Common Gateway Interface connects HTML forms with application programs. It is a protocol that defines how arguments from forms are passed to programs at the server side. Programs that communicate with the webserver via CGI are often called **CGI scripts**, since many such application programs were written in a scripting language such like Perl.As an example of a program that interfaces with an HTML form via CGI, consider the sample page shown in Figure 7.14. This webpage contains a form where a user can fill in the name of an author. If the user presses the 'Sendit' button, the Perl script 'findBooks.cgi' shown in Figure 7.14 is executed as a separate process. The CGl protocol defines how the communication between the form and the script is performed.

```
<HTML><HEAD><TITLE>The Database Bookstore</TITLE></HEAD>
<BODY>
<FORM ACTION="find_books.cgi" METHOD=POST>
    Type an author name:
    <INPUT TYPE="text" NAME=1authorName"
            SIZE=30 MAXLENGTH=50>
    <INPUT TYPE="submiti1 value="Send it">
    <INPUT TYPE=1reset" VALUE="Clear form">
</FORM>
</BODY></HTML>
```

Figure 7.14 A Sample Web Page Where Form Input Is Sent to a CGI Script

Figure 7.15 illustrates the processes created when using the CGl protocol.

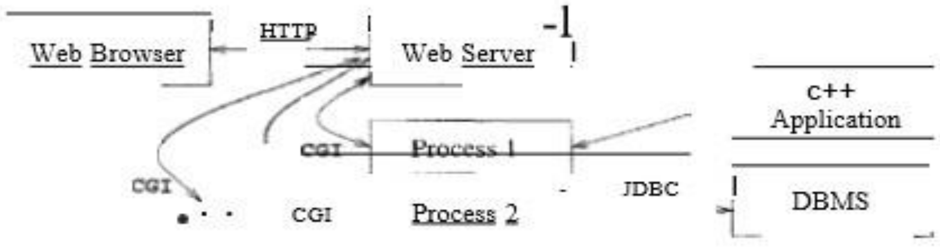


Figure 7.15 Process Structure with eGI Scripts

Figure 7.16 shows the example CGl script, written in Perl. We omit errorchecking code for simplicity. Perl is an interpreted language that is often used for CGl scripting and many Perl libraries, called modules, provide high-level interfaces to the CGl protocol. We use one such library, called the DBI library, in our example. The CGI module is a convenient collection of functions for creating CGl scripts. In part 1 of the sample script, we extract the argument of the HTML form that is passed along from the client as follows:

$authorName = $dataln- >paramCauthorName');

```
#!/usr/bin/perl
use CGI;

### part 1
$dataln = new CGI;
$dataIn-¿header();
$authorName = $dataln-1,param('authorName');

### part 2
print (II<HTML><TITLE>Argument passing test</TITLE> II) ;
print (II The user passed the following argument: II) ;
print (II authorName: ", $authorName);

### part 3
print ("</HTML>");
exit;
```

Figure 7.16 A Simple Perl Script

7.7.2 Application Servers

Application logic can be enforced through server-side programs that are invoked using the CGl protocol. However, since each page request results in the creation of a new process, this solution does not scale well to a large number of simultaneous requests. This performance problem led to the development of specialized programs called application servers. An **application serve**r maintains a pool of threads or processes and uses these to execute requests. Thus, it avoids the startup cost of creating a new process for each request.

A possible architecture for a website with an application server is shown in Figure 7.17. The client (a Web browser) interacts with the webserver through the HTTP protocol. The webserver delivers static HTML or XML pages directly to the client. To assemble dynamic pages, the webserver sends a request to the application server. The application server contacts one or more data sources to retrieve necessary data or sends update requests to the data sources. After the interaction with the data sources is completed, the application server assembles the webpage and reports the result to the webserver, which retrieves the page and delivers it to the client.

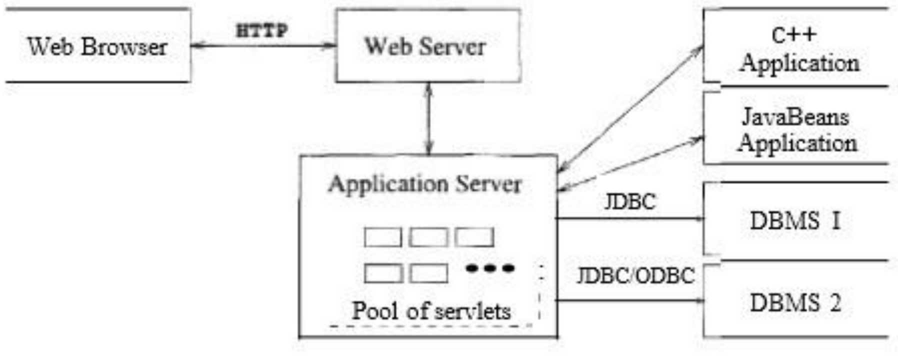


Figure 7.17 Process Structure in the Application Server Architecture

7.7.3 Servlets

Java servlets are pieces of Java code that run on the middle tier, in either webservers or application servers. There are special conventions on how to read the input from the user request and how to write output generated by the servlet. Servlets are truly platform-independent, and so they have become very popular with Web developers.

Since servlets are Java programs, they are very versatile. For example, servlets can build webpages, access databases, and maintain state. Servlets have accessto all Java APls, including JDBC. All servlets must implement the Servlet interface. In most cases, servlets extend the specific HttpServlet class for servers that communicate with clients via HTTP. The HttpServlet class provides methods such as doGet and doPost to receive arguments from HTML forms, and it sends its output back to the elient via HTTP. Servlets that communicate through other protocols (such as ftp) need to extend the class GenericServlet.

Servlets are compiled Java classes executed and maintained by a servlet container. The servlet container manages the lifespan of individual servlets by creating and destroying them. Although servlets can respond to any type of request, they are commonly used to extend the applications hosted by webservers. For such applications, there is a useful library of HTTP-specific servlet classes.

Servlets usually handle requests from HTML forms and maintain state between the client and the server.A template of a generic servlet structure is shown in Figure 7.18. This simple servlet just outputs the two words "Hello World," but it shows the general structure of a full-fledged servlet. The request object is used to read HTML form data. The response object is used to specify the HTTP response status code and headers of the HTTP response. The object out is used to compose the content that is returned to the client.

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

pUblic class ServletTemplate extends HttpServlet {
    public void doGet(HttpServletRequest request,
            HttpServletResponse response)
            throws ServletException, IOException {
        PrintWriter out = response.getWriter();
        // Use 'out' to send content to browser
        out.println("Hello World");
    }
}
```

Figure 7.18 Servlet Template

<u>7.7.4</u> <u>JavaServer Pages</u>

JavaServer pages (.JSPs) interchange the roles of output and application logic. JavaServer pages are written in HTML with servlet-like code embedded in special HTML tags. Thus, in comparison to servlets, JavaServer pages are better suited to quickly building interfaces that have some logic inside, whereas servlets are better suited for complex application logic.

While there is a big difference for the programmer, the middle tier handles JavaServer pages in a very simple way: They are usually compiled into a servlet, which is then handled by a servlet container analogous to other servlets.

The code fragment in Figure 7.20 shows a simple JSP example. In the middle of the HTML code, we access information that was passed from a form.

```
<!DOCTYPE HTML PUBLIC 11_//W3C//DTD HTML 4.0
        Transitional//EN‖>
<HTML>
<HEAD><TITLE>Welcome to Barnes and Nobble</TITLE></HEAD>
<BODY>
    <H1>Welcome back!</H1>
    <% String name="NewUser‖;
        if (request.getParameter(1Iusername11) != null) {
            name=request.getParameter("username");
        }
    %>
    You are logged on as user <%=name%>
    <P>
    Regular HTML for all the rest of the on-line store's webpage.
</BODY>
</HTML>
```

Figure 7.20 Reading Form Parameters in JSP

7.7.5 Maintaining State

As discussed in previous sections, there is a need to maintain a user's state across different pages. As an example, consider a user who wants to make a purchase at the Barnes and Nobble website. The user must first add items into her shopping basket, which persists while she navigates through the site. Thus, we use the notion of state mainly to remember information as the user navigates through the site.

The HTTP protocol is stateless. We call an interaction with a webserver **stateless** if no information is retained from one request to the next request. We call an interaction with a webserver **stateful**, or we say that state is maintained, if some memory is stored between requests to the server, and different actions are taken depending on the contents stored.

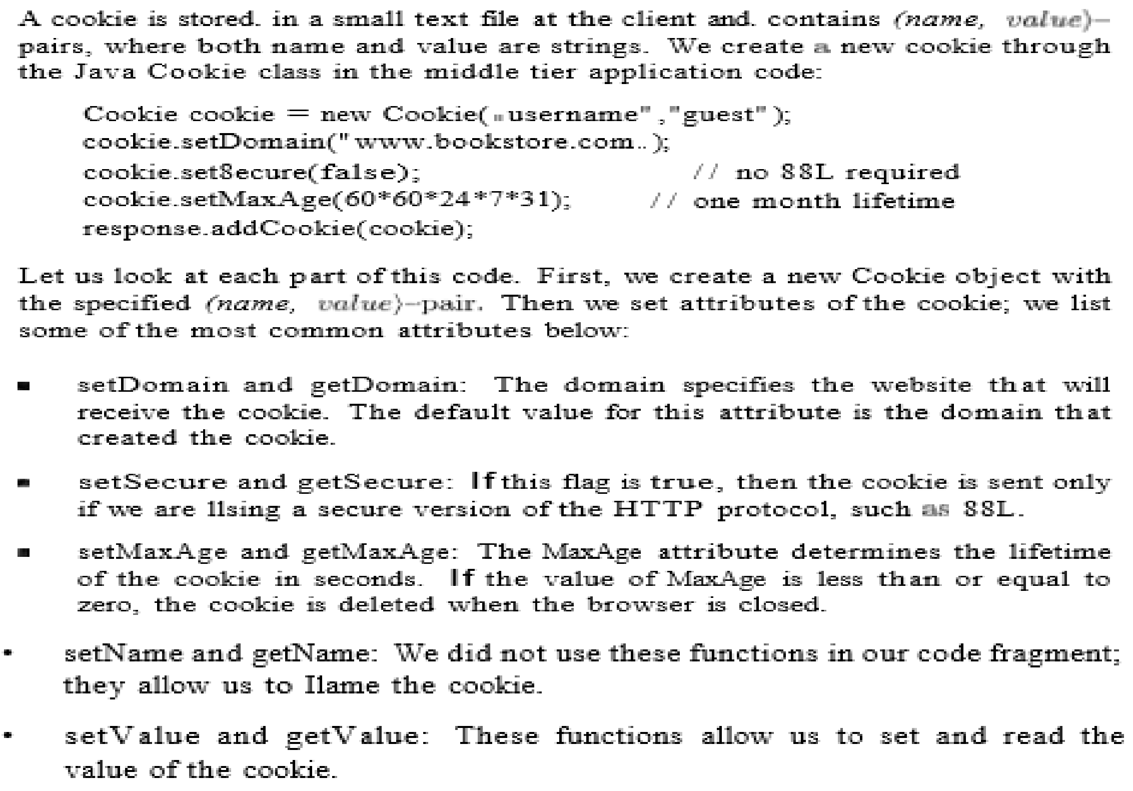
Maintaining State at the Middle Tier

At the middle tier, we have several choices as to where we maintain state. First, we could store the state at the bottom tier, in the database server. The state survives crashes of the system, but a database access is required to query or update the state, a potential performance bottleneck. An alternative is to store state in main memory at the middle tier.

Maintaining State at the Presentation Tier: Cookies

A cookie is a collection of (name, value) pairs that can be manipulated at the presentation and middle tiers. Cookies are easy to use in Java servlets and Javaserver Pages and provide a simple way to make non-essential data persistent at the client. They survive several client sessions because they persist in the browser cache even after the browser is closed.

The Servlet Cookie API



A cookie is stored. in a small text file at the client and. contains *(name, value)*–pairs, where both name and value are strings. We create a new cookie through the Java Cookie class in the middle tier application code:

```
Cookie cookie = new Cookie(„username","guest");
cookie.setDomain("www.bookstore.com..);
cookie.set8ecure(false);                  // no 88L required
cookie.setMaxAge(60*60*24*7*31);       // one month lifetime
response.addCookie(cookie);
```

Let us look at each part of this code. First, we create a new Cookie object with the specified *(name, value)*–pair. Then we set attributes of the cookie; we list some of the most common attributes below:

- setDomain and getDomain: The domain specifies the website that will receive the cookie. The default value for this attribute is the domain that created the cookie.
- setSecure and getSecure: If this flag is true, then the cookie is sent only if we are llsing a secure version of the HTTP protocol, such as 88L.
- setMaxAge and getMaxAge: The MaxAge attribute determines the lifetime of the cookie in seconds. If the value of MaxAge is less than or equal to zero, the cookie is deleted when the browser is closed.
- setName and getName: We did not use these functions in our code fragment; they allow us to Ilame the cookie.
- setValue and getValue: These functions allow us to set and read the value of the cookie.