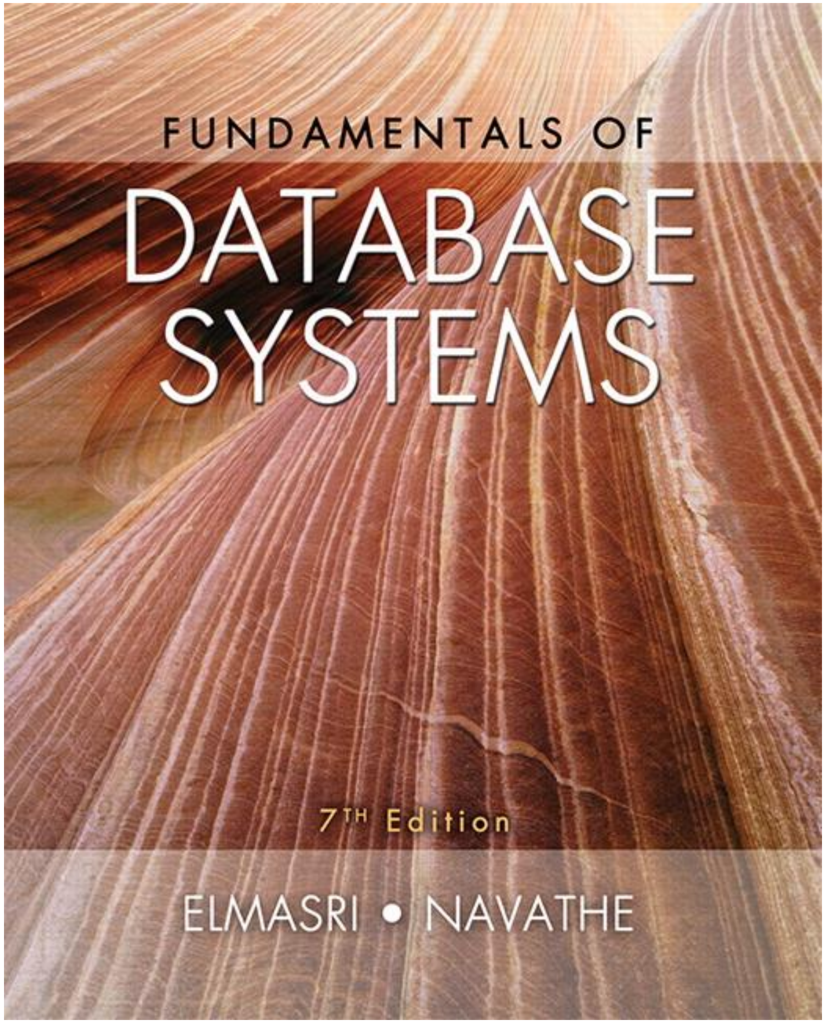


FUNDAMENTALS OF DATABASE SYSTEMS

7TH Edition

ELMASRI • NAVATHE

Chapter 10 Outline

- Database Programming: Techniques and Issues
- Embedded SQL, Dynamic SQL, and SQLJ
- Database Programming with Function Calls: SQL/CLI and JDBC
- Database Stored Procedures and SQL/PSM
- Comparing the Three Approaches

Introduction to SQL Programming Techniques

- **Database applications**
  - Host language
    - Java, C/C++/C#, COBOL, or some other programming language
  - Data sublanguage
    - SQL
- SQL standards
  - Continually evolving
  - Each DBMS vendor may have some variations from standard

Database Programming: Techniques and Issues

- **Interactive interface**
  - SQL commands typed directly into a monitor
- Execute **file of commands**
  - *@<filename>*
- **Application programs** or **database applications**
  - Used as canned transactions by the end users access a database
  - May have **Web interface**

Approaches to Database Programming

- **Embedding** database commands in a general-purpose programming language
  - Database statements identified by a special prefix
  - **Precompiler** or **preprocessor** scans the source program code
    - Identify database statements and extract them for processing by the DBMS
  - Called **embedded SQL**

Approaches to Database Programming (cont'd.)

- Using a library of database functions
  - **Library of functions** available to the host programming language
  - **Application programming interface (API)**
- Designing a brand-new language
  - **Database programming language** designed from scratch
- First two approaches are more common

Impedance Mismatch

- Differences between database model and programming language model
- **Binding** for each host programming language
  - Specifies for each attribute type the compatible programming language types
- Cursor or iterator variable
  - Loop over the tuples in a query result

Typical Sequence of Interaction in Database Programming

- Open a connection to database server
- Interact with database by submitting queries, updates, and other database commands
- Terminate or close connection to database

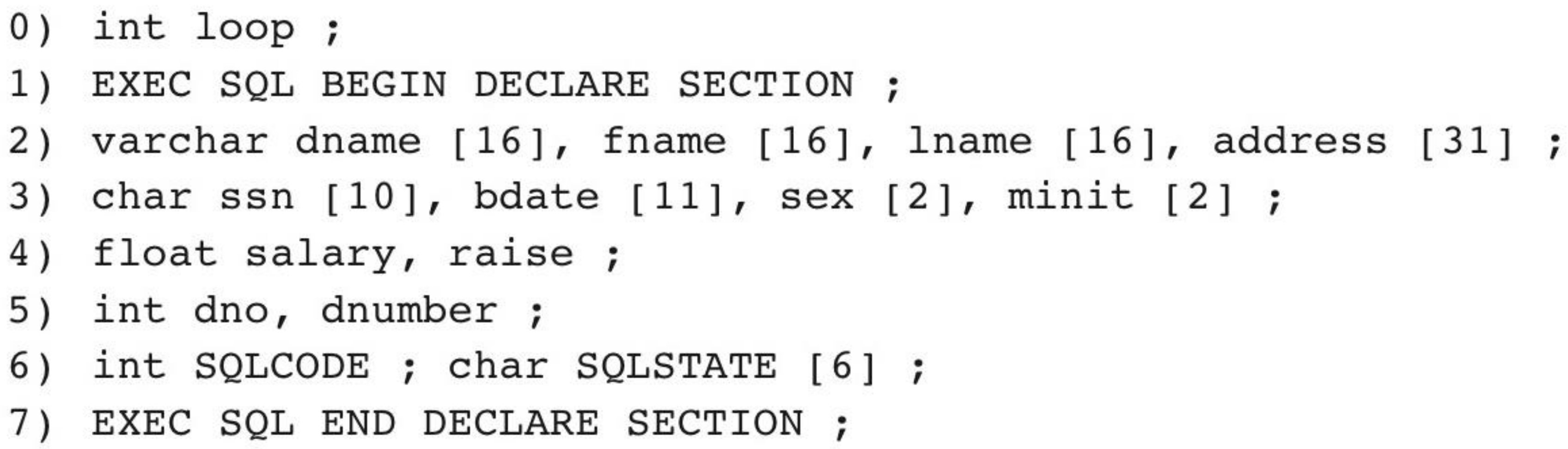
Embedded SQL, Dynamic SQL, and SQLJ

- **Embedded SQL**
  - C language
- **SQLJ**
  - Java language
- Programming language called **host language**

Retrieving Single Tuples with Embedded SQL

- `EXEC SQL`
  - Prefix
  - **Preprocessor** separates embedded SQL statements from host language code
  - Terminated by a matching `END-EXEC`
    - Or by a semicolon (;)
- **Shared variables**
  - Used in both the C program and the embedded SQL statements
  - Prefixed by a colon (:) in SQL statement

Figure 10.1 C program variables used in the embedded SQL examples E1 and E2.



```
int loop ;
EXEC SQL BEGIN DECLARE SECTION ;
varchar dname [16], fname [16], lname [16], address [31] ;
char ssn [10], bdate [11], sex [2], minit [2] ;
float salary, raise ;
int dno, dnumber ;
int SQLCODE ; char SQLSTATE [6] ;
EXEC SQL END DECLARE SECTION ;
```

Retrieving Single Tuples with Embedded SQL (cont'd.)

- Connecting to the database

```
CONNECT TO <server name>AS <connection name>
AUTHORIZATION <user account name and password> ;
```

- Change connection

```
SET CONNECTION <connection name> ;
```

- Terminate connection

```
DISCONNECT <connection name> ;
```

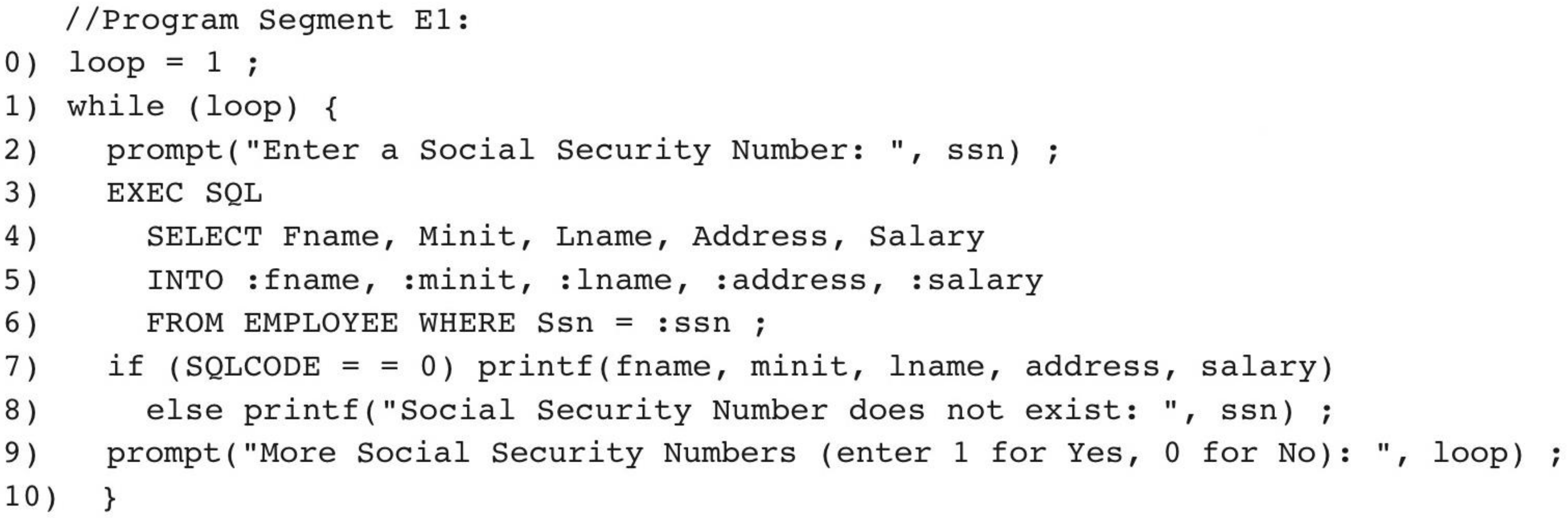
Retrieving Single Tuples with Embedded SQL (cont'd.)

- **SQLCODE** and **SQLSTATE** communication variables
  - Used by DBMS to communicate exception or error conditions
- SQLCODE variable
  - 0 = statement executed successfully
  - 100 = no more data available in query result
  - < 0 = indicates some error has occurred

Retrieving Single Tuples with Embedded SQL (cont'd.)

- SQLSTATE
  - String of five characters
  - '00000' = no error or exception
  - Other values indicate various errors or exceptions
  - For example, '02000' indicates 'no more data' when using SQLSTATE

Figure 10.2 Program segment E1, a C program segment with embedded SQL.

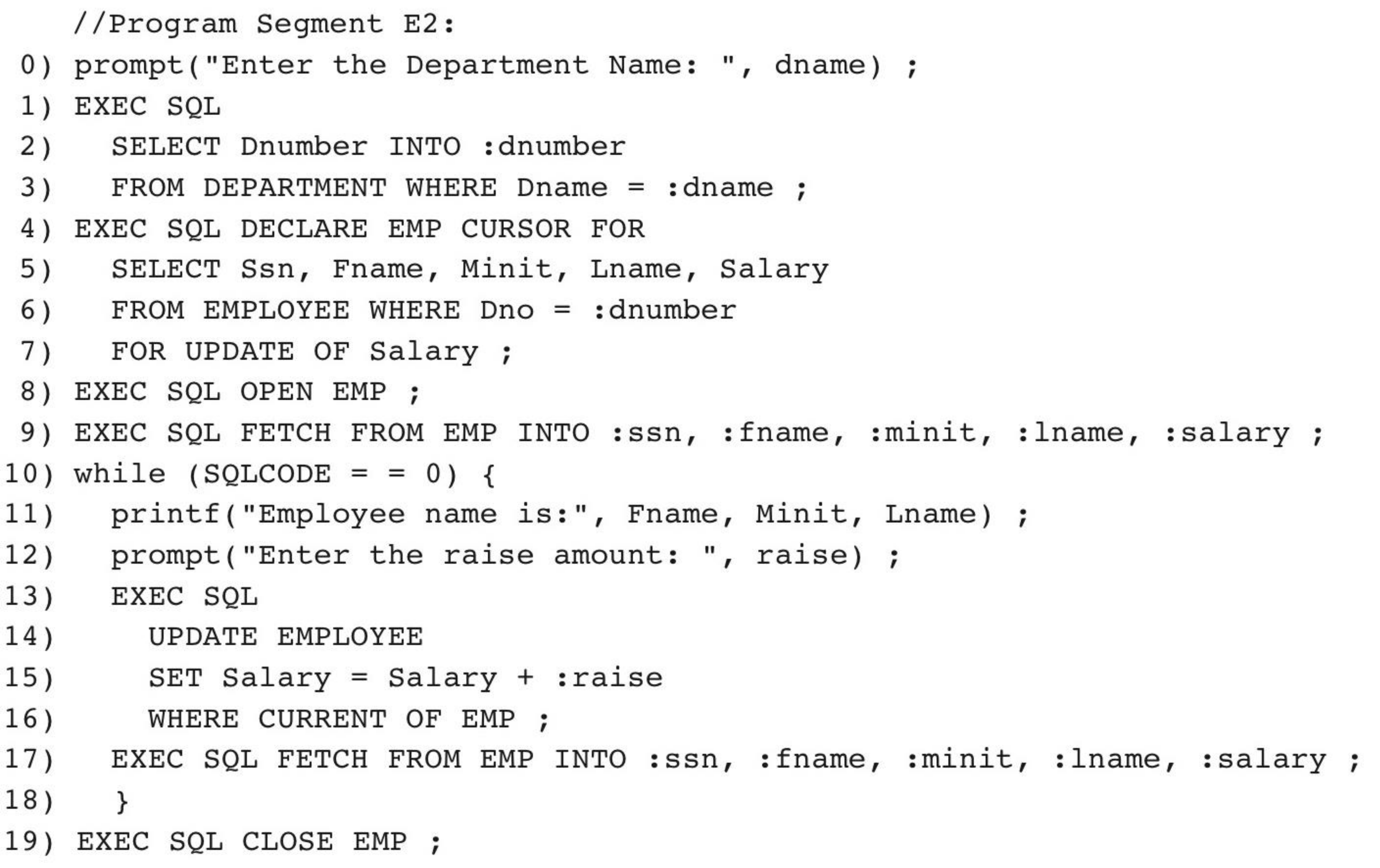


```
//Program Segment E1:
loop = 1 ;
while (loop) {
  prompt("Enter a Social Security Number: ", ssn) ;
  EXEC SQL
    SELECT Fname, Minit, Lname, Address, Salary
    INTO :fname, :minit, :lname, :address, :salary
    FROM EMPLOYEE WHERE Ssn = :ssn ;
  if (SQLCODE = = 0) printf(fname, minit, lname, address, salary)
    else printf("Social Security Number does not exist: ", ssn) ;
  prompt("More Social Security Numbers (enter 1 for Yes, 0 for No): ", loop) ;
  }
```

Retrieving Multiple Tuples with Embedded SQL Using Cursors

- Cursor
  - Points to a single tuple (row) from result of query
- **`OPEN CURSOR`** command
  - Fetches query result and sets cursor to a position before first row in result
  - Becomes current row for cursor
- **`FETCH`** commands
  - Moves cursor to next row in result of query

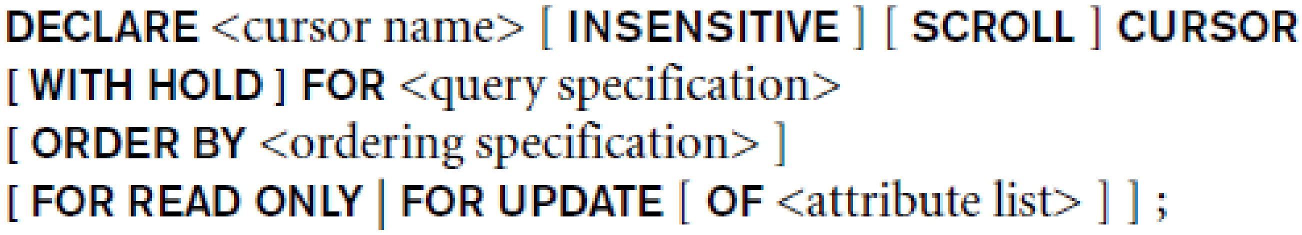
Figure 10.3 Program segment E2, a C program segment that uses cursors with em



```
//Program Segment E2:
prompt("Enter the Department Name: ", dname) ;
EXEC SQL
  SELECT Dnumber INTO :dnumber
  FROM DEPARTMENT WHERE Dname = :dname ;
EXEC SQL DECLARE EMP CURSOR FOR
  SELECT Ssn, Fname, Minit, Lname, Salary
  FROM EMPLOYEE WHERE Dno = :dnumber
  FOR UPDATE OF Salary ;
EXEC SQL OPEN EMP ;
EXEC SQL FETCH FROM EMP INTO :ssn, :fname, :minit, :lname, :salary ;
while (SQLCODE = = 0) {
  printf("Employee name is:", Fname, Minit, Lname) ;
  prompt("Enter the raise amount: ", raise) ;
  EXEC SQL
    UPDATE EMPLOYEE
    SET Salary = Salary + :raise
    WHERE CURRENT OF EMP ;
  EXEC SQL FETCH FROM EMP INTO :ssn, :fname, :minit, :lname, :salary ;
  }
EXEC SQL CLOSE EMP ;
```

Retrieving Multiple Tuples with Embedded SQL Using Cursors (cont'd.)

- `FOR UPDATE OF`
  - List the names of any attributes that will be updated by the program
- Fetch orientation
  - Added using value: `NEXT`, `PRIOR`, `FIRST`, `LAST`, `ABSOLUTE` *`i`*, and `RELATIVE` *`i`*

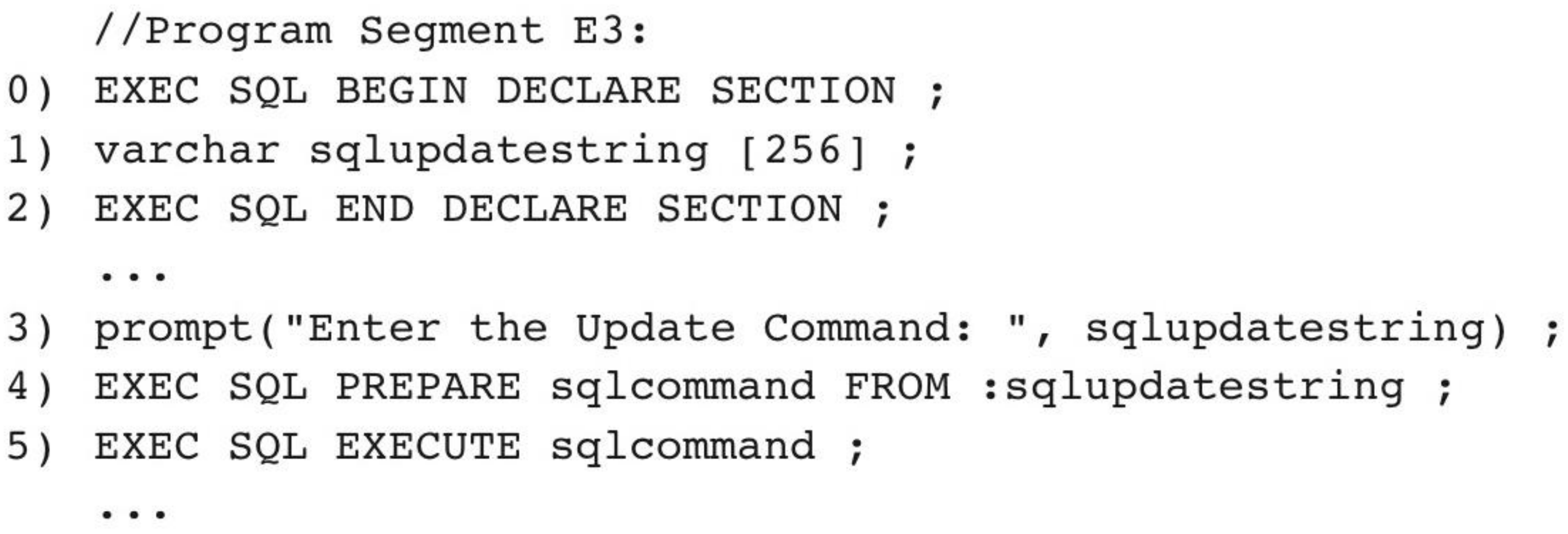


```
DECLARE <cursor name> [ INSENSITIVE ] [ SCROLL ] CURSOR
[ WITH HOLD ] FOR <query specification>
[ ORDER BY <ordering specification> ]
[ FOR READ ONLY | FOR UPDATE [ OF <attribute list> ] ] ;
```

Specifying Queries at Runtime Using Dynamic SQL

- **Dynamic SQL**
  - Execute different SQL queries or updates dynamically at runtime
- Dynamic update
- Dynamic query

Figure 10.4 Program segment E3, a C program segment that uses dynamic SQL for updating a table.

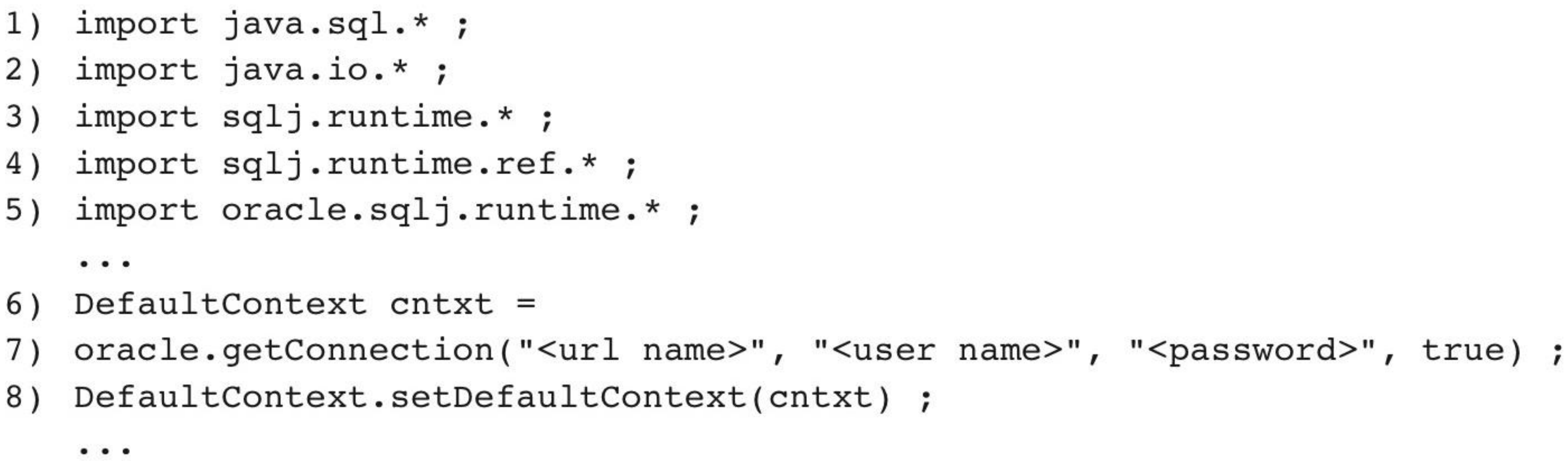


```
//Program Segment E3:
EXEC SQL BEGIN DECLARE SECTION ;
varchar sqlupdatestring [256] ;
EXEC SQL END DECLARE SECTION ;
...
prompt("Enter the Update Command: ", sqlupdatestring) ;
EXEC SQL PREPARE sqlcommand FROM :sqlupdatestring ;
EXEC SQL EXECUTE sqlcommand ;
...
```

SQLJ: Embedding SQL Commands in Java

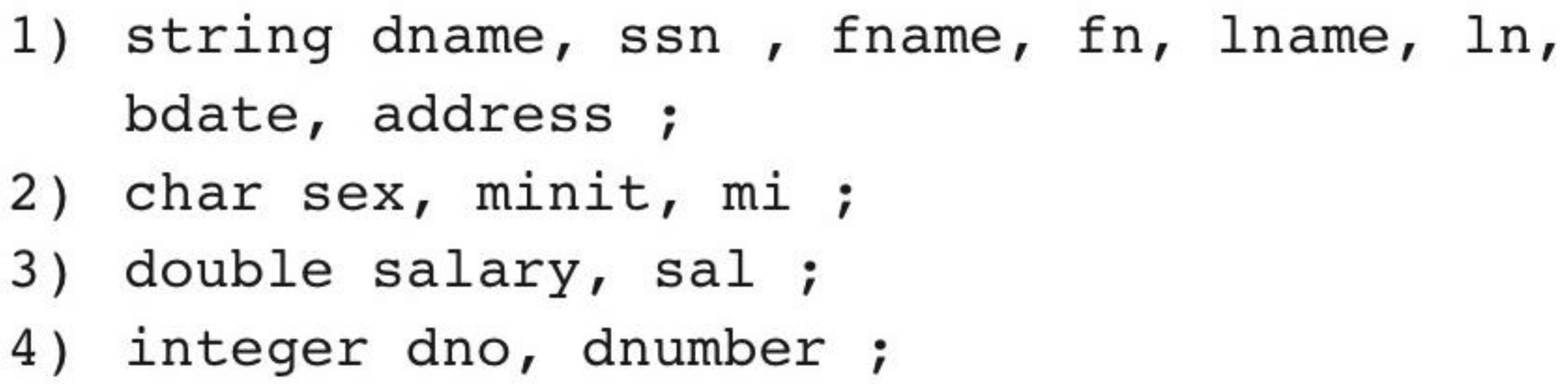
- Standard adopted by several vendors for embedding SQL in Java
- Import several class libraries
- **Default context**
- Uses **exceptions** for error handling
  - `SQLException` is used to return errors or exception conditions

Figure 10.5 Importing classes needed for including SQLJ in Java programs in Oracle, and establishing a connection and default context.



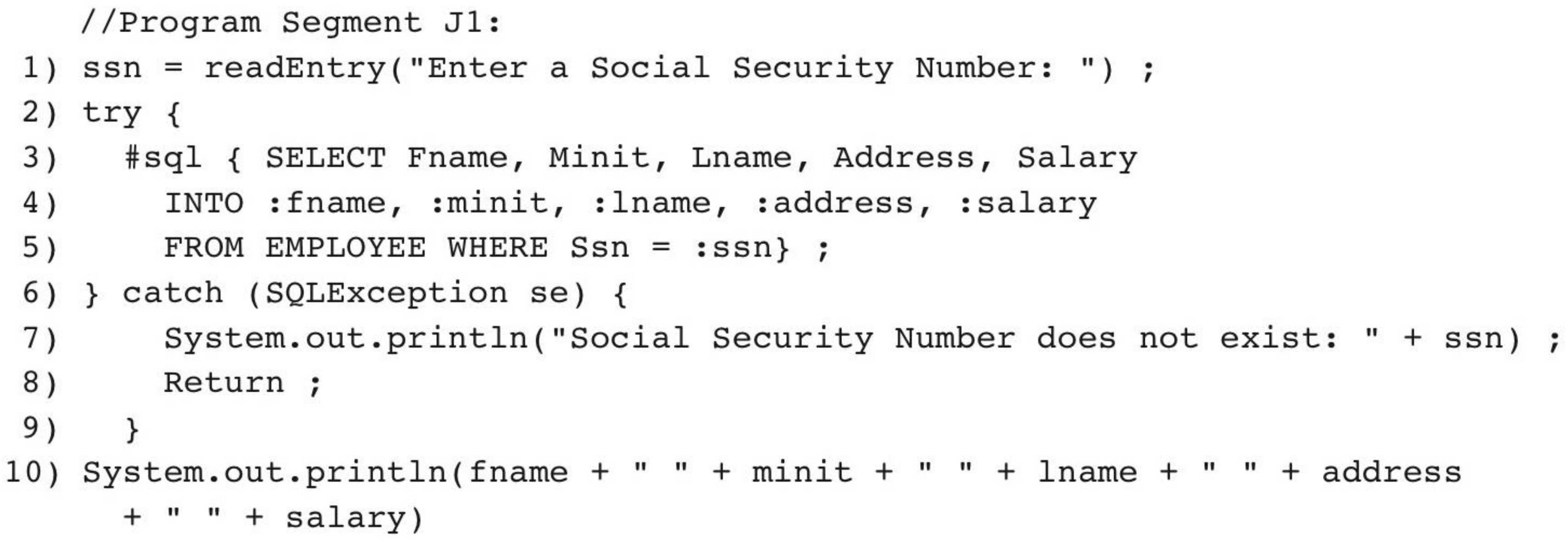
```
import java.sql.* ;
import java.io.* ;
import sqlj.runtime.* ;
import sqlj.runtime.ref.* ;
import oracle.sqlj.runtime.* ;
...
DefaultContext cntxt =
oracle.getConnection("<url name>", "<user name>", "<password>", true) ;
DefaultContext.setDefaultContext(cntxt) ;
...
```

Figure 10.6 Java program variables used in SQLJ examples J1 and J2.



```
1) string dname, ssn , fname, fn, lname, ln,
   bdate, address ;
2) char sex, minit, mi ;
3) double salary, sal ;
4) integer dno, dnumber ;
```

Figure 10.7 Program segment J1, a Java program segment with SQLJ.

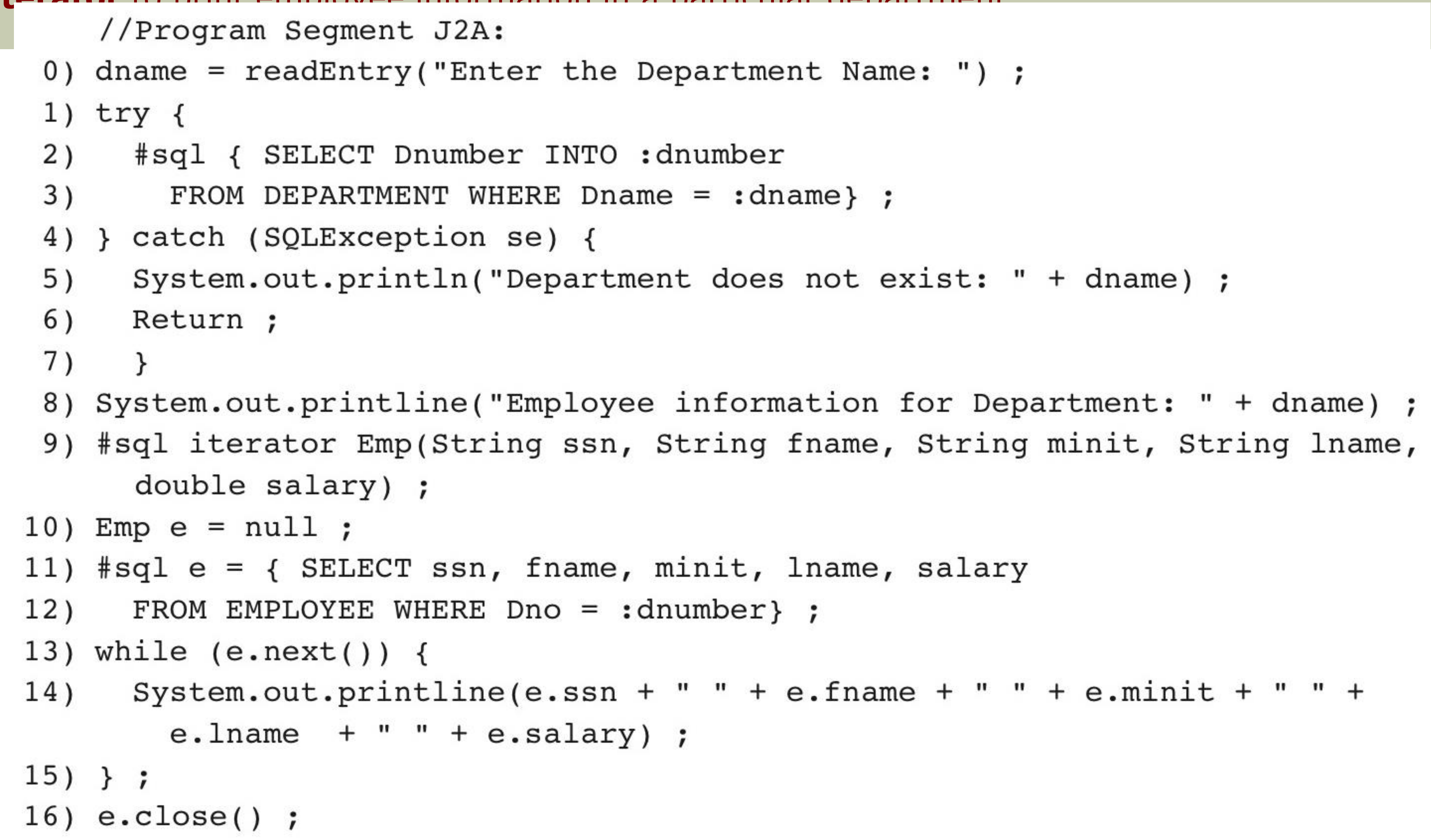


```
//Program Segment J1:
ssn = readEntry("Enter a Social Security Number: ") ;
try {
  #sql { SELECT Fname, Minit, Lname, Address, Salary
    INTO :fname, :minit, :lname, :address, :salary
    FROM EMPLOYEE WHERE Ssn = :ssn} ;
} catch (SQLException se) {
    System.out.println("Social Security Number does not exist: " + ssn) ;
    Return ;
  }
System.out.println(fname + " " + minit + " " + lname + " " + address
  + " " + salary)
```

Retrieving Multiple Tuples in SQLJ Using Iterators

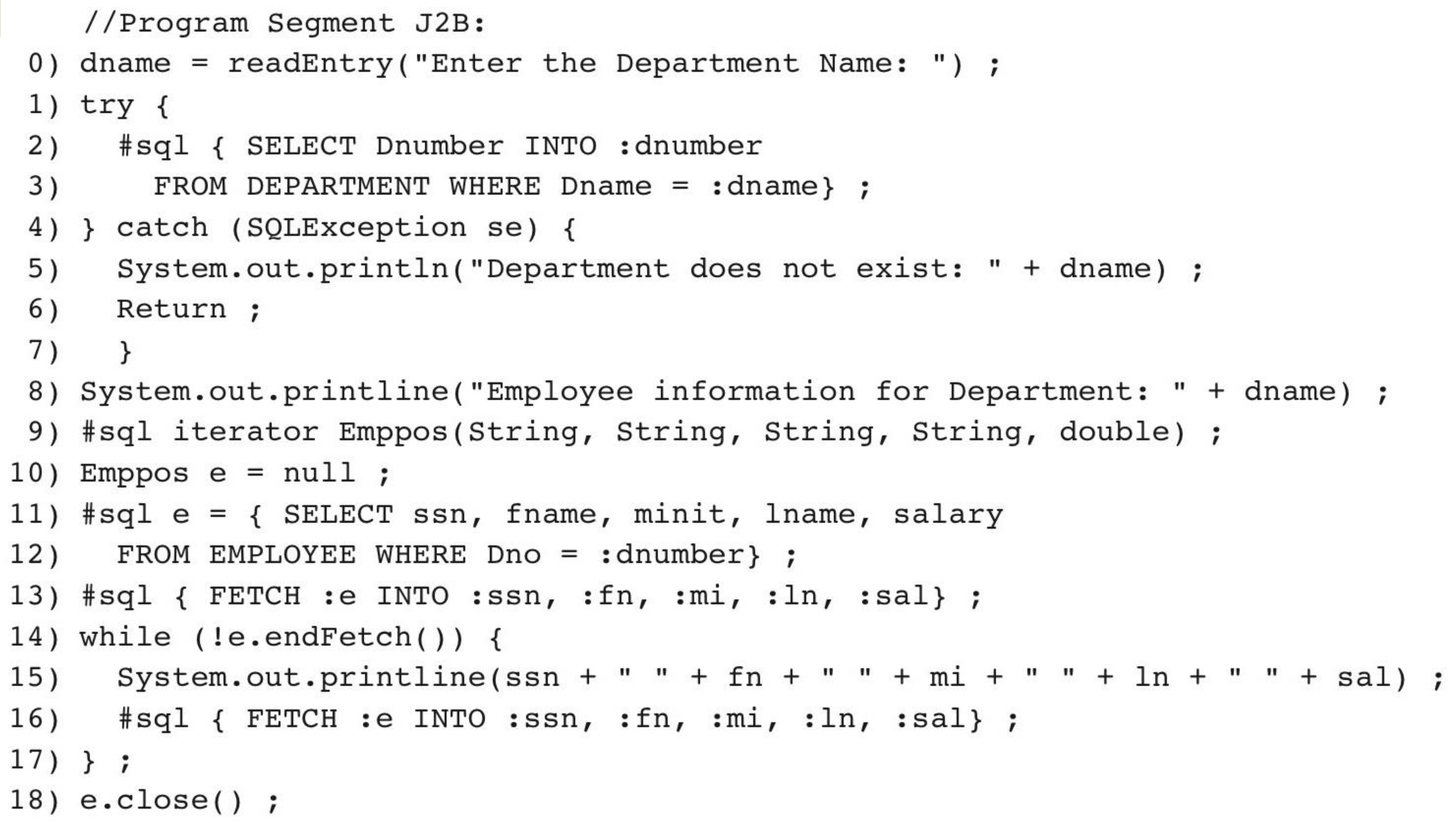
- **Iterator**
  - Object associated with a collection (set or multiset) of records in a query result
- **Named iterator**
  - Associated with a query result by listing attribute names and types in query result
- **Positional iterator**
  - Lists only attribute types in query result

Figure 10.8 Program segment J2A, a Java program segment that uses a **named iterator** to print employee information in a particular department



```
//Program Segment J2A:
dname = readEntry("Enter the Department Name: ") ;
try {
  #sql { SELECT Dnumber INTO :dnumber
    FROM DEPARTMENT WHERE Dname = :dname} ;
} catch (SQLException se) {
  System.out.println("Department does not exist: " + dname) ;
  Return ;
  }
System.out.printline("Employee information for Department: " + dname) ;
#sql iterator Emp(String ssn, String fname, String minit, String lname,
  double salary) ;
Emp e = null ;
#sql e = { SELECT ssn, fname, minit, lname, salary
  FROM EMPLOYEE WHERE Dno = :dnumber} ;
while (e.next()) {
  System.out.printline(e.ssn + " " + e.fname + " " + e.minit + " " +
    e.lname  + " " + e.salary) ;
} ;
e.close() ;
```

Figure 10.9 Program segment J2B, a Java program segment that uses a **positional iterator** to print employee information in a particular department.



```
//Program Segment J2B:
dname = readEntry("Enter the Department Name: ") ;
try {
  #sql { SELECT Dnumber INTO :dnumber
    FROM DEPARTMENT WHERE Dname = :dname} ;
} catch (SQLException se) {
  System.out.println("Department does not exist: " + dname) ;
  Return ;
  }
System.out.printline("Employee information for Department: " + dname) ;
#sql iterator Emppos(String, String, String, String, double) ;
Emppos e = null ;
#sql e = { SELECT ssn, fname, minit, lname, salary
  FROM EMPLOYEE WHERE Dno = :dnumber} ;
#sql { FETCH :e INTO :ssn, :fn, :mi, :ln, :sal} ;
while (!e.endFetch()) {
  System.out.printline(ssn + " " + fn + " " + mi + " " + ln + " " + sal) ;
  #sql { FETCH :e INTO :ssn, :fn, :mi, :ln, :sal} ;
} ;
e.close() ;
```

Database Programming with Function Calls: SQL/CLI & JDBC

- Use of function calls
  - **Dynamic** approach for database programming
- Library of functions
  - Also known as **application programming interface (API)**
  - Used to access database
- **SQL Call Level Interface (SQL/CLI)**
  - Part of SQL standard

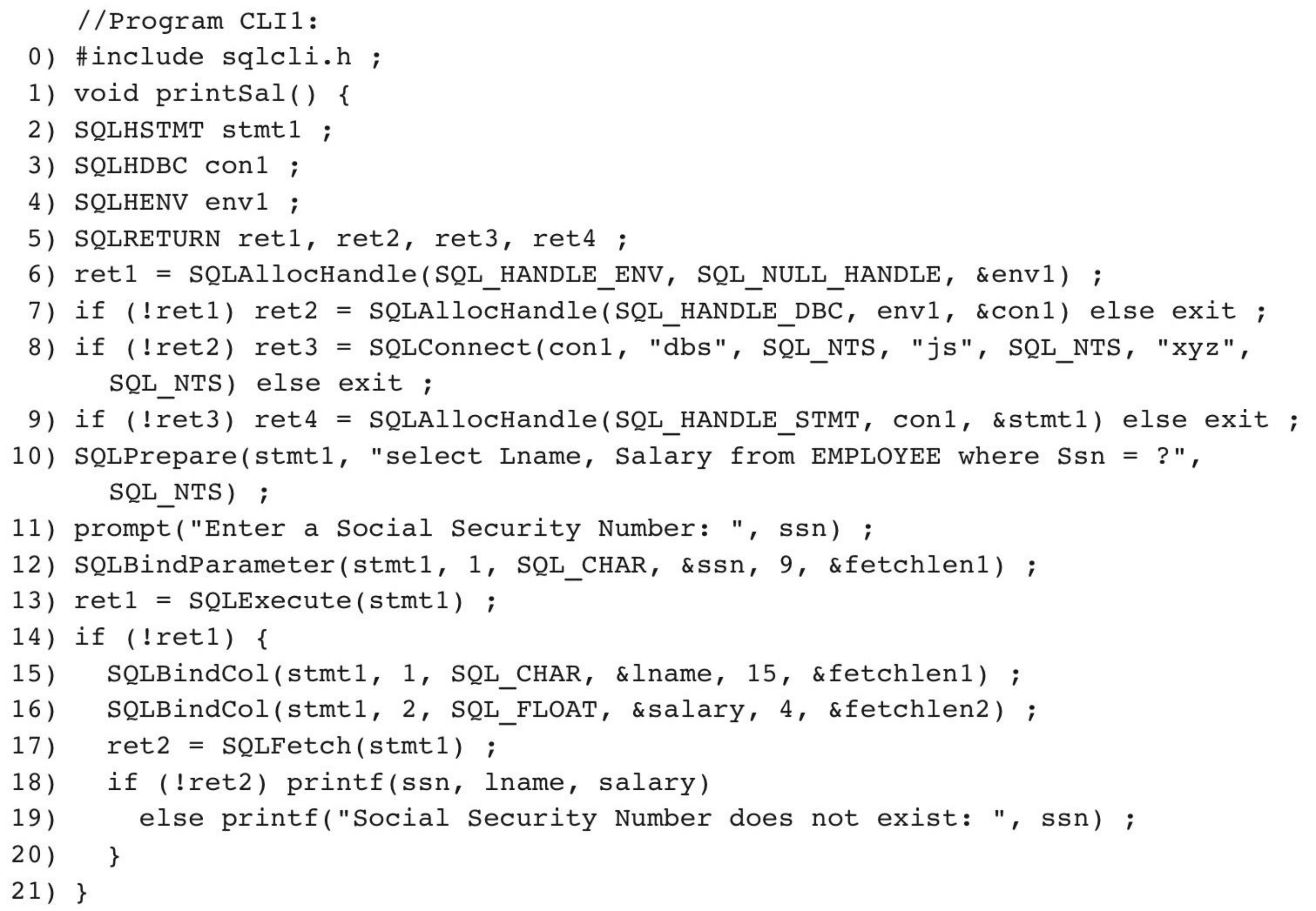
SQL/CLI: Using C as the Host Language

- **Environment record**
  - Track one or more database connections
  - Set environment information
- **Connection record**
  - Keeps track of information needed for a particular database connection
- **Statement record**
  - Keeps track of the information needed for one SQL statement

SQL/CLI: Using C as the Host Language (cont’d.)

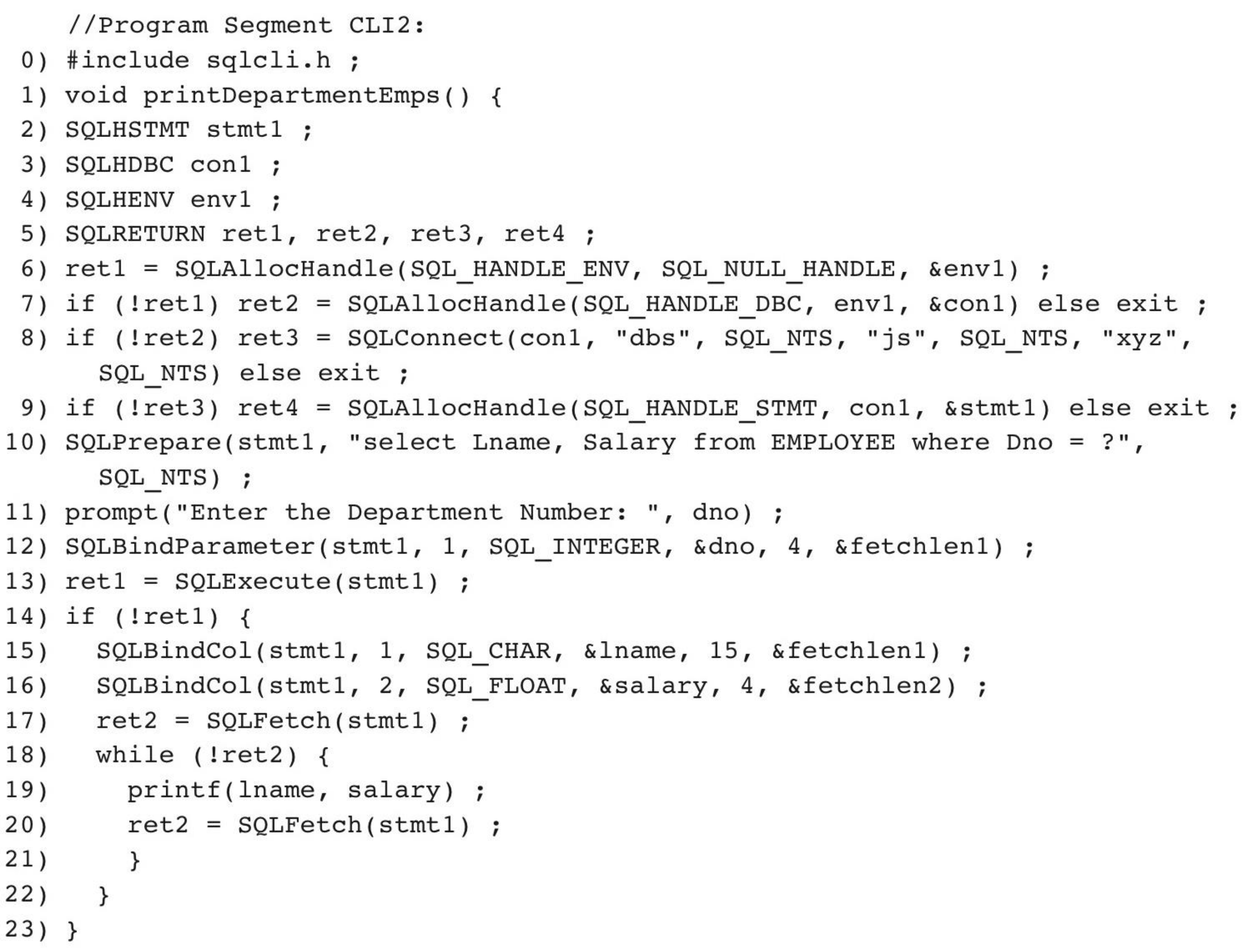
- **Description record**
  - Keeps track of information about tuples or parameters
- **Handle** to the record
  - C pointer variable makes record accessible to program

Figure



```
//Program CLI1:
#include sqlcli.h ;
void printSal() {
SQLHSTMT stmt1 ;
SQLHDBC con1 ;
SQLHENV env1 ;
SQLRETURN ret1, ret2, ret3, ret4 ;
ret1 = SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &env1) ;
if (!ret1) ret2 = SQLAllocHandle(SQL_HANDLE_DBC, env1, &con1) else exit ;
if (!ret2) ret3 = SQLConnect(con1, "dbs", SQL_NTS, "js", SQL_NTS, "xyz",
  SQL_NTS) else exit ;
if (!ret3) ret4 = SQLAllocHandle(SQL_HANDLE_STMT, con1, &stmt1) else exit ;
SQLPrepare(stmt1, "select Lname, Salary from EMPLOYEE where Ssn = ?",
  SQL_NTS) ;
prompt("Enter a Social Security Number: ", ssn) ;
SQLBindParameter(stmt1, 1, SQL_CHAR, &ssn, 9, &fetchlen1) ;
ret1 = SQLExecute(stmt1) ;
if (!ret1) {
  SQLBindCol(stmt1, 1, SQL_CHAR, &lname, 15, &fetchlen1) ;
  SQLBindCol(stmt1, 2, SQL_FLOAT, &salary, 4, &fetchlen2) ;
  ret2 = SQLFetch(stmt1) ;
  if (!ret2) printf(ssn, lname, salary)
    else printf("Social Security Number does not exist: ", ssn) ;
  }
}
```

Figure 10.11 Program segment CLI2, a C program segment that uses SQL/CLI for a query with a **collection**



```
//Program Segment CLI2:
#include sqlcli.h ;
void printDepartmentEmps() {
SQLHSTMT stmt1 ;
SQLHDBC con1 ;
SQLHENV env1 ;
SQLRETURN ret1, ret2, ret3, ret4 ;
ret1 = SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &env1) ;
if (!ret1) ret2 = SQLAllocHandle(SQL_HANDLE_DBC, env1, &con1) else exit ;
if (!ret2) ret3 = SQLConnect(con1, "dbs", SQL_NTS, "js", SQL_NTS, "xyz",
    SQL_NTS) else exit ;
if (!ret3) ret4 = SQLAllocHandle(SQL_HANDLE_STMT, con1, &stmt1) else exit ;
SQLPrepare(stmt1, "select Lname, Salary from EMPLOYEE where Dno = ?",
    SQL_NTS) ;
prompt("Enter the Department Number: ", dno) ;
SQLBindParameter(stmt1, 1, SQL_INTEGER, &dno, 4, &fetchlen1) ;
ret1 = SQLExecute(stmt1) ;
if (!ret1) {
  SQLBindCol(stmt1, 1, SQL_CHAR, &lname, 15, &fetchlen1) ;
  SQLBindCol(stmt1, 2, SQL_FLOAT, &salary, 4, &fetchlen2) ;
  ret2 = SQLFetch(stmt1) ;
  while (!ret2) {
    printf(lname, salary) ;
    ret2 = SQLFetch(stmt1) ;
    }
  }
}
```

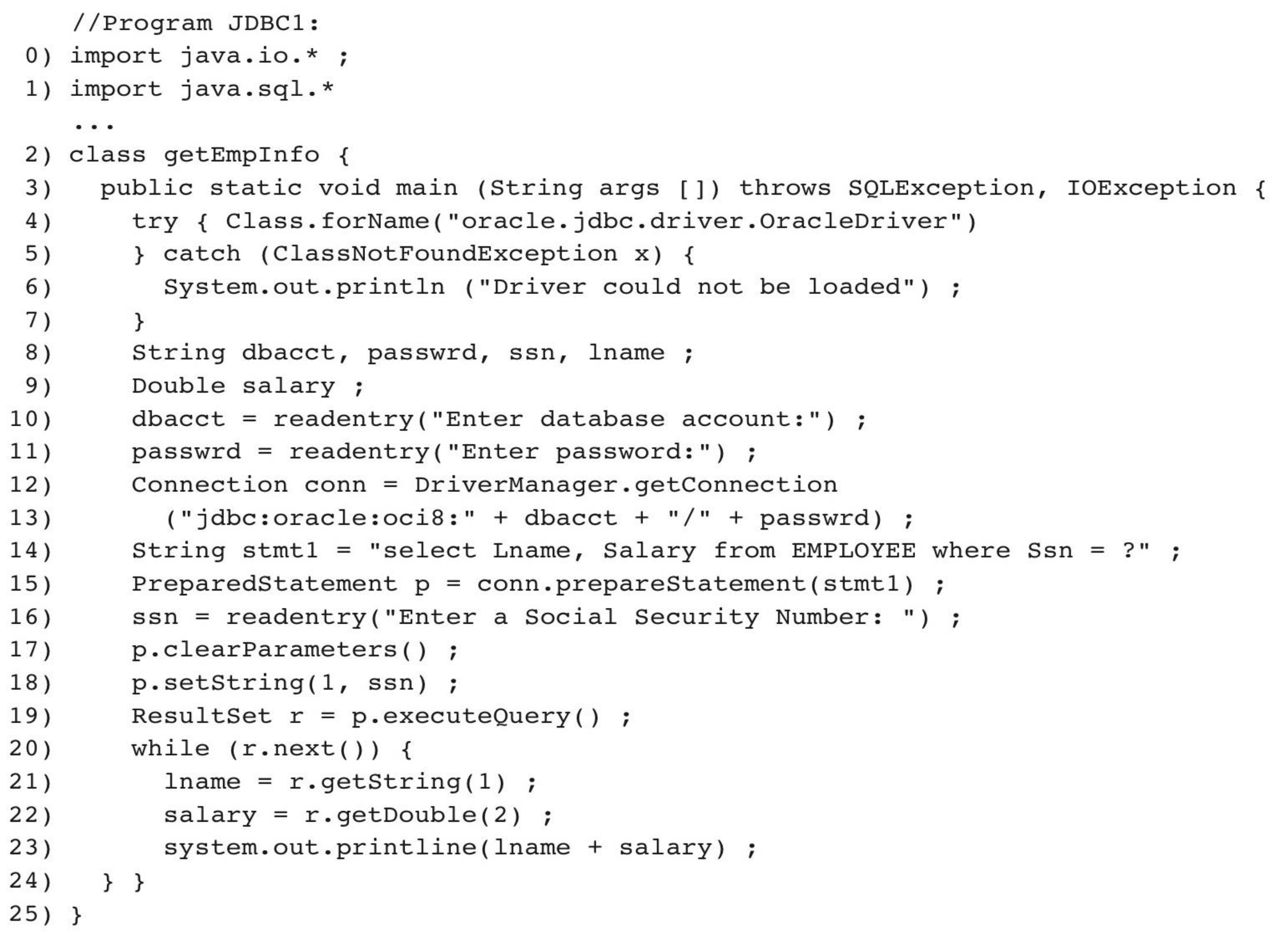
JDBC: SQL Function Calls for Java Programming

- JDBC
  - Java function libraries
- Single Java program can connect to several different databases
  - Called data sources accessed by the Java program
- `Class.forName("oracle.jdbc.driver.OracleDriver")`
  - Load a **JDBC driver** explicitly

JDBC: SQL Function Calls for Java Programming

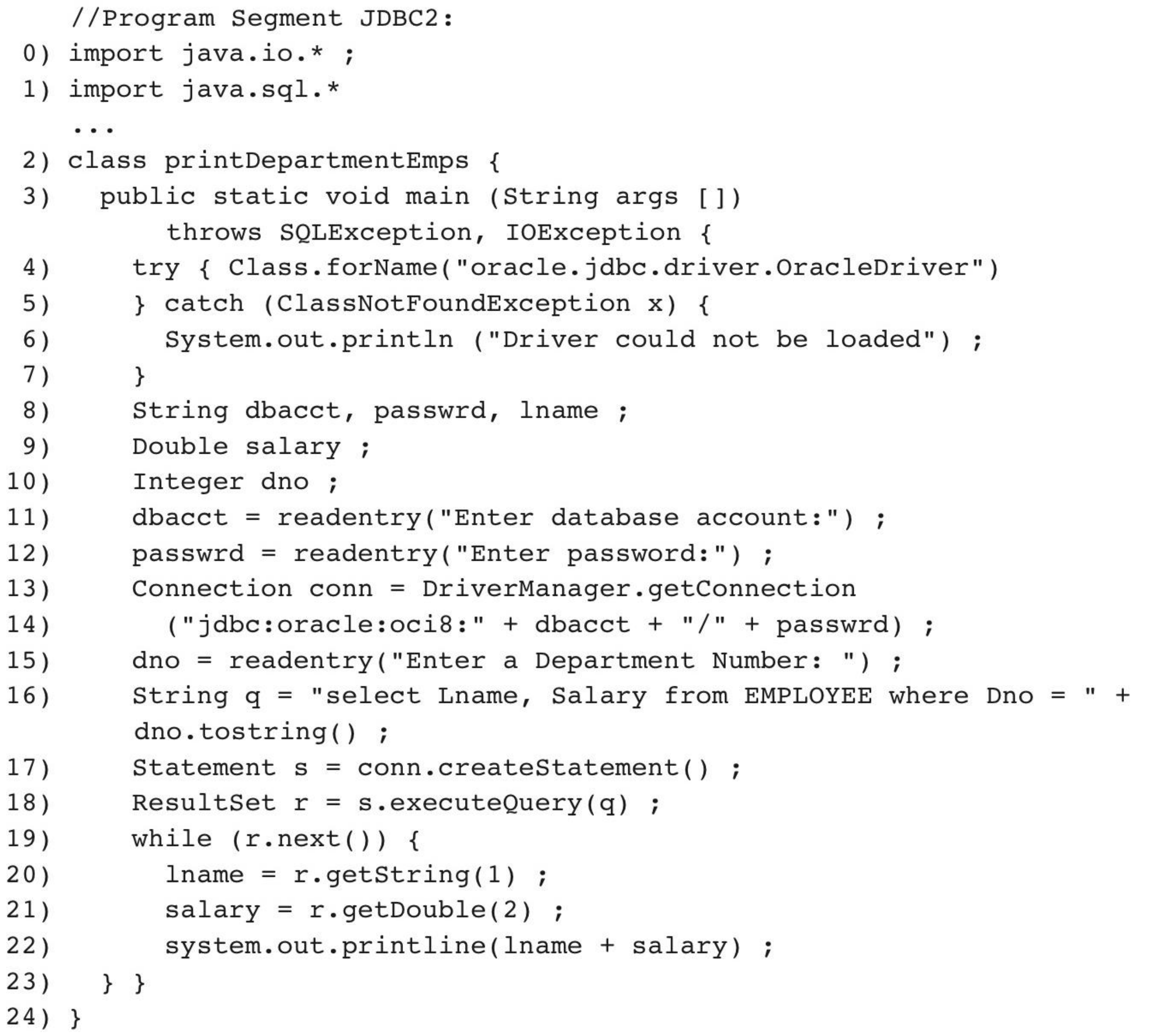
- **`Connection` object**
- **`Statement` object** has two subclasses:
  - `PreparedStatement` and `CallableStatement`
- Question mark (`?`) symbol
  - Represents a statement parameter
  - Determined at runtime
- **`ResultSet` object**
  - Holds results of query

Figure 10.12 Program segment JDBC1, a Java program segment with JDBC.



```
//Program JDBC1:
import java.io.* ;
import java.sql.*
...
class getEmpInfo {
  public static void main (String args []) throws SQLException, IOException {
    try { Class.forName("oracle.jdbc.driver.OracleDriver")
    } catch (ClassNotFoundException x) {
      System.out.println ("Driver could not be loaded") ;
    }
    String dbacct, passwrd, ssn, lname ;
    Double salary ;
    dbacct = readentry("Enter database account:") ;
    passwrd = readentry("Enter password:") ;
    Connection conn = DriverManager.getConnection
      ("jdbc:oracle:oci8:" + dbacct + "/" + passwrd) ;
    String stmt1 = "select Lname, Salary from EMPLOYEE where Ssn = ?" ;
    PreparedStatement p = conn.prepareStatement(stmt1) ;
    ssn = readentry("Enter a Social Security Number: ") ;
    p.clearParameters() ;
    p.setString(1, ssn) ;
    ResultSet r = p.executeQuery() ;
    while (r.next()) {
      lname = r.getString(1) ;
      salary = r.getDouble(2) ;
      system.out.printline(lname + salary) ;
  } }
}
```

Figure 10.13 Program segment JDBC2, a Java program segment that uses JDBC for a query with a **collection of tuples** in its result.



```
//Program Segment JDBC2:
import java.io.* ;
import java.sql.*
...
class printDepartmentEmps {
  public static void main (String args [])
      throws SQLException, IOException {
    try { Class.forName("oracle.jdbc.driver.OracleDriver")
    } catch (ClassNotFoundException x) {
      System.out.println ("Driver could not be loaded") ;
    }
    String dbacct, passwrd, lname ;
    Double salary ;
    Integer dno ;
    dbacct = readentry("Enter database account:") ;
    passwrd = readentry("Enter password:") ;
    Connection conn = DriverManager.getConnection
      ("jdbc:oracle:oci8:" + dbacct + "/" + passwrd) ;
    dno = readentry("Enter a Department Number: ") ;
    String q = "select Lname, Salary from EMPLOYEE where Dno = " +
    dno.tostring() ;
    Statement s = conn.createStatement() ;
    ResultSet r = s.executeQuery(q) ;
    while (r.next()) {
      lname = r.getString(1) ;
      salary = r.getDouble(2) ;
      system.out.printline(lname + salary) ;
  } }
}
```

Database Stored Procedures and SQL/PSM

- **Stored procedures**
  - Program modules stored by the DBMS at the database server
  - Can be functions or procedures
- SQL/PSM (**SQL/Persistent Stored Modules**)
  - Extensions to SQL
  - Include general-purpose programming constructs in SQL

Database Stored Procedures and Functions

- **Persistent stored modules**
  - Stored persistently by the DBMS
- Useful:
  - When database program is needed by several applications
  - To reduce data transfer and communication cost between client and server in certain situations
  - To enhance modeling power provided by views

Database Stored Procedures and Functions (cont'd.)

- Declaring stored procedures:

```
CREATE PROCEDURE <procedure name> (<parameters>)
<local declarations>
<procedure body> ;
```

declaring a function, a return type is necessary, so the declaration form is

```
CREATE FUNCTION <function name> (<parameters>)
RETURNS <return type>
<local declarations>
<function body> ;
```

Database Stored Procedures and Functions (cont'd.)

- Each parameter has parameter type
  - **Parameter type**: one of the SQL data types
  - **Parameter mode**: `IN`, `OUT`, or `INOUT`
- Calling a stored procedure:

```
CALL <procedure or function name>
(<argument list>) ;
```

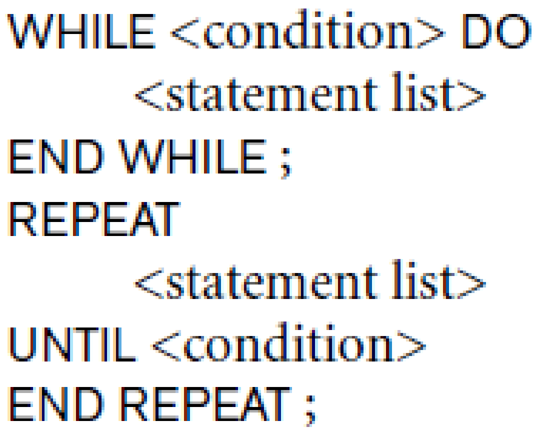
SQL/PSM: Extending SQL for Specifying Persistent Stored Modules

- Conditional branching statement:

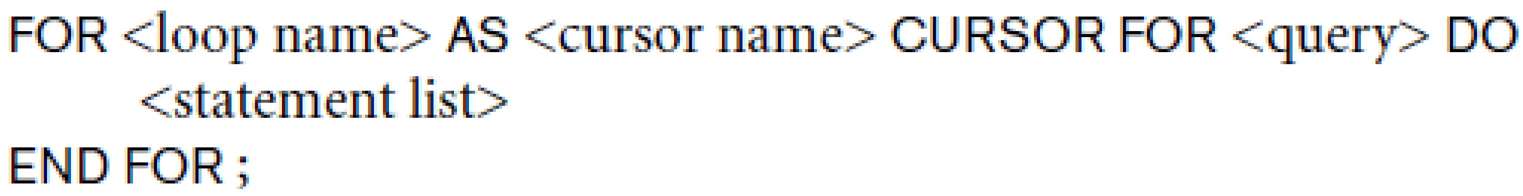
```
IF <condition> THEN <statement list>
ELSEIF <condition> THEN <statement list>
...
ELSEIF <condition> THEN <statement list>
ELSE <statement list>
END IF ;
```

SQL/PSM (cont'd.)

- Constructs for looping

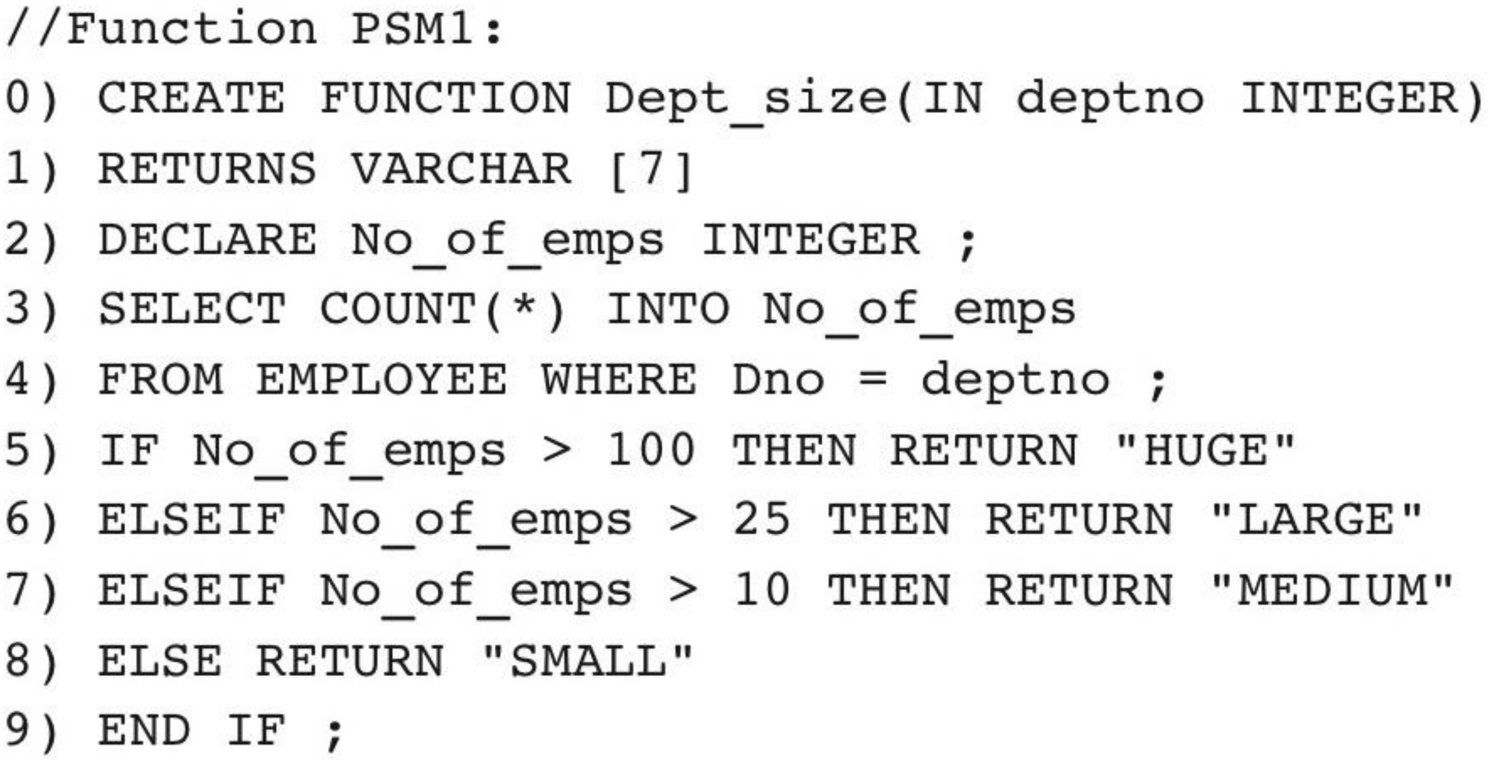


```
WHILE <condition> DO
        <statement list>
END WHILE ;
REPEAT
        <statement list>
UNTIL <condition>
END REPEAT ;
```



```
FOR <loop name> AS <cursor name> CURSOR FOR <query> DO
        <statement list>
END FOR ;
```

Figure 10.14 Declaring a function in SQL/PSM.



```
//Function PSM1:
CREATE FUNCTION Dept_size(IN deptno INTEGER)
RETURNS VARCHAR [7]
DECLARE No_of_emps INTEGER ;
SELECT COUNT(*) INTO No_of_emps
FROM EMPLOYEE WHERE Dno = deptno ;
IF No_of_emps > 100 THEN RETURN "HUGE"
ELSEIF No_of_emps > 25 THEN RETURN "LARGE"
ELSEIF No_of_emps > 10 THEN RETURN "MEDIUM"
ELSE RETURN "SMALL"
END IF ;
```

Comparing the Three Approaches

- Embedded SQL Approach
  - Query text checked for syntax errors and validated against database schema at compile time
  - For complex applications where queries have to be generated at runtime
    - Function call approach more suitable

Comparing the Three Approaches (cont’d.)

- Library of Function Calls Approach
  - More flexibility
  - More complex programming
  - No checking of syntax done at compile time
- Database Programming Language Approach
  - Does not suffer from the impedance mismatch problem
  - Programmers must learn a new language

Summary

- Techniques for database programming
  - Embedded SQL
  - SQLJ
  - Function call libraries
  - SQL/CLI standard
  - JDBC class library
  - Stored procedures
  - SQL/PSM