Informix Product Family
Informix
Version 12.10

IBM Informix Guide to SQL: Tutorial

SC27-4524-01

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Note
Before using this information and the product it supports, read the information in “Notices” on page B-1.

Edition

This edition replaces SC27-4524-00.

Contents

Introduction

In this introduction

This introduction provides an overview of the information in this publication and describes the conventions it uses.

About this publication

This publication shows how to use basic and advanced structured query language (SQL) to access and manipulate the data in your databases. It discusses the data manipulation language (DML) statements as well as triggers and stored procedure language (SPL) routines, which DML statements often use.

This publication is one of a series of publications that discusses the IBM® Informix® implementation of SQL. The *IBM Informix Guide to SQL: Syntax* contains all the syntax descriptions for SQL and SPL. The *IBM Informix Guide to SQL: Reference* provides reference information for aspects of SQL other than the language statements. The *IBM Informix Database Design and Implementation Guide* shows how to use SQL to implement and manage your databases.

Types of users

This publication is written for the following users:
- Database users
- Database administrators
- Database-application programmers

This publication assumes that you have the following background:
- A working knowledge of your computer, your operating system, and the utilities that your operating system provides
- Some experience working with relational databases or exposure to database concepts
- Some experience with computer programming

Software dependencies

This publication is written with the assumption that you are using IBM Informix Version 12.10.

Assumptions about your locale

IBM Informix products can support many languages, cultures, and code sets. All the information related to character set, collation, and representation of numeric data, currency, date, and time is brought together in a single environment, called a Global Language Support (GLS) locale.

The examples in this publication are written with the assumption that you are using the default locale, **en_us.8859-1**. This locale supports U.S. English format conventions for date, time, and currency. In addition, this locale supports the ISO 8859-1 code set, which includes the ASCII code set plus many 8-bit characters such as è, é, and ñ.

If you plan to use nondefault characters in your data or your SQL identifiers, or if you want to conform to the nondefault collation rules of character data, you need to specify the appropriate nondefault locale.

For instructions on how to specify a nondefault locale, additional syntax, and other considerations related to GLS locales, see the *IBM Informix GLS User's Guide*.

Demonstration database

The DB-Access utility, which is provided with the database server products, includes one or more of the following demonstration databases:

- The **stores_demo** database illustrates a relational schema with information about a fictitious wholesale sporting-goods distributor. Many examples in IBM Informix publications are based on the **stores_demo** database.
- The **superstores_demo** database illustrates an object-relational schema. The **superstores_demo** database contains examples of extended data types, type and table inheritance, and user-defined routines.

For information about how to create and populate the demonstration databases, see the *IBM Informix DB-Access User's Guide*. For descriptions of the databases and their contents, see the *IBM Informix Guide to SQL: Reference*.

The scripts that you use to install the demonstration databases reside in the **$INFORMIXDIR/bin** directory on UNIX platforms and in the **%INFORMIXDIR%\bin** directory in Windows environments.

Example code conventions

Examples of SQL code occur throughout this publication. Except as noted, the code is not specific to any single IBM Informix application development tool.

If only SQL statements are listed in the example, they are not delimited by semicolons. For instance, you might see the code in the following example:

```
CONNECT TO stores_demo
...

DELETE FROM customer
   WHERE customer_num = 121
...

COMMIT WORK
DISCONNECT CURRENT
```

To use this SQL code for a specific product, you must apply the syntax rules for that product. For example, if you are using an SQL API, you must use EXEC SQL at the start of each statement and a semicolon (or other appropriate delimiter) at the end of the statement. If you are using DB–Access, you must delimit multiple statements with semicolons.

Tip: Ellipsis points in a code example indicate that more code would be added in a full application, but it is not necessary to show it to describe the concept that is being discussed.

For detailed directions on using SQL statements for a particular application development tool or SQL API, see the documentation for your product.

Additional documentation

Documentation about this release of IBM Informix products is available in various formats.

You can access Informix technical information such as information centers, technotes, white papers, and IBM Redbooks® publications online at http://www.ibm.com/software/data/sw-library/.

Compliance with industry standards

IBM Informix products are compliant with various standards.

IBM Informix SQL-based products are fully compliant with SQL-92 Entry Level (published as ANSI X3.135-1992), which is identical to ISO 9075:1992. In addition, many features of IBM Informix database servers comply with the SQL-92 Intermediate and Full Level and X/Open SQL Common Applications Environment (CAE) standards.

Chapter 1. Database concepts

This chapter describes fundamental database concepts and focuses on the following topics:

- Data models
- Multiple users
- Database terminology
- SQL (Structured Query Language)

Your real use of a database begins with the SELECT statement, which Chapter 2, “Compose SELECT statements,” on page 2-1, describes.

Illustration of a data model

The principal difference between information collected in a database versus information collected in a file is the way the data is organized. A flat file is organized physically; certain items precede or follow other items. But the contents of a database are organized according to a *data model*. A data model is a plan, or map, that defines the units of data and specifies how each unit relates to the others.

For example, a number can appear in either a file or a database. In a file, it is simply a number that occurs at a certain point in the file. A number in a database, however, has a role that the data model assigns to it. The role might be a *price* that is associated with a *product* that was sold as one *item* of an *order* that a *customer* placed. Each of these components, price, product, item, order, and customer, also has a role that the data model specifies. For an illustration of a data model, see the following figure.

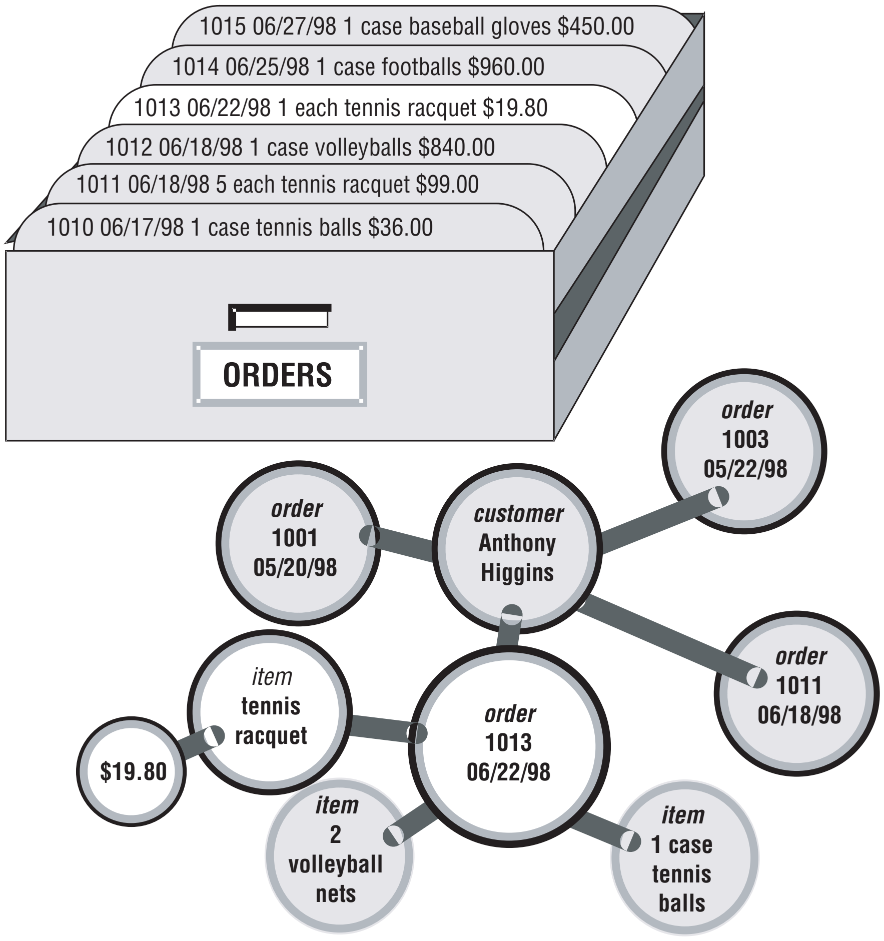

1015 06/27/98 1 case baseball gloves $450.00
1014 06/25/98 1 case footballs $960.00
1013 06/22/98 1 each tennis racquet $19.80
1012 06/18/98 1 case volleyballs $840.00
1011 06/18/98 5 each tennis racquet $99.00
1010 06/17/98 1 case tennis balls $36.00
ORDERS
order 1003 05/22/98
order 1001 05/20/98
customer Anthony Higgins
order 1011 06/18/98
item tennis racquet
order 1013 06/22/98
$19.80
item 2 volleyball nets
item 1 case tennis balls

Figure 1-1. The advantage of using a data model

You design the data model when you create the database. You then insert units of data according to the plan that the model lays out. Some books use the term *schema* instead of *data model*.

Store data

Another difference between a database and a file is that the organization of the database is stored with the database.

A file can have a complex inner structure, but the definition of that structure is not within the file; it is in the programs that create or use the file. For example, a document file that a word-processing program stores might contain detailed structures that describe the format of the document. However, only the word-processing program can decipher the contents of the file, because the structure is defined within the program, not within the file.

A data model, however, is contained in the database it describes. It travels with the database and is available to any program that uses the database. The model defines not only the names of the data items but also their data types, so a program can adapt itself to the database. For example, a program can find out that, in the current database, a price item is a decimal number with eight digits, two to the right of the decimal point; then it can allocate storage for a number of that type. How programs work with databases is the subject of Chapter 8, “SQL programming,” on page 8-1, and Chapter 9, “Modify data through SQL programs,” on page 9-1.

Query data

Another difference between a database and a file is the way you can access them. You can search a file sequentially, looking for particular values at particular physical locations in each line or record. That is, you might ask, “What records have the number 1013 in the first field?” The following figure shows this type of search.

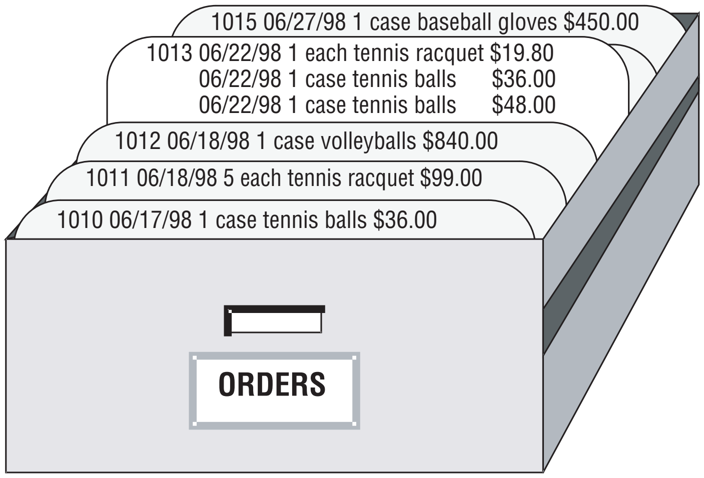
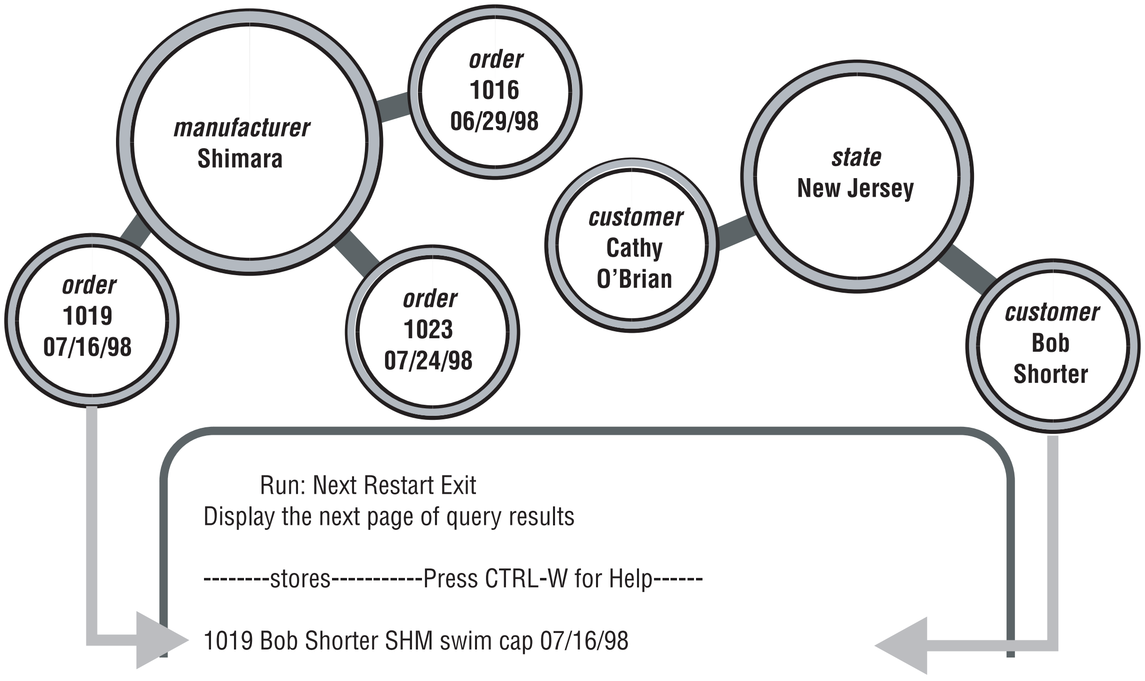

1015 06/27/98 1 case baseball gloves $450.00
1013 06/22/98 1 each tennis racquet $19.80
06/22/98 1 case tennis balls $36.00
06/22/98 1 case tennis balls $48.00
1012 06/18/98 1 case volleyballs $840.00
1011 06/18/98 5 each tennis racquet $99.00
1010 06/17/98 1 case tennis balls $36.00
ORDERS

Figure 1-2. Search a file sequentially

In contrast, when you query a database, you use the terms that the model defines. You can query the database with questions such as, “What *orders* have been placed for *products* made by the Shimara Corporation, by *customers* in New Jersey, with *ship dates* in the third quarter?” The following figure shows this type of query.



```
        Run: Next Restart Exit
Display the next page of query results

--------stores-----------Press CTRL-W for Help------

1019 Bob Shorter SHM swim cap 07/16/98
```

Figure 1-3. Query a database

In other words, when you access data that is stored in a file, you must state your question in terms of the physical layout of the file. When you query a database, you can ignore the arcane details of computer storage and state your query in terms that reflect the real world, at least to the extent that the data model reflects the real world.

Chapter 2, "Compose SELECT statements," on page 2-1, and Chapter 5, "Compose advanced SELECT statements," on page 5-1, discuss the language you use to make queries.

For information about how to build and implement your data model, see the *IBM Informix Database Design and Implementation Guide*.

Modify data

The data model also makes it possible to modify the contents of the database with less chance for error. You can query the database with statements such as, "Find every *stock item* with a *manufacturer* of Presta or Schraeder, and increase its *price* by 13 percent." You state changes in terms that reflect the meaning of the data. You do not have to waste time and effort thinking about details of fields within records in a file, so the chances for error are fewer.

The statements you use to modify stored data are covered in Chapter 6, "Modify data," on page 6-1.

Concurrent use and security

A database can be a common resource for many users. Multiple users can query and modify a database simultaneously. The database server (the program that manages the contents of all databases) ensures that the queries and modifications are done in sequence and without conflict.

Having concurrent users on a database provides great advantages but also introduces new problems of security and privacy. Some databases are private; individuals set them up for their own use. Other databases contain confidential material that must be shared, but only among a restricted group; still other databases provide public access.

Control database use

IBM Informix database software provides the means to control database use. When you design a database, you can perform any of the following functions:

- Keep the database completely private
- Open its entire contents to all users or to selected users
- Restrict the selection of data that some users can view (different selections of data to different groups of users)
- Allow specified users to view certain items, but not modify them
- Allow specified users to add new data, but not modify old data
- Allow specified users to modify all, or specified items of, existing data
- Ensure that added or modified data conforms to the data model

Access-management strategies

IBM Informix supports two access-management systems:

Label-Based Access Control (LBAC)
Label-Based Access Control is an implementation of Mandatory Access Control, which is typically used in databases that store highly sensitive data, such as systems maintained by armed forces or security services. The primary documentation of IBM Informix features relating to LBAC is the *IBM Informix Security Guide*. *IBM Informix Guide to SQL: Syntax* describes how LBAC security objects are created and maintained by the Database Security Administrator (DBSECADM). Only the Database Server Administrator (DBSA) can grant the DBSECADM role.

Discretionary Access Control (DAC)
Discretionary Access Control is a simpler system that involves less overhead than LBAC. Based on access privileges and roles, DAC is enabled in all Informix databases, including those that implement LBAC.

Creating and granting a role:
To support DAC, the database administrator (DBA) can define *roles* and assign them to users to standardize the access privileges of groups of users who need access to the same database objects. When the DBA assigns privileges to that role, every user who is granted role holds those privileges when that role is activated. In order to activate a specific role, a user must issue the SET ROLE statement. The SQL statements used for defining and manipulating roles include: CREATE ROLE, DROP ROLE, GRANT, REVOKE, and SET ROLE.

For more information on the SQL syntax statements for defining and manipulating roles, see the *IBM Informix Guide to SQL: Syntax*.

To create and grant a role:

1. Use the CREATE ROLE statement to create a new role in the current database.
2. Use the GRANT statement to grant access privileges to that role
3. Use the GRANT statement to grant the role to a user or to PUBLIC (all users).
4. The user must issue the SET ROLE statement to enable that role.

Defining and granting privileges for a default role:
The DBA can also define a *default role* to assign to individual users or to the PUBLIC group for a specific database. The role is automatically activated when the user establishes a connection with that database, without the requiring the user to issue a SET ROLE statement. At connection time, each user who holds a default role has whatever access privileges are granted to the user individually, as well as the privileges of the default role.

Only one role that the CREATE ROLE statement defines can be in effect for a given user at a given time. If a user who holds both a default role and one or more other roles uses the SET ROLE statement to make a nondefault role the active role, then any access privileges that were granted only to the default role (and not to the user individually, nor to PUBLIC, nor to the new active role) are no longer in effect for that user. The same user can issue the SET ROLE DEFAULT statement to reactivate the default role, but this action disables any privileges that the user held only through the previously enabled nondefault role.

If different default roles are assigned to the user and to PUBLIC, the default role of the user takes precedence.

To define and grant privileges for a default role:
1. Use the CREATE ROLE statement to create a new role in the current database.
2. Use the GRANT statement to grant privileges to the role.
3. Grant the role to a user and set the role as the default user or PUBLIC role using the one of the following syntax:
   - `GRANT DEFAULT ROLE` *`rolename`* `TO` *`username`*`;`
   - `GRANT DEFAULT ROLE` *`rolename`* `TO PUBLIC;`
4. Use the REVOKE DEFAULT ROLE statement to disassociate a default role from a user.

   Restriction: Only the DBA or the database owner can remove the default role.
5. Use the SET ROLE DEFAULT statement to reset the current role back to the default role.

Built-in roles:
For security reasons, IBM Informix supports certain built-in roles that are in effect for any user who is granted the role and is connected to the database, regardless of whether any other role is also active.

For example, in a database in which the IFX_EXTEND_ROLE configuration parameter is set to ON, only the Database Server Administrator (DBSA) or users to whom the DBSA has granted the built-in EXTEND role can create or drop UDRs that are defined with the EXTERNAL keyword.

Similarly, in a database that implements LBAC security policies, the DBSA can grant the built-in DBSECADM role. The grantee of this role becomes the Database Security Administrator, who can define and implement LBAC security policies and can assign security labels to data and to users.

Unlike user-defined roles, built-in roles cannot be destroyed by the DROP ROLE statement. The SET ROLE statement has no effect on a built-in role, because it is always active while users are connected to a database in which they have been granted the built-in role.

For more information on the External Routine Reference segment or SQL statements for defining and manipulating roles, see the *IBM Informix Guide to SQL: Syntax*.

For more information on the DBSECADM role or SQL statements for defining and manipulating LBAC security objects, see the *IBM Informix Security Guide*.

For more information on default roles, see the *IBM Informix Administrator's Guide*.

For more information about how to grant and limit access to your database, see the *IBM Informix Database Design and Implementation Guide*.

Centralized management

Databases that many people use are valuable and must be protected as important business assets. You create a significant problem when you compile a store of valuable data and simultaneously allow many employees to access it. You handle this problem by protecting data while maintaining performance. The database server lets you centralize these tasks.

Databases must be guarded against loss or damage. The hazards are many: failures in software and hardware, and the risks of fire, flood, and other natural disasters. Losing an important database creates a huge potential for damage. The damage could include not only the expense and difficulty of re-creating the lost data, but also the loss of productive time by the database users as well as the loss of business and goodwill while users cannot work. A plan for regular backups helps avoid or mitigate these potential disasters.

A large database that many people use must be maintained and tuned. Someone must monitor its use of system resources, chart its growth, anticipate bottlenecks, and plan for expansion. Users will report problems in the application programs; someone must diagnose these problems and correct them. If rapid response is important, someone must analyze the performance of the system and find the causes of slow responses.

Important database terms

You should know a number of terms before you begin the next chapter. Depending on the database server you use, a different set of terms can describe the database and the data model that apply.

The relational database model

The databases you create with an IBM Informix database server are *object-relational* databases. In practical terms this means that all data is presented in the form of *tables* with *rows* and *columns* where the following simple corresponding relationships apply.

Relationship	Description
table = entity	A table represents all that the database knows about one subject or kind of thing.
column = attribute	A column represents one feature, characteristic, or fact that is true of the table subject.

row = instance
A row represents one individual instance of the table subject.

Some rules apply about how you choose entities and attributes, but they are important only when you are designing a new database. (For more information about database design, see the *IBM Informix Database Design and Implementation Guide*.) The data model in an existing database is already set. To use the database, you need to know only the names of the tables and columns and how they correspond to the real world.

Tables

A *database* is a collection of information that is grouped into one or more tables. A table is an array of data *items* organized into rows and columns. A demonstration database is distributed with every IBM Informix database server product. A partial table from the demonstration database follows.

stock_num	**manu_code**	**description**	**unit_price**	**unit**	**unit_descr**
. . .	. . .	. . .	. . .	. . .	. . .
1	HRO	baseball gloves	250.00	case	10 gloves/case
1	HSK	baseball gloves	800.00	case	10 gloves/case
1	SMT	baseball gloves	450.00	case	10 gloves/case
2	HRO	baseball	126.00	case	24/case
3	HSK	baseball bat	240.00	case	12/case
4	HSK	football	960.00	case	24/case
4	HRO	football	480.00	case	24/case
5	NRG	tennis racquet	28.00	each	each
. . .	. . .	. . .	. . .	. . .	. . .
313	ANZ	swim cap	60.00	case	12/box

A table represents all that the database administrator (DBA) wants to store about one *entity*, one type of thing that the database describes. The example table, **stock**, represents all that the DBA wants to store about the merchandise that a sporting goods store stocks. Other tables in the demonstration database represent such entities as **customer** and **orders**.

Columns

Each column of a table contains one *attribute*, which is one characteristic, feature, or fact that describes the subject of the table. The **stock** table has columns for the following facts about items of merchandise: stock numbers, manufacturer codes, descriptions, prices, and units of measure.

Rows

Each row of a table is one *instance* of the subject of the table, which is one particular example of that entity. Each row of the **stock** table stands for one item of merchandise that the sporting goods store sells.

Views

A *view* is a virtual table based on a specified SELECT statement. A view is a dynamically controlled picture of the contents in a database and allows a programmer to determine what information the user sees and manipulates.

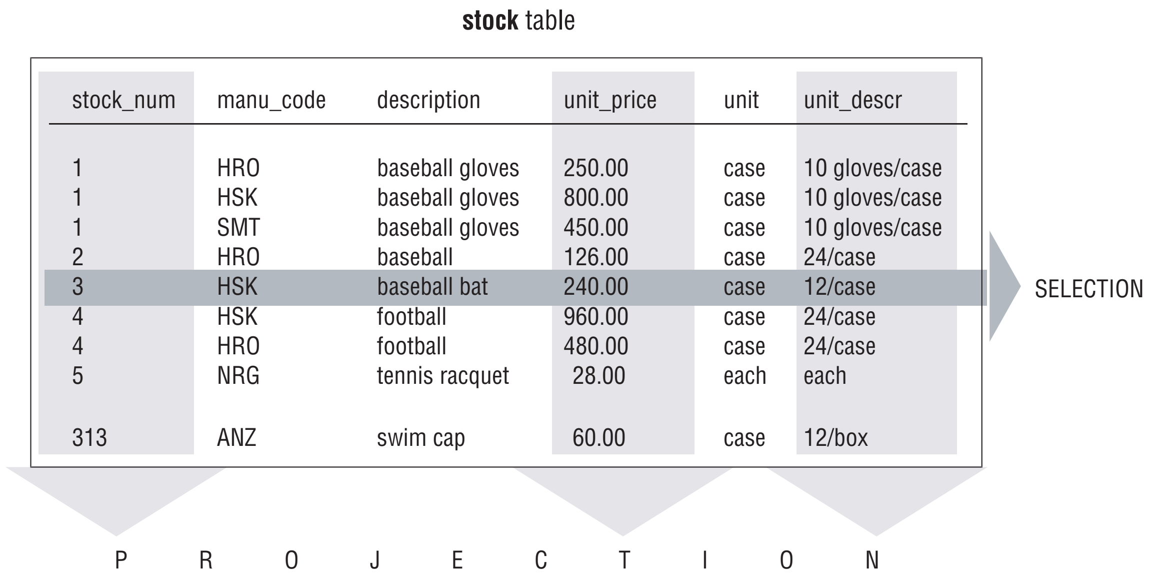
Different users can be given different views of the contents of a database, and their access to those contents can be restricted in several ways.

Sequences

A *sequence* is a database object that generates a sequence of whole numbers within a defined range. The sequence of numbers can run in either ascending or descending order, and is monotonic. For more information about sequences, see the *IBM Informix Guide to SQL: Syntax*.

Operations on tables

Because a database is really a collection of tables, database operations are operations on tables. The object-relational model supports three fundamental operations: selection, projection, and joining. The following figure shows the selection and projection operations. (All three operations are defined in detail, with many examples, in the following topics.)



stock_num	manu_code	description	unit_price	unit	unit_descr
1	HRO	baseball gloves	250.00	case	10 gloves/case
1	HSK	baseball gloves	800.00	case	10 gloves/case
1	SMT	baseball gloves	450.00	case	10 gloves/case
2	HRO	baseball	126.00	case	24/case
3	HSK	baseball bat	240.00	case	12/case
4	HSK	football	960.00	case	24/case
4	HRO	football	480.00	case	24/case
5	NRG	tennis racquet	28.00	each	each
313	ANZ	swim cap	60.00	case	12/box

Figure 1-4. Illustration of selection and projection

When you *select* data from a table, you are choosing certain rows and ignoring others. For example, you can query the **stock** table by asking the database management system to, “Select all rows in which the manufacturer code is HSK and the unit price is between 200.00 and 300.00.”

When you *project* from a table, you are choosing certain columns and ignoring others. For example, you can query the **stock** table by asking the database management system to “project the **stock_num**, **unit_descr**, and **unit_price** columns.”

A table contains information about only one entity; when you want information about multiple entities, you must *join* their tables. You can join tables in many ways. For more information about join operations, refer to Chapter 5, “Compose advanced SELECT statements,” on page 5-1.

The object-relational model

IBM Informix (Informix) allows you to build *object-relational* databases. In addition to supporting alphanumeric data such as character strings, integers, date, and decimal, an object-relational database extends the features of a relational model with the following object-oriented capabilities:

Extensibility
: You can extend the capability of the database server by defining new data types (and the access methods and functions to support them) and user-defined routines (UDRs) that allow you to store and manage images, audio, video, large text documents, and so forth.

  IBM, as well as third-party vendors, packages some data types and access methods into DataBlade® modules or shared class libraries, that you can add on to the database server, if it suits your needs. A DataBlade module enables you to store non-traditional data types such as two-dimensional spatial objects (lines, polygons, ellipses, and circles) and to access them through R-tree indexes. A DataBlade module might also provide new types of access to large text documents, including phrase matching, fuzzy searches, and synonym matching.

  You can also extend the database server on your own by using the features of IBM Informix that enable you to add data types and access methods. For more information, see *IBM Informix User-Defined Routines and Data Types Developer's Guide*.

  You can create UDRs in SPL and the C programming language to encapsulate application logic or to enhance the functionality of the Informix. For more information, see Chapter 11, "Create and use SPL routines," on page 11-1.

Complex types
: You can define new data types that combine one or more existing data types. Complex types enable greater flexibility in organizing data at the level of columns and tables. For example, with complex types, you can define columns that contain collections of values of a single type and columns that contain multiple component types.

Inheritance
: You can define objects (types and tables) that acquire the properties of other objects and add new properties that are specific to the object that you define.

Informix provides object-oriented capabilities beyond those of the relational model but represents all data in the form of tables with rows and columns. Although the object-relational model extends the capabilities of the relational model, you can implement your data model as a traditional relational database if you choose.

Some rules apply about how you choose entities and attributes, but they are important only when you are designing a new database. For more information about object-relational database design, see the *IBM Informix Database Design and Implementation Guide*.

Structured Query Language

Most computer software has not yet reached a point where you can literally ask a database, "What orders have been placed by customers in New Jersey with ship dates in the third quarter?" You must still phrase questions in a restricted syntax that the software can easily parse. You can pose the same question to the demonstration database in the following terms:

```
SELECT * FROM customer, orders
   WHERE customer.customer_num = orders.customer_num
      AND customer.state = 'NJ'
      AND orders.ship_date
      BETWEEN DATE('7/1/98') AND DATE('9/30/98');
```

This question is a sample of Structured Query Language (SQL). It is the language that you use to direct all operations on the database. SQL is composed of statements, each of which begins with one or two keywords that specify a function. The IBM Informix implementation of SQL includes a large number of SQL statements, from ALLOCATE DESCRIPTOR to WHENEVER.

You will use most of the statements only when you set up or tune your database. You will use three or four statements regularly to query or update your database. For details on SQL statements, see the *IBM Informix Guide to SQL: Syntax*.

One statement, SELECT, is in almost constant use. SELECT is the only statement that you can use to retrieve data from the database. It is also the most complicated statement, and the next two chapters of this book explore its many uses.

Standard SQL

The relational model and SQL and were invented and developed at IBM in the early and middle 1970s. Once IBM proved that it was possible to implement practical relational databases and that SQL was a usable language for manipulating them, other implementations of SQL were developed.

For reasons of performance or competitive advantage, or to take advantage of local hardware or software features, each SQL implementation differed in small ways from the others and from the IBM version of the language. To ensure that the differences remained small, a standards committee was formed in the early 1980s.

Committee X3H2, sponsored by the American National Standards Institute (ANSI), issued the SQL1 standard in 1986. This standard defines a core set of SQL features and the syntax of statements such as SELECT.

Informix SQL and ANSI SQL

The IBM Informix implementation of SQL is compatible with standard SQL. IBM Informix SQL is also compatible with the IBM version of the language. However, Informix SQL contains *extensions* to the standard; that is, extra options or features for certain statements, and looser rules for others. Most of the differences occur in the statements that are not in everyday use. For example, few differences occur in the SELECT statement, which accounts for 90 percent of SQL use.

When a difference exists between Informix SQL and ANSI standard, the *IBM Informix Guide to SQL: Syntax* identifies the Informix syntax as an extension to the ANSI standard for SQL.

Interactive SQL

To carry out the examples in this book and to experiment with SQL and database design, you need a program that lets you execute SQL statements interactively. DB-Access is such a program. It helps you compose SQL statements and then passes your SQL statements to the database server for execution and displays the results to you.

General programming

You can write programs that incorporate SQL statements and exchange data with the database server. That is, you can write a program to retrieve data from the database and format it however you choose. You can also write programs that take data from any source in any format, prepare it, and insert it into the database.

You can also write programs called stored routines to work with database data and objects. The stored routines that you write are stored directly in a database in tables. You can then execute a stored routine from DB-Access or an SQL Application Programming Interface (API) such as IBM Informix ESQL/C.

Chapter 8, “SQL programming,” on page 8-1, and Chapter 9, “Modify data through SQL programs,” on page 9-1, present an overview of how SQL is used in programs.

ANSI-compliant databases

Use the MODE ANSI keywords when you create a database to designate it as ANSI compliant. Within such a database, certain characteristics of the ANSI/ISO standard apply. For example, all actions that modify data take place within a transaction automatically, which means that the changes are made in their entirety or not at all. Differences in the behavior of ANSI-compliant databases are noted, where appropriate, in the statement descriptions in the *IBM Informix Guide to SQL: Syntax*. For a detailed discussion of ANSI-compliant databases, see the *IBM Informix Database Design and Implementation Guide*.

Global Language Support

IBM Informix database server products provide the Global Language Support (GLS) feature. In addition to U.S. ASCII English, GLS allows you to work in other locales and use non-ASCII characters in SQL data and identifiers. You can use the GLS feature to conform to the customs of a specific locale. The locale files contain culture-specific information, such as money and date formats and collation orders. For more GLS information, see the *IBM Informix GLS User's Guide*.

Summary

A database contains a collection of related information but differs in a fundamental way from other methods of storing data. The database contains not only the data, but also a data model that defines each data item and specifies its meaning with respect to the other items and to the real world.

More than one user can access and modify a database at the same time. Each user has a different view of the contents of a database, and each user's access to those contents can be restricted in several ways.

A relational database consists of tables, and the tables consist of columns and rows. The relational model supports three fundamental operations on tables: selections, projections, and joins.

An object-relational database extends the features of a relational database. You can define new data types to store and manage audio, video, large text documents, and so forth. You can define complex types that combine one or more existing data types to provide greater flexibility in how you organize your data in columns and tables. You can define types and tables that inherit the properties of other database objects and add new properties that are specific to the object that you define.

To manipulate and query a database, use SQL. IBM pioneered SQL and ANSI standardized it. IBM Informix extensions that you can use to your advantage add to the ANSI-defined language. IBM Informix tools also make it possible to maintain strict compliance with ANSI standards.

Two layers of software mediate all your work with databases. The bottom layer is always a database server that executes SQL statements and manages the data on disk and in computer memory. The top layer is one of many applications, some from IBM and some written by you, by other vendors, or your colleagues. Middleware is the component that links the database server to the application, and is provided by the database vendor to bind the client programs with the database server. IBM Informix Stored Procedure Language (SPL) is an example of such a tool.

Chapter 2. Compose SELECT statements

The SELECT statement is the most important and the most complex SQL statement. You can use it and the SQL statements INSERT, UPDATE, and DELETE to manipulate data. You can use the SELECT statement to retrieve data from a database, as part of an INSERT statement to produce new rows, or as part of an UPDATE statement to update information.

The SELECT statement is the primary way to query information in a database. It is your key to retrieving data in a program, report, form, or spreadsheet. You can use SELECT statements with a query tool such as DB-Access or embed SELECT statements in an application.

This chapter introduces the basic methods for using the SELECT statement to query and retrieve data from relational databases. It discusses how to tailor your statements to select columns or rows of information from one or more tables, how to include expressions and functions in SELECT statements, and how to create various join conditions between database tables. The syntax and usage for the SELECT statement are described in detail in the *IBM Informix Guide to SQL: Syntax*.

Most examples in this publication come from the tables in the **stores_demo** database, which is included with the software for your IBM Informix SQL API or database utility. In the interest of brevity, the examples show only part of the data that is retrieved for each SELECT statement. For information on the structure and contents of the demonstration database, see the *IBM Informix Guide to SQL: Reference*. For emphasis, keywords are shown in uppercase letters in the examples, although SQL is not case sensitive.

SELECT statement overview

The SELECT statement is constructed of clauses that let you look at data in a relational database. These clauses let you select columns and rows from one or more database tables or views, specify one or more conditions, order and summarize the data, and put the selected data in a temporary table.

This chapter shows how to use five SELECT statement clauses. If you include all five of these clauses, they must appear in the SELECT statement in the following order:

1. Projection clause
2. FROM clause
3. WHERE clause
4. ORDER BY clause
5. INTO TEMP clause

Only the Projection clause and FROM clause are required. These two clauses form the basis for every database query, because they specify the column values to be retrieved, and the tables that contain those columns. Use one or more of the other clauses from the following list:

- Add a WHERE clause to select specific rows or create a *join* condition.
- Add an ORDER BY clause to change the order in which data is produced.
- Add an INTO TEMP clause to save the results as a table for further queries.

Two additional SELECT statement clauses, GROUP BY and HAVING, let you perform more complex data retrieval. They are introduced in Chapter 5, "Compose advanced SELECT statements," on page 5-1. Another clause, INTO, specifies the program or host variable to receive data from a SELECT statement in an application program. Complete syntax and rules for using the SELECT statement are in the *IBM Informix Guide to SQL: Syntax*.

Output from SELECT statements

Although the syntax remains the same across all IBM Informix products, the formatting and display of the resulting output depends on the application. The examples in this chapter and in Chapter 5, "Compose advanced SELECT statements," on page 5-1 display the SELECT statements and their output as they appear when you use the interactive Query-language option in DB-Access.

Output from large object data types

When you issue a SELECT statement that includes a large object, DB-Access displays the results as follows:

- For a TEXT column or CLOB column, the contents of the column are displayed.
- For a BYTE column, the words `<BYTE value>` are displayed instead of the actual value.
- For a BLOB column, the words `<SBlob data>` are displayed instead of the actual value.

Output from user-defined data types

DB-Access uses special conventions to display output from columns that contain complex or opaque data types. For more information about these data types, refer to the *IBM Informix Database Design and Implementation Guide*.

Output in non-default code sets

You can issue a SELECT statement that queries NCHAR columns instead of CHAR columns or NVARCHAR columns instead of VARCHAR columns.

For more Global Language Support (GLS) information, see the *IBM Informix GLS User's Guide*. For additional information on using NCHAR and NVARCHAR data types with non-default code sets, see the *IBM Informix Database Design and Implementation Guide* and the *IBM Informix Guide to SQL: Reference*.

Some basic concepts

The SELECT statement, unlike INSERT, UPDATE, and DELETE statements, does not modify the data in a database. It simply queries the data. Whereas only one user at a time can modify data, multiple users can query or select the data concurrently. For more information about statements that modify data, see Chapter 6, "Modify data," on page 6-1. The syntax descriptions of the INSERT, UPDATE, and DELETE statements appear in the *IBM Informix Guide to SQL: Syntax*.

In a relational database, a *column* is a data element that contains a particular type of information that occurs in every row in the table. A *row* is a group of related items of information about a single entity across all columns in a database table.

You can select columns and rows from a database table; from a *system catalog table*, a special table that contains information on the database; or from a *view*, a virtual table created to contain a customized set of data. System catalog tables are described in the *IBM Informix Guide to SQL: Reference*. Views are discussed in the *IBM Informix Database Design and Implementation Guide*.

Privileges

Before you make a query against data, make sure you have the Connect privilege on the database and the Select privilege on the table. These privileges are normally granted to all users. Database access privileges are discussed in the *IBM Informix Database Design and Implementation Guide* and in the GRANT and REVOKE statements in the *IBM Informix Guide to SQL: Syntax*.

Relational operations

A *relational operation* involves manipulating one or more tables, or *relations*, to result in another table. The three kinds of relational operations are selection, projection, and join. This chapter includes examples of selection, projection, and simple joining.

Selection and projection

In relational terminology, *selection* is defined as taking the horizontal subset of rows of a single table that satisfies a particular condition. This kind of SELECT statement returns some of the rows and all the columns in a table. Selection is implemented through the WHERE clause of a SELECT statement, as the following figure shows.

```
SELECT * FROM customer WHERE state = 'NJ';
```

Figure 2-1. Query

The result contains the same number of columns as the **customer** table, but only a subset of its rows. In this example, DB-Access displays the data from each column on a separate line.

```
customer_num  119
fname         Bob
lname         Shorter
company       The Triathletes Club
address1      2405 Kings Highway
address2
city          Cherry Hill
state         NJ
zipcode       08002
phone         609-663-6079

customer_num  122
fname         Cathy
lname         O'Brian
company       The Sporting Life
address1      543d Nassau
address2
city          Princeton
state         NJ
zipcode       08540
phone         609-342-0054
```

Figure 2-2. Query result

In relational terminology, *projection* is defined as taking a vertical subset from the columns of a single table that retains the unique rows. This kind of SELECT statement returns some of the columns and all the rows in a table.

Projection is implemented through the *projection list* in the Projection clause of a SELECT statement, as the following figure shows.

```
SELECT city, state, zipcode FROM customer;
```

Figure 2-3. Query

The result contains the same number of rows as the **customer** table, but it *projects* only a subset of the columns in the table. Because only a small amount of data is selected from each row, DB-Access is able to display all of the data from the row on one line.

```
city            state zipcode

Sunnyvale       CA    94086
San Francisco   CA    94117
Palo Alto       CA    94303
Redwood City    CA    94026
Los Altos       CA    94022
Mountain View   CA    94063
Palo Alto       CA    94304
Redwood City    CA    94063
Sunnyvale       CA    94086
Redwood City    CA    94062
Sunnyvale       CA    94085
⋮
Oakland         CA    94609
Cherry Hill     NJ    08002
Phoenix         AZ    85016
Wilmington      DE    19898
Princeton       NJ    08540
Jacksonville    FL    32256
Bartlesville    OK    74006
```

Figure 2-4. Query result

The most common kind of SELECT statement uses both selection and projection. A query of this kind returns some of the rows and some of the columns in a table, as the following figure shows.

```
SELECT UNIQUE city, state, zipcode
   FROM customer
   WHERE state = 'NJ';
```

Figure 2-5. Query

Figure 2-6 contains a subset of the rows and a subset of the columns in the **customer** table.

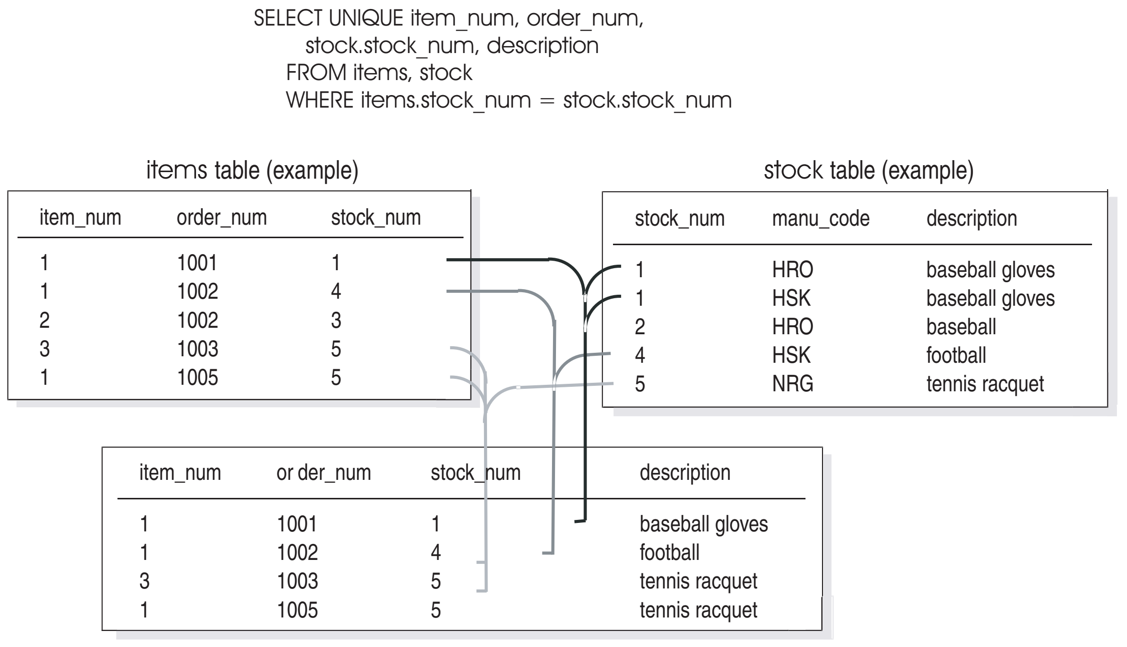
```
city            state zipcode

Cherry Hill     NJ    08002
Princeton       NJ    08540
```

Figure 2-6. Query result

Join

A join occurs when two or more tables are connected by one or more columns in common, which creates a new table of results. The following figure shows a query that uses a subset of the **items** and **stock** tables to illustrate the concept of a join.



```
SELECT UNIQUE item_num, order_num,
      stock.stock_num, description
   FROM items, stock
   WHERE items.stock_num = stock.stock_num
```

items table (example)

item_num	order_num	stock_num
1	1001	1
1	1002	4
2	1002	3
3	1003	5
1	1005	5

stock table (example)

stock_num	manu_code	description
1	HRO	baseball gloves
1	HSK	baseball gloves
2	HRO	baseball
4	HSK	football
5	NRG	tennis racquet

item_num	or der_num	stock_num	description
1	1001	1	baseball gloves
1	1002	4	football
3	1003	5	tennis racquet
1	1005	5	tennis racquet

Figure 2-7. A join between two tables

The following query joins the **customer** and **state** tables.

```
SELECT UNIQUE city, state, zipcode, sname
   FROM customer, state
   WHERE customer.state = state.code;
```

Figure 2-8. Query

The result consists of specified rows and columns from both the **customer** and **state** tables.

```
city            state zipcode sname

Bartlesville    OK    74006   Oklahoma
Blue Island     NY    60406   New York
Brighton        MA    02135   Massachusetts
Cherry Hill     NJ    08002   New Jersey
Denver          CO    80219   Colorado
Jacksonville    FL    32256   Florida
Los Altos       CA    94022   California
Menlo Park      CA    94025   California
Mountain View   CA    94040   California
Mountain View   CA    94063   California
Oakland         CA    94609   California
Palo Alto       CA    94303   California
Palo Alto       CA    94304   California
Phoenix         AZ    85008   Arizona
Phoenix         AZ    85016   Arizona
Princeton       NJ    08540   New Jersey
Redwood City    CA    94026   California
Redwood City    CA    94062   California
Redwood City    CA    94063   California
San Francisco   CA    94117   California
Sunnyvale       CA    94085   California
Sunnyvale       CA    94086   California
Wilmington      DE    19898   Delaware
```

Figure 2-9. Query result

Single-table SELECT statements

You can query a single table in a database in many ways. You can tailor a SELECT statement to perform the following actions:

- Retrieve all or specific columns
- Retrieve all or specific rows
- Perform computations or other functions on the retrieved data
- Order the data in various ways

The most basic SELECT statement contains only the two required clauses, the Projection clause and FROM.

The asterisk symbol (*)

The following query specifies all the columns in the **manufact** table in a projection list. An *explicit* projection list is a list of the column names or expressions that you want to project from a table.

```
SELECT manu_code, manu_name, lead_time FROM manufact;
```

Figure 2-10. Query

The following query uses the *wildcard* asterisk symbol (*) as shorthand in the projection list to represent the names of all the columns in the table. You can use the asterisk symbol (*) when you want all the columns in their defined order. An *implicit* select list uses the asterisk symbol.

```
SELECT * FROM manufact;
```

Figure 2-11. Query

Because the **manufact** table has only three columns, Figure 2-10 on page 2-6 and Figure 2-11 are equivalent and display the same results; that is, a list of every column and row in the **manufact** table. The following figure shows the results.

```
manu_code manu_name       lead_time

 SMT      Smith               3
 ANZ      Anza                5
 NRG      Norge               7
 HSK      Husky               5
 HRO      Hero                4
 SHM      Shimara            30
 KAR      Karsten            21
 NKL      Nikolus             8
 PRC      ProCycle            9
```

Figure 2-12. Query result

Reorder the columns

The following query shows how you can change the order in which the columns are listed by changing their order in your projection list.

```
SELECT manu_name, manu_code, lead_time FROM manufact;
```

Figure 2-13. Query

The query result includes the same columns as the previous query result, but because the columns are specified in a different order, the display is also different.

```
manu_name       manu_code lead_time

 Smith           SMT          3
 Anza            ANZ          5
 Norge           NRG          7
 Husky           HSK          5
 Hero            HRO          4
 Shimara         SHM         30
 Karsten         KAR         21
 Nikolus         NKL          8
 ProCycle        PRC          9
```

Figure 2-14. Query result

The ORDER BY clause to sort the rows

The results from a query are not arranged in any particular order. For example, Figure 2-4 on page 2-4 and Figure 2-14 appear to be in random order.

You can add an ORDER BY clause to your SELECT statement to direct the system to sort the data in a specific order. The ORDER BY clause is a list of column names from any remote or local table or view. Any expressions that are allowed in the projection list are allowed in the ORDER BY list. If a column used in the ORDER BY list has a Select trigger on it, the trigger will not be activated.

The following query returns every row from the **manu_code**, **manu_name**, and **lead_time** columns in the **manufact** table, sorted according to **lead_time**.

```
SELECT manu_code, manu_name, lead_time
   FROM manufact
   ORDER BY lead_time;
```

Figure 2-15. Query

For IBM Informix, you do not need to include the columns that you want to use in the ORDER BY clause in the projection list. That is, you can sort the data according to a column that is not retrieved in the projection list. The following query returns every row from the **manu_code** and **manu_name** columns in the **manufact** table, sorted according to **lead_time**. The **lead_time** column is in the ORDER BY clause although it is not included in the projection list.

```
SELECT manu_code, manu_name
   FROM manufact
   ORDER BY lead_time;
```

Figure 2-16. Query

Ascending order

The retrieved data is sorted and displayed, by default, in *ascending* order. In the ASCII character set, ascending order is uppercase `A` to lowercase `z` for character data types, and lowest to highest value for numeric data types. DATE and DATETIME data is sorted from earliest to latest, and INTERVAL data is ordered from shortest to longest span of time.

Descending order

Descending order is the opposite of ascending order, from lowercase `z` to uppercase `A` for character types, and from highest to lowest for numeric data types. DATE and DATETIME data is sorted from latest to earliest, and INTERVAL data is ordered from longest to shortest span of time. The following query shows an example of descending order.

```
SELECT * FROM manufact ORDER BY lead_time DESC;
```

Figure 2-17. Query

The keyword DESC following a column name causes the retrieved data to be sorted in descending order, as the result shows.

```
manu_code manu_name       lead_time

 SHM       Shimara           30
 KAR       Karsten           21
 PRC       ProCycle           9
 NKL       Nikolus            8
 NRG       Norge              7
 HSK       Husky              5
 ANZ       Anza               5
 HRO       Hero               4
 SMT       Smith              3
```

Figure 2-18. Query result

You can specify any column of a built-in data type (except TEXT, BYTE, BLOB, or CLOB) in the ORDER BY clause, and the database server sorts the data based on the values in that column.

Sorting on multiple columns

You can also ORDER BY two or more columns, which creates a *nested sort*. The default is still ascending, and the column that is listed first in the ORDER BY clause takes precedence.

The following query and Figure 2-21 and the corresponding query results show nested sorts. To modify the order in which selected data is displayed, change the order of the two columns that are named in the ORDER BY clause.

```
SELECT stock_num, manu_code, description, unit_price
   FROM stock
   ORDER BY manu_code, unit_price;
```

Figure 2-19. Query

In the query result, the **manu_code** column data appears in alphabetical order and, within each set of rows with the same **manu_code** (for example, ANZ, HRO), the **unit_price** is listed in ascending order.

```
stock_num manu_code description     unit_price

        5 ANZ       tennis racquet      $19.80
        9 ANZ       volleyball net      $20.00
        6 ANZ       tennis ball         $48.00
      313 ANZ       swim cap            $60.00
      201 ANZ       golf shoes          $75.00
      310 ANZ       kick board          $84.00
⋮
      111 SHM       10-spd, assmbld    $499.99
      112 SHM       12-spd, assmbld    $549.00
      113 SHM       18-spd, assmbld    $685.90
        5 SMT       tennis racquet      $25.00
        6 SMT       tennis ball         $36.00
        1 SMT       baseball gloves    $450.00
```

Figure 2-20. Query result

The following query shows the reverse order of the columns in the ORDER BY clause.

```
SELECT stock_num, manu_code, description, unit_price
   FROM stock
   ORDER BY unit_price, manu_code;
```

Figure 2-21. Query

In the query result, the data appears in ascending order of **unit_price** and, where two or more rows have the same **unit_price** (for example, $20.00, $48.00, $312.00), the **manu_code** is in alphabetical order.

```
stock_num manu_code description     unit_price

      302 HRO       ice pack             $4.50
      302 KAR       ice pack             $5.00
        5 ANZ       tennis racquet      $19.80
        9 ANZ       volleyball net      $20.00
      103 PRC       frnt derailleur     $20.00
⋮
      108 SHM       crankset            $45.00
        6 ANZ       tennis ball         $48.00
      305 HRO       first-aid kit       $48.00
      303 PRC       socks               $48.00
      311 SHM       water gloves        $48.00
⋮
      113 SHM       18-spd, assmbld    $685.90
        1 HSK       baseball gloves    $800.00
        8 ANZ       volleyball         $840.00
        4 HSK       football           $960.00
```

Figure 2-22. Query result

The order of the columns in the ORDER BY clause is important, and so is the position of the DESC keyword. Although the statements in the following query contain the same components in the ORDER BY clause, each produces a different result (not shown).

```
SELECT * FROM stock ORDER BY manu_code, unit_price DESC;

SELECT * FROM stock ORDER BY unit_price, manu_code DESC;

SELECT * FROM stock ORDER BY manu_code DESC, unit_price;

SELECT * FROM stock ORDER BY unit_price DESC, manu_code;
```

Figure 2-23. Query

Select specific columns

The previous section shows how to select and order all data from a table. However, often all you want to see is the data in one or more specific columns. Again, the formula is to use the Projection and FROM clauses, specify the columns and table, and perhaps order the data in ascending or descending order with an ORDER BY clause.

If you want to find all the customer numbers in the **orders** table, use a statement such as the one in the following query.

```
SELECT customer_num FROM orders;
```

Figure 2-24. Query

The result shows how the statement simply selects all data in the **customer_num** column in the **orders** table and lists the customer numbers on all the orders, including duplicates.

```
customer_num

        104
        101
        104
⋮
        122
        123
        124
        126
        127
```

Figure 2-25. Query result

The output includes several duplicates because some customers have placed more than one order. Sometimes you want to see duplicate rows in a projection. At other times, you want to see only the distinct values, not how often each value appears.

To suppress duplicate rows, you can include the keyword DISTINCT or its synonym UNIQUE at the start of the select list, once in each level of a query, as the following query shows.

```
SELECT DISTINCT customer_num FROM orders;

SELECT UNIQUE customer_num FROM orders;
```

Figure 2-26. Query

To produce a more readable list, Figure 2-26 limits the display to show each customer number in the **orders** table only once, as the result shows.

```
customer_num

        101
        104
        106
        110
        111
        112
        115
        116
        117
        119
        120
        121
        122
        123
        124
        126
        127
```

Figure 2-27. Query result

Suppose you are handling a customer call, and you want to locate purchase order number DM354331. To list all the purchase order numbers in the **orders** table, use a statement such as the following query shows.

```
SELECT po_num FROM orders;
```

Figure 2-28. Query

The result shows how the statement retrieves data in the **po_num** column in the **orders** table.

```
po_num

B77836
9270
B77890
8006
2865
Q13557
278693
⋮
```

Figure 2-29. Query result

However, the list is not in a useful order. You can add an ORDER BY clause to sort the column data in ascending order and make it easier to find that particular **po_num**, as shown in the following query.

```
SELECT po_num FROM orders ORDER BY po_num;
```

Figure 2-30. Query

```
po_num

278693
278701
2865
429Q
4745
8006
8052
9270
B77836
B77890
⋮
```

Figure 2-31. Query result

To select multiple columns from a table, list them in the projection list in the Projection clause. The following query shows that the order in which the columns are selected is the order in which they are retrieved, from left to right.

```
SELECT ship_date, order_date, customer_num,
       order_num, po_num
   FROM orders
   ORDER BY order_date, ship_date;
```

Figure 2-32. Query

As “Sorting on multiple columns” on page 2-9 shows, you can use the ORDER BY clause to sort the data in ascending or descending order and perform nested sorts. The result shows ascending order.

```
ship_date  order_date customer_num   order_num po_num

06/01/1998 05/20/1998          104        1001 B77836
05/26/1998 05/21/1998          101        1002 9270
05/23/1998 05/22/1998          104        1003 B77890
05/30/1998 05/22/1998          106        1004 8006
06/09/1998 05/24/1998          116        1005 2865
           05/30/1998          112        1006 Q13557
06/05/1998 05/31/1998          117        1007 278693
07/06/1998 06/07/1998          110        1008 LZ230
06/21/1998 06/14/1998          111        1009 4745
06/29/1998 06/17/1998          115        1010 429Q
06/29/1998 06/18/1998          117        1012 278701
07/03/1998 06/18/1998          104        1011 B77897
07/10/1998 06/22/1998          104        1013 B77930
07/03/1998 06/25/1998          106        1014 8052
07/16/1998 06/27/1998          110        1015 MA003
07/12/1998 06/29/1998          119        1016 PC6782
07/13/1998 07/09/1998          120        1017 DM354331
07/13/1998 07/10/1998          121        1018 S22942
07/16/1998 07/11/1998          122        1019 Z55709
07/16/1998 07/11/1998          123        1020 W2286
07/25/1998 07/23/1998          124        1021 C3288
07/30/1998 07/24/1998          126        1022 W9925
07/30/1998 07/24/1998          127        1023 KF2961
```

Figure 2-33. Query result

When you use SELECT and ORDER BY on several columns in a table, you might find it helpful to use integers to refer to the position of the columns in the ORDER BY clause. When an integer is an element in the ORDER BY list, the database server treats it as the position in the projection list. For example, using 3 in the ORDER BY list (ORDER BY 3) refers to the third item in the projection list. The statements in the following query retrieve and display the same data, as Figure 2-35 on page 2-14 shows.

```
SELECT customer_num, order_num, po_num, order_date
   FROM orders
   ORDER BY 4, 1;

SELECT customer_num, order_num, po_num, order_date
   FROM orders
   ORDER BY order_date, customer_num;
```

Figure 2-34. Query

```
customer_num   order_num po_num     order_date

         104        1001 B77836     05/20/1998
         101        1002 9270       05/21/1998
         104        1003 B77890     05/22/1998
         106        1004 8006       05/22/1998
         116        1005 2865       05/24/1998
         112        1006 Q13557     05/30/1998
         117        1007 278693     05/31/1998
         110        1008 LZ230      06/07/1998
         111        1009 4745       06/14/1998
         115        1010 429Q       06/17/1998
         104        1011 B77897     06/18/1998
         117        1012 278701     06/18/1998
         104        1013 B77930     06/22/1998
         106        1014 8052       06/25/1998
         110        1015 MA003      06/27/1998
         119        1016 PC6782     06/29/1998
         120        1017 DM354331   07/09/1998
         121        1018 S22942     07/10/1998
         122        1019 Z55709     07/11/1998
         123        1020 W2286      07/11/1998
         124        1021 C3288      07/23/1998
         126        1022 W9925      07/24/1998
         127        1023 KF2961     07/24/1998
```

Figure 2-35. Query result

You can include the DESC keyword in the ORDER BY clause when you assign integers to column names, as the following query shows.

```
SELECT customer_num, order_num, po_num, order_date
   FROM orders
   ORDER BY 4 DESC, 1;
```

Figure 2-36. Query

In this case, data is first sorted in descending order by **order_date** and in ascending order by **customer_num**.

Select substrings

To select part of the value of a character column, include a *substring* in the projection list. Suppose your marketing department is planning a mailing to your customers and wants their geographical distribution based on zip codes. You could write a query similar to the following.

```
SELECT zipcode[1,3], customer_num
   FROM customer
   ORDER BY zipcode;
```

Figure 2-37. Query

The query uses a substring to select the first three characters of the **zipcode** column (which identify the state) and the full **customer_num**, and lists them in ascending order by zip code, as the result shows.

```
zipcode customer_num

021             125
080             119
085             122
198             121
322             123
⋮
943             103
943             107
946             118
```

Figure 2-38. Query result

ORDER BY and non-English data

By default, IBM Informix database servers use the U.S. English language environment, called a locale, for database data. The U.S. English locale specifies data sorted in code-set order. This default locale uses the ISO 8859-1 code set.

If your database contains non-English data, you should store non-English data in NCHAR (or NVARCHAR) columns to obtain results sorted by the language. The ORDER BY clause should return data in the order appropriate to that language. The following query uses a SELECT statement with an ORDER BY clause to search the table, **abonnés**, and to order the selected information by the data in the **nom** column.

```
SELECT numéro,nom,prénom
   FROM abonnés
   ORDER BY nom;
```

Figure 2-39. Query

The collation order for the results of this query can vary, depending on the following system variations:

- Whether the **nom** column is CHAR or NCHAR data type. The database server sorts data in CHAR columns by the order the characters appear in the code set. The database server sorts data in NCHAR columns by the order the characters are listed in the collation portion of the locale.
- Whether the database server is using the correct non-English locale when it accesses the database. To use a non-English locale, you must set the **CLIENT_LOCALE** and **DB_LOCALE** environment variables to the appropriate locale name.

For the query to return expected results, the **nom** column should be NCHAR data type in a database that uses a French locale. Other operations, such as less than, greater than, or equal to, are also affected by the user-specified locale. For more information on non-English data and locales, see the *IBM Informix GLS User's Guide*.

The following result and Figure 2-41 on page 2-16 show two sample sets of output.

```
numéro      nom               prénom

13612       Azevedo           Edouardo Freire
13606       Dupré             Michèle Françoise
13607       Hammer            Gerhard
13602       Hämmer            le Greta
13604       LaForêt           Jean-Noël
13610       LeMaître          Héloïse
13613       Llanero           Gloria Dolores
13603       Montaña           José Antonio
13611       Oatfield          Emily
13609       Tiramisù          Paolo Alfredo
13600       da Sousa          João Lourenço Antunes
13615       di Girolamo       Giuseppe
13601       Ålesund           Sverre
13608       Étaix             Émile
13605       Ötker             Hans-Jürgen
13614       Øverst            Per-Anders
```

Figure 2-40. Query result

The following query result follows the ISO 8859-1 code-set order, which ranks uppercase letters before lowercase letters and moves names that contain an accented character (Ålesund, Étaix, Ötker, and Øverst) to the end of the list.

```
numéro        nom            prénom

13601         Ålesund        Sverre
13612         Azevedo        Edouardo Freire
13600         da Sousa       João Lourenço Antunes
13615         di Girolamo    Giuseppe
13606         Dupré          Michèle Françoise
13608         Étaix          Émile
13607         Hammer         Gerhard
13602         Hämmer         le Greta
13604         LaForêt        Jean-Noël
13610         LeMaître       Héloïse
13613         Llanero        Gloria Dolores
13603         Montaña        José Antonio
13611         Oatfield       Emily
13605         Ötker          Hans-Jürgen
13614         Øverst         Per-Anders
13609         Tiramisù       Paolo Alfredo
```

Figure 2-41. Query result

The result shows that when the appropriate locale file is referenced by the database server, names including non-English characters (Ålesund, Étaix, Ötker, and Øverst) are collated differently than they are in the ISO 8859-1 code set. They are sorted correctly for the locale. It does not distinguish between uppercase and lowercase letters.

The WHERE clause

The set of rows that a SELECT statement returns is its *active set*. A *singleton* SELECT statement returns a single row. You can add a WHERE clause to a SELECT statement if you want to see only specific rows. For example, you use a

WHERE clause to restrict the rows that the database server returns to only the orders that a particular customer placed or the calls that a particular customer service representative entered.

You can use the WHERE clause to set up a comparison condition or a join condition. This section demonstrates only the first use. Join conditions are described in a later section and in the next chapter.

Create a comparison condition

The WHERE clause of a SELECT statement specifies the rows that you want to see. A comparison condition employs specific *keywords* and *operators* to define the search criteria.

For example, you might use one of the keywords BETWEEN, IN, LIKE, or MATCHES to test for equality, or the keywords IS NULL to test for null values. You can combine the keyword NOT with any of these keywords to specify the opposite condition.

The following table lists the relational operators that you can use in a WHERE clause in place of a keyword to test for equality.

Operator	**Operation**
=	equals
!= or <>	does not equal
>	greater than
>=	greater than or equal to
<	less than
<=	less than or equal to

For CHAR expressions, greater than means *after* in ASCII collating order, where lowercase letters are after uppercase letters, and both are after numerals. See the ASCII Character Set chart in the *IBM Informix Guide to SQL: Syntax*. For DATE and DATETIME expressions, greater than means *later in time*, and for INTERVAL expressions, it means *of longer duration*.

You cannot use TEXT or BYTE columns to create a comparison condition, except when you use the IS NULL or IS NOT NULL keywords to test for NULL values.

You cannot specify BLOB or CLOB columns to create a comparison condition on IBM Informix, except when you use the IS NULL or IS NOT NULL keywords to test for NULL values.

You can use the preceding keywords and operators in a WHERE clause to create comparison-condition queries that perform the following actions:
- Include values
- Exclude values
- Find a range of values
- Find a subset of values
- Identify NULL values

To perform variable text searches using the following criteria, use the preceding keywords and operators in a WHERE clause to create comparison-condition queries:

- Exact-text comparison
- Single-character wildcards
- Restricted single-character wildcards
- Variable-length wildcards
- Subscripting

The following section contains examples that illustrate these types of queries.

Include rows

Use the equal sign (=) relational operator to include rows in a WHERE clause, as the following query shows.

```
SELECT customer_num, call_code, call_dtime, res_dtime
   FROM cust_calls
   WHERE user_id = 'maryj';
```

Figure 2-42. Query

The query returns the set of rows that is shown.

```
customer_num  call_code  call_dtime       res_dtime

         106  D          1998-06-12  08:20 1998-06-12 08:25
         121  O          1998-07-10 14:05 1998-07-10 14:06
         127  I          1998-07-31 14:30
```

Figure 2-43. Query result

Exclude rows

Use the relational operators != or <> to exclude rows in a WHERE clause.

The following query assumes that you are selecting from an ANSI-compliant database; the statements specify the owner or login name of the creator of the **customer** table. This qualifier is not required when the creator of the table is the current user, or when the database is not ANSI compliant. However, you can include the qualifier in either case. For a detailed discussion of owner naming, see the *IBM Informix Guide to SQL: Syntax*.

```
SELECT customer_num, company, city, state
   FROM odin.customer
   WHERE state != 'CA';

SELECT customer_num, company, city, state
   FROM odin.customer
   WHERE state <> 'CA';
```

Figure 2-44. Query

Both statements in the query exclude values by specifying that, in the **customer** table that the user **odin** owns, the value in the **state** column should not be equal to `CA`, as the result shows.

```
customer_num  company              city           state

       119  The Triathletes Club Cherry Hill     NJ
       120  Century Pro Shop     Phoenix         AZ
       121  City Sports          Wilmington      DE
       122  The Sporting Life    Princeton       NJ
       123  Bay Sports           Jacksonville    FL
       124  Putnum's Putters     Bartlesville    OK
       125  Total Fitness Sports Brighton        MA
       126  Neelie's Discount Sp Denver          CO
       127  Big Blue Bike Shop   Blue Island     NY
       128  Phoenix College      Phoenix         AZ
```

Figure 2-45. Query result

Specify a range of rows

The following query shows two ways to specify a range of rows in a WHERE clause.

```
SELECT catalog_num, stock_num, manu_code, cat_advert
   FROM catalog
   WHERE catalog_num BETWEEN 10005 AND 10008;

SELECT catalog_num, stock_num, manu_code, cat_advert
   FROM catalog
   WHERE catalog_num >= 10005 AND catalog_num <= 10008;
```

Figure 2-46. Query

Each statement in the query specifies a range for **catalog_num** from 10005 through 10008, inclusive. The first statement uses keywords, and the second statement uses relational operators to retrieve the rows, as the result shows.

```
catalog_num  10005
stock_num    3
manu_code    HSK
cat_advert   High-Technology Design Expands the Sweet Spot

catalog_num  10006
stock_num    3
manu_code    SHM
cat_advert   Durable Aluminum for High School and Collegiate Athletes

catalog_num  10007
stock_num    4
manu_code    HSK
cat_advert   Quality Pigskin with Joe Namath Signature

catalog_num  10008
stock_num    4
manu_code    HRO
cat_advert   Highest Quality Football for High School
              and Collegiate Competitions
```

Figure 2-47. Query result

Although the **catalog** table includes a column with the BYTE data type, that column is not included in this SELECT statement because the output would show only the words `<BYTE value>` by the column name. You can write an SQL API application to display TEXT and BYTE values.

Exclude a range of rows

The following query uses the keywords NOT BETWEEN to exclude rows that have the character range 94000 through 94999 in the **zipcode** column, as the result shows.

```
SELECT fname, lname, city, state
   FROM customer
   WHERE zipcode NOT BETWEEN '94000' AND '94999'
   ORDER BY state;
```

Figure 2-48. Query

```
fname           lname           city            state

Frank           Lessor          Phoenix         AZ
Fred            Jewell          Phoenix         AZ
Eileen          Neelie          Denver          CO
Jason           Wallack         Wilmington      DE
Marvin          Hanlon          Jacksonville    FL
James           Henry           Brighton        MA
Bob             Shorter         Cherry Hill     NJ
Cathy           O'Brian         Princeton       NJ
Kim             Satifer         Blue Island     NY
Chris           Putnum          Bartlesville    OK
```

Figure 2-49. Query result

Use a WHERE clause to find a subset of values

Like "Exclude rows" on page 2-18, the following query assumes the use of an ANSI-compliant database. The owner qualifier is in quotation marks to preserve the case sensitivity of the literal string.

```
SELECT lname, city, state, phone
   FROM 'Aleta'.customer
   WHERE state = 'AZ' OR state = 'NJ'
   ORDER BY lname;

SELECT lname, city, state, phone
   FROM 'Aleta'.customer
   WHERE state IN ('AZ', 'NJ')
   ORDER BY lname;
```

Figure 2-50. Query

Each statement in the query retrieves rows that include the subset of `AZ` or `NJ` in the **state** column of the **Aleta.customer** table.

```
lname      city            state phone

Jewell     Phoenix         AZ    602-265-8754
Lessor     Phoenix         AZ    602-533-1817
O'Brian    Princeton       NJ    609-342-0054
Shorter    Cherry Hill     NJ    609-663-6079
```

Figure 2-51. Query result

You cannot test TEXT or BYTE columns with the IN keyword.

Also, when you use IBM Informix, you cannot test BLOB or CLOB columns with the IN keyword.

In the example of a query on an ANSI-compliant database, no quotation marks exist around the table owner name. Whereas the two statements in Figure 2-50 on page 2-20 searched the **Aleta.customer** table, the following query searches the table ALETA.**customer**, which is a different table, because of the way ANSI-compliant databases look at owner names.

```
SELECT lname, city, state, phone
   FROM Aleta.customer
   WHERE state NOT IN ('AZ', 'NJ')
   ORDER BY state;
```

Figure 2-52. Query

The previous query adds the keywords NOT IN, so the subset changes to exclude the subsets `AZ` and `NJ` in the **state** column. The following figure shows the results in order of the **state** column.

```
lname        city            state phone

Pauli        Sunnyvale       CA    408-789-8075
Sadler       San Francisco   CA    415-822-1289
Currie       Palo Alto       CA    415-328-4543
Higgins      Redwood City    CA    415-368-1100
Vector       Los Altos       CA    415-776-3249
Watson       Mountain View   CA    415-389-8789
Ream         Palo Alto       CA    415-356-9876
Quinn        Redwood City    CA    415-544-8729
Miller       Sunnyvale       CA    408-723-8789
Jaeger       Redwood City    CA    415-743-3611
Keyes        Sunnyvale       CA    408-277-7245
Lawson       Los Altos       CA    415-887-7235
Beatty       Menlo Park      CA    415-356-9982
Albertson    Redwood City    CA    415-886-6677
Grant        Menlo Park      CA    415-356-1123
Parmelee     Mountain View   CA    415-534-8822
Sipes        Redwood City    CA    415-245-4578
Baxter       Oakland         CA    415-655-0011
Neelie       Denver          CO    303-936-7731
Wallack      Wilmington      DE    302-366-7511
Hanlon       Jacksonville    FL    904-823-4239
Henry        Brighton        MA    617-232-4159
Satifer      Blue Island     NY    312-944-5691
Putnum       Bartlesville    OK    918-355-2074
```

Figure 2-53. Query result

Identify NULL values

Use the IS NULL or IS NOT NULL option to check for NULL values. A NULL value represents either the absence of data or an unknown value. A NULL value is not the same as a zero or a blank.

The following query returns all rows that have a null **paid_date**, as the result shows.

```
SELECT order_num, customer_num, po_num, ship_date
   FROM orders
   WHERE paid_date IS NULL
   ORDER BY customer_num;
```

Figure 2-54. Query

```
order_num  customer_num  po_num   ship_date

     1004           106  8006     05/30/1998
     1006           112  Q13557
     1007           117  278693   06/05/1998
     1012           117  278701   06/29/1998
     1016           119  PC6782   07/12/1998
     1017           120  DM354331 07/13/1998
```

Figure 2-55. Query result

Form compound conditions

To connect two or more comparison conditions, or *Boolean expressions*, use the logical operators AND, OR, and NOT. A Boolean expression evaluates as `true` or `false` or, if NULL values are involved, as `unknown`.

In the following query, the operator AND combines two comparison expressions in the WHERE clause.

```
SELECT order_num, customer_num, po_num, ship_date
   FROM orders
   WHERE paid_date IS NULL
      AND ship_date IS NOT NULL
   ORDER BY customer_num;
```

Figure 2-56. Query

The query returns all rows that have NULL paid_date or a NOT NULL ship_date.

```
order_num customer_num po_num     ship_date

     1004          106 8006       05/30/1998
     1007          117 278693     06/05/1998
     1012          117 278701     06/29/1998
     1017          120 DM354331   07/13/1998
```

Figure 2-57. Query result

Exact-text comparisons

The following examples include a WHERE clause that searches for exact-text comparisons by using the keyword LIKE or MATCHES or the equal sign (=) relational operator. Unlike earlier examples, these examples illustrate how to query a table that is not in the current database. You can access a table that is not in the current database only if the database that contains the table has the same ANSI compliance status as the current database. If the current database is an ANSI-compliant database, the table you want to access must also reside in an ANSI-compliant database. If the current database is not an ANSI-compliant database, the table you want to access must also reside in a database that is not an ANSI-compliant database.

Although the database used previously in this chapter is the demonstration database, the FROM clause in the following examples specifies the **manatee** table, created by the owner **bubba**, which resides in an ANSI-compliant database named **syzygy**. For more information on how to access tables that are not in the current database, see the *IBM Informix Guide to SQL: Syntax*.

Each statement in the following query retrieves all the rows that have the single word *helmet* in the **description** column, as the result shows.

```
SELECT stock_no, mfg_code, description, unit_price
   FROM syzygy:bubba.manatee
   WHERE description = 'helmet'
   ORDER BY mfg_code;

SELECT stock_no, mfg_code, description, unit_price
   FROM syzygy:bubba.manatee
   WHERE description LIKE 'helmet'
   ORDER BY mfg_code;

SELECT stock_no, mfg_code, description, unit_price
   FROM syzygy:bubba.manatee
   WHERE description MATCHES 'helmet'
   ORDER BY mfg_code;
```

Figure 2-58. Query

The results might look like the following figure.

```
stock_no mfg_code  description     unit_price

    991 ABC       helmet            $222.00
    991 BKE       helmet            $269.00
    991 HSK       helmet            $311.00
    991 PRC       helmet            $234.00
    991 SPR       helmet            $245.00
```

Figure 2-59. Query result

Variable-text searches

You can use the keywords LIKE and MATCHES for variable-text queries that are based on substring searches of fields. Include the keyword NOT to indicate the opposite condition.

The keyword LIKE complies with the ISO/ANSI standard for SQL, whereas MATCHES is an IBM Informix extension.

Variable-text search strings can include the wildcard symbols that are listed with the keywords LIKE or MATCHES in the following table.

Keyword	Symbol	Explanation
LIKE	%	Evaluates to zero or more characters
LIKE	_	Evaluates to a single character
LIKE	\	Escapes special significance of next character
MATCHES	*	Evaluates to zero or more characters
MATCHES	?	Evaluates to a single character (except null)
MATCHES	[ ]	Evaluates to a single character or range of values

Keyword	Symbol	Explanation
MATCHES	\	Escapes special significance of next character

You cannot test BLOB, CLOB, TEXT, or BYTE columns with the LIKE or MATCHES operators.

A single-character wildcard

The statements in the following query illustrate the use of a single-character wildcard in a WHERE clause. Further, they demonstrate a query on a table that is not in the current database. The **stock** table is in the database **sloth**. Besides being outside the current demonstration database, **sloth** is on a separate database server called **meerkat**.

For more information, see Chapter 7, "Access and modify data in an external database," on page 7-1 and the *IBM Informix Guide to SQL: Syntax*.

```
SELECT stock_num, manu_code, description, unit_price
   FROM sloth@meerkat:stock
   WHERE manu_code LIKE '_R_'
       AND unit_price >= 100
   ORDER BY description, unit_price;

SELECT stock_num, manu_code, description, unit_price
   FROM sloth@meerkat:stock
   WHERE manu_code MATCHES '?R?'
      AND unit_price >= 100
   ORDER BY description, unit_price;
```

Figure 2-60. Query

Each statement in the query retrieves only those rows for which the middle letter of the **manu_code** is R, as the result shows. The comparison '_R_' (for LIKE) or '?R?' (for MATCHES) specifies, from left to right, the following items:

- Any single character
- The letter R
- Any single character

```
stock_num manu_code description     unit_price

      205 HRO       3 golf balls       $312.00
        2 HRO       baseball           $126.00
        1 HRO       baseball gloves    $250.00
        7 HRO       basketball         $600.00
      102 PRC       bicycle brakes     $480.00
      114 PRC       bicycle gloves     $120.00
        4 HRO       football           $480.00
      110 PRC       helmet             $236.00
      110 HRO       helmet             $260.00
      307 PRC       infant jogger      $250.00
      306 PRC       tandem adapter     $160.00
      308 PRC       twin jogger        $280.00
      304 HRO       watch              $280.00
```

Figure 2-61. Query result

WHERE clause to specify a range of initial characters:

The following query selects only those rows where the **manu_code** begins with A through H and returns the rows that the result shows. The test '[A-H]' specifies any single letter from A through H, inclusive. No equivalent wildcard symbol exists for the LIKE keyword.

```
SELECT stock_num, manu_code, description, unit_price
   FROM stock
   WHERE manu_code MATCHES '[A-H]*'
   ORDER BY description, manu_code;
```

Figure 2-62. Query

```
stock_num manu_code description     unit_price

      205 ANZ       3 golf balls       $312.00
      205 HRO       3 golf balls       $312.00
        2 HRO       baseball           $126.00
        3 HSK       baseball bat       $240.00
        1 HRO       baseball gloves    $250.00
        1 HSK       baseball gloves    $800.00
        7 HRO       basketball         $600.00
⋮
      313 ANZ       swim cap            $60.00
        6 ANZ       tennis ball         $48.00
        5 ANZ       tennis racquet      $19.80
        8 ANZ       volleyball         $840.00
        9 ANZ       volleyball net      $20.00
      304 ANZ       watch              $170.00
```

Figure 2-63. Query result

WHERE clause with variable-length wildcard:
The statements in the following query use a wildcard at the end of a string to retrieve all the rows where the **description** begins with the characters bicycle.

```
SELECT stock_num, manu_code, description, unit_price
   FROM stock
   WHERE description LIKE 'bicycle%'
   ORDER BY description, manu_code;

SELECT stock_num, manu_code, description, unit_price
   FROM stock
   WHERE description MATCHES 'bicycle*'
   ORDER BY description, manu_code;
```

Figure 2-64. Query

Either statement returns the following rows.

```
stock_num manu_code description     unit_price

      102 PRC       bicycle brakes     $480.00
      102 SHM       bicycle brakes     $220.00
      114 PRC       bicycle gloves     $120.00
      107 PRC       bicycle saddle      $70.00
      106 PRC       bicycle stem        $23.00
      101 PRC       bicycle tires       $88.00
      101 SHM       bicycle tires       $68.00
      105 PRC       bicycle wheels      $53.00
      105 SHM       bicycle wheels      $80.00
```

Figure 2-65. Query result

The comparison 'bicycle%' or 'bicycle*' specifies the characters bicycle followed by any sequence of zero or more characters. It matches bicycle stem with stem matched by the wildcard. It matches to the characters bicycle alone, if a row exists with that description.

The following query narrows the search by adding another comparison condition that excludes a **manu_code** of PRC.

```
SELECT stock_num, manu_code, description, unit_price
   FROM stock
   WHERE description LIKE 'bicycle%'
      AND manu_code NOT LIKE 'PRC'
   ORDER BY description, manu_code;
```

Figure 2-66. Query

The statement retrieves only the following rows.

```
stock_num manu_code description     unit_price

      102 SHM       bicycle brakes     $220.00
      101 SHM       bicycle tires       $68.00
      105 SHM       bicycle wheels      $80.00
```

Figure 2-67. Query result

When you select from a large table and use an initial wildcard in the comparison string (such as '%cycle'), the query often takes longer to execute. Because indexes cannot be used, every row is searched.

MATCHES clause and non-default locales

By default, IBM Informix database servers use the U.S. English language environment, called a locale, for database data. This default locale uses the ISO 8859-1 code set. The U.S. English locale specifies that MATCHES will use code-set order.

If your database uses a non-default locale, a MATCHES clause that specifies a range uses the collation order of that locale for character data types (including CHAR, NCHAR, VARCHAR, NVARCHAR, and LVARCHAR). This feature of MATCHES ranges is an exception to the general rule that only NCHAR and NVARCHAR columns can use locale-specific collation. If the locale does not specify any special collation order, however, then MATCHES uses the code-set order.

With IBM Informix, you can use the SET COLLATION statement to specify a database locale for your session that is different from the DB_LOCALE setting. See the *IBM Informix Guide to SQL: Syntax* for a description of SET COLLATION.

```
SELECT numéro,nom,prénom
   FROM abonnés
   WHERE nom MATCHES '[E-P]*'
   ORDER BY nom;
```

Figure 2-68. Query

In the result, the rows for Étaix, Ötker, and Øverst are not selected and listed because, with ISO 8859-1 code-set order, the accented first letter of each name is not in the `E` through `P` MATCHES range for the **nom** column.

```
numéro        nom          prénom

13607      Hammer          Gerhard
13602      Hämmer          Greta
13604      LaForêt         Jean-Noël
13610      LeMaître        Héloïse
13613      Llanero         Gloria Dolores
13603      Montaña         José Antonio
13611      Oatfield        Emily
```

Figure 2-69. Query result

For more information on non-English data and locales, see the *IBM Informix GLS User's Guide*.

Protect special characters

The following query uses the keyword ESCAPE with LIKE or MATCHES so you can protect a special character from misinterpretation as a wildcard symbol.

```
SELECT * FROM cust_calls
   WHERE res_descr LIKE '%!%%' ESCAPE '!';
```

Figure 2-70. Query

The ESCAPE keyword designates an escape character (`!` in this example) that protects the next character so that it is interpreted as data and not as a wildcard. In the example, the escape character causes the middle percent sign (%) to be treated as data. By using the ESCAPE keyword, you can search for occurrences of a percent sign (%) in the **res_descr** column by using the LIKE wildcard percent sign (%). The query retrieves the following row.

```
customer_num   116
call_dtime     1997-12-21 11:24
user_id        mannyn
call_code      I
call_descr     Second complaint from this customer!
               Received two cases righthanded outfielder
               glove (1 HRO) instead of one case lefties.
res_dtime      1997-12-27 08:19
res_descr      Memo to shipping (Ava Brown) to send case
               of lefthanded gloves, pick up wrong case;
               memo to billing requesting 5% discount to
               placate customer due to second offense
               and lateness of resolution because of
               holiday.
```

Figure 2-71. Query result

Subscripting in a WHERE clause

You can use *subscripting* in the WHERE clause of a SELECT statement to specify a range of characters or numbers in a column, as the following query shows.

```
SELECT catalog_num, stock_num, manu_code, cat_advert,
         cat_descr
   FROM catalog
   WHERE cat_advert[1,4] = 'High';
```

Figure 2-72. Query

The subscript `[1,4]` causes the query to retrieve all rows in which the first four letters of the **cat_advert** column are `High`, as result shows.

```
catalog_num  10004
stock_num    2
manu_code    HRO
cat_advert   Highest Quality Ball Available, from Hand-Sti
             tching to the Robinson Signature
cat_descr
Jackie Robinson signature ball. Highest professional quality,
used by National League.

catalog_num  10005
stock_num    3
manu_code    HSK
cat_advert   High-Technology Design Expands the Sweet Spot
cat_descr
Pro-style wood. Available in sizes: 31, 32, 33, 34, 35.
⋮
catalog_num  10045
stock_num    204
manu_code    KAR
cat_advert   High-Quality Beginning Set of Irons. Appropriate
             for High School Competitions
cat_descr
Ideally balanced for optimum control. Nylon covered shaft.

catalog_num  10068
stock_num    310
manu_code    ANZ
cat_advert   High-Quality Kickboard
cat_descr
White. Standard size.
```

Figure 2-73. Query result

FIRST clause to select specific rows

You can include a FIRST *max* specification in the Projection clause of a SELECT statement, where *max* has an integer value, to instruct the query to return no more than the first *max* rows that match the conditions of the SELECT statement. You can also use the keyword LIMIT as a synonym for FIRST in this context (and only in this context). The rows that a SELECT statement with a FIRST clause returns might depend on whether the statement also includes an ORDER BY clause.

The keyword SKIP, followed by an unsigned integer, can precede the FIRST or LIMIT keyword in the Projection clause. The SKIP *offset* clause instructs the database server to exclude the first *offset* qualifying rows from the result set of the query before returning the number of rows that the FIRST clause specifies. In SPL routines, the parameter of SKIP, FIRST, or LIMIT can be a literal integer or a local SPL variable. If the Projection clause includes SKIP *offset* but no FIRST or LIMIT specification, then the query returns all of the qualifying rows except for the first *offset* rows.

The Projection clause cannot include the SKIP, FIRST, or LIMIT keywords in these contexts:

- when the SELECT statement is part of a view definition
- in a subquery, except in the FROM clause of the outer query
- in a cross-server distributed query in which a participating database server does not support the SKIP, FIRST, or LIMIT keywords.

For information about restrictions on use of the FIRST clause, see the description of the Projection clause of the SELECT statement in the *IBM Informix Guide to SQL: Syntax*.

FIRST clause without an ORDER BY clause

If you do not include an ORDER BY clause in a SELECT statement with a FIRST clause, any rows that match the conditions of the SELECT statement might be returned. In other words, the database server determines which of the qualifying rows to return, and the query result can vary depending on the query plan that the optimizer chooses.

The following query uses the FIRST clause to return the first five rows from the **state** table.

```
SELECT FIRST 5 * FROM state;
```

Figure 2-74. Query

```
code sname

AK   Alaska
HI   Hawaii
CA   California
OR   Oregon
WA   Washington
```

Figure 2-75. Query result

You can use a FIRST clause when you simply want to know the names of all the columns and the type of data that a table contains, or to test a query that otherwise would return many rows. The following query shows how to use the FIRST clause to return column values for the first row of a table.

```
SELECT FIRST 1 * FROM orders;
```

Figure 2-76. Query

```
order_num      1001
order_date     05/20/1998
customer_num   104
ship_instruct  express
backlog        n
po_num         B77836
ship_date      06/01/1998
ship_weight    20.40
ship_charge    $10.00
paid_date      07/22/1998
```

Figure 2-77. Query result

FIRST clause with an ORDER BY clause

You can include an ORDER BY clause in a SELECT statement with a FIRST clause to return rows that contain the highest or lowest values for a specified column. The following query shows a query that includes an ORDER BY clause to return (by alphabetical order) the first five states contained in the **state** table. The query, which is the same as Figure 2-74 except for the ORDER BY clause, returns a different set of rows than Figure 2-74 on page 2-30.

```
SELECT FIRST 5 * FROM state ORDER BY sname;
```

Figure 2-78. Query

```
code sname

AL   Alabama
AK   Alaska
AZ   Arizona
AR   Arkansas
CA   California
```

Figure 2-79. Query result

The following query shows how to use a FIRST clause in a query with an ORDER BY clause to find the 10 most expensive items listed in the **stock** table.

```
SELECT FIRST 10 description, unit_price
   FROM stock ORDER BY unit_price DESC;
```

Figure 2-80. Query

```
description     unit_price

football           $960.00
volleyball         $840.00
baseball gloves    $800.00
18-spd, assmbld    $685.90
irons/wedge        $670.00
basketball         $600.00
12-spd, assmbld    $549.00
10-spd, assmbld    $499.99
football           $480.00
bicycle brakes     $480.00
```

Figure 2-81. Query result

Applications can use the SKIP and FIRST keywords of the Projection clause, in conjunction with the ORDER BY clause, to perform successive queries that incrementally retrieve all of the qualifying rows in subsets of some fixed size (for example, the maximum number of rows that are visible without scrolling a screen display). You can accomplish this by incrementing the *offset* parameter of the SKIP clause by the *max* parameter of the FIRST clause after each query. By imposing a unique order on the qualifying rows, the ORDER BY clause ensures that each query returns a disjunct subset of the qualifying rows.

The following query shows a query that includes SKIP, FIRST, and ORDER BY specifications to return (by alphabetical order) the sixth through tenth states in the **state** table, but not the first five states. This query resembles Figure 2-74 on page 2-30, except that the SKIP 5 specification instructs the database server to returns a different set of rows than Figure 2-74 on page 2-30.

```
SELECT SKIP 5 FIRST 5 * FROM state ORDER BY sname;
```

Figure 2-82. Query

```
code sname

CO   Colorado
CT   Connecticut
DE   Delaware
FL   Florida
GA   Georgia
```

Figure 2-83. Query result

If you use the SKIP, FIRST, or LIMIT keywords, you must take care to specify parameters that correspond to the design goals of your application. If the *offset* parameter of skip is larger than the number of qualifying rows, then any FIRST or LIMIT specification has no effect, and the query returns nothing.

Expressions and derived values

You are not limited to selecting columns by name. You can list an *expression* in the Projection clause of a SELECT statement to perform computations on column data and to display information *derived* from the contents of one or more columns.

An expression consists of a column name, a constant, a quoted string, a keyword, or any combination of these items connected by operators. It can also include host variables (program data) when the SELECT statement is embedded in a program.

Arithmetic expressions

An arithmetic expression contains at least one of the arithmetic operators listed in the following table and produces a number.

Operator	**Operation**
+	addition
-	subtraction
*****	multiplication
/	division

You cannot use TEXT or BYTE columns in arithmetic expressions.

With IBM Informix, you cannot specify BLOB or CLOB in arithmetic expressions.

Arithmetic operations enable you to see the results of proposed computations without actually altering the data in the database. You can add an INTO TEMP clause to save the altered data in a temporary table for further reference, computations, or impromptu reports. The following query calculates a 7 percent sales tax on the **unit_price** column when the **unit_price** is $400 or more (but does not update it in the database).

```
SELECT stock_num, description, unit_price, unit_price * 1.07
   FROM stock
   WHERE unit_price >= 400;
```

Figure 2-84. Query

The result appears in the **expression** column.

```
stock_num description     unit_price     (expression)

        1 baseball gloves    $800.00          $856.00
        1 baseball gloves    $450.00          $481.50
        4 football           $960.00         $1027.20
        4 football           $480.00          $513.60
        7 basketball         $600.00          $642.00
        8 volleyball         $840.00          $898.80
      102 bicycle brakes     $480.00          $513.60
      111 10-spd, assmbld    $499.99          $534.99
      112 12-spd, assmbld    $549.00          $587.43
      113 18-spd, assmbld    $685.90          $733.91
      203 irons/wedge        $670.00          $716.90
```

Figure 2-85. Query result

The following query calculates a surcharge of $6.50 on orders when the quantity ordered is less than 5.

```
SELECT item_num, order_num, quantity,
       total_price, total_price + 6.50
   FROM items
   WHERE quantity < 5;
```

Figure 2-86. Query

The result appears in the **expression** column.

```
item_num   order_num quantity total_price  (expression)

       1        1001        1     $250.00      $256.50
       1        1002        1     $960.00      $966.50
       2        1002        1     $240.00      $246.50
       1        1003        1      $20.00       $26.50
       2        1003        1     $840.00      $846.50
       1        1004        1     $250.00      $256.50
       2        1004        1     $126.00      $132.50
       3        1004        1     $240.00      $246.50
       4        1004        1     $800.00      $806.50
⋮
       1        1023        2      $40.00       $46.50
       2        1023        2     $116.00      $122.50
       3        1023        1      $80.00       $86.50
       4        1023        1     $228.00      $234.50
       5        1023        1     $170.00      $176.50
       6        1023        1     $190.00      $196.50
```

Figure 2-87. Query result

The following query calculates and displays in the **expression** column the interval between when the customer call was received (**call_dtime**) and when the call was resolved (**res_dtime**), in days, hours, and minutes.

```
SELECT customer_num, call_code, call_dtime,
       res_dtime - call_dtime
   FROM cust_calls
   ORDER BY customer_num;
```

Figure 2-88. Query

```
customer_num call_code call_dtime             (expression)

         106 D         1998-06-12 08:20         0 00:05
         110 L         1998-07-07 10:24         0 00:06
         116 I         1997-11-28 13:34         0 03:13
         116 I         1997-12-21 11:24         5 20:55
         119 B         1998-07-01 15:00         0 17:21
         121 O         1998-07-10 14:05         0 00:01
         127 I         1998-07-31 14:30
```

Figure 2-89. Query result

Display labels:
You can assign a *display label* to a computed or derived data column to replace the default column header **expression**. In Figure 2-84 on page 2-32, Figure 2-86 on page 2-33, and Figure 2-90, the derived data appears in the **expression** column. The following query also presents derived values, but the column that displays the derived values has the descriptive header **taxed**.

```
SELECT stock_num, description, unit_price,
       unit_price * 1.07 taxed
   FROM stock
   WHERE unit_price >= 400;
```

Figure 2-90. Query

The result shows that the label **taxed** is assigned to the expression in the projection list that displays the results of the operation `unit_price * 1.07`.

```
stock_num description     unit_price           taxed

        1 baseball gloves    $800.00         $856.00
        1 baseball gloves    $450.00         $481.50
        4 football           $960.00        $1027.20
        4 football           $480.00         $513.60
        7 basketball         $600.00         $642.00
        8 volleyball         $840.00         $898.80
      102 bicycle brakes     $480.00         $513.60
      111 10-spd, assmbld    $499.99         $534.99
      112 12-spd, assmbld    $549.00         $587.43
      113 18-spd, assmbld    $685.90         $733.91
      203 irons/wedge        $670.00         $716.90
```

Figure 2-91. Query result

In the following query, the label **surcharge** is defined for the column that displays the results of the operation `total_price + 6.50`.

```
SELECT item_num, order_num, quantity,
       total_price, total_price + 6.50 surcharge
   FROM items
   WHERE quantity < 5;
```

Figure 2-92. Query

The **surcharge** column is labeled in the output.

```
item_num   order_num quantity total_price    surcharge

       1        1001        1     $250.00      $256.50
       1        1002        1     $960.00      $966.50
       2        1002        1     $240.00      $246.50
       1        1003        1      $20.00       $26.50
       2        1003        1     $840.00      $846.50
⋮
       1        1023        2      $40.00       $46.50
       2        1023        2     $116.00      $122.50
       3        1023        1      $80.00       $86.50
       4        1023        1     $228.00      $234.50
       5        1023        1     $170.00      $176.50
       6        1023        1     $190.00      $196.50
```

Figure 2-93. Query result

The following query assigns the label **span** to the column that displays the results of subtracting the DATETIME column **call_dtime** from the DATETIME column **res_dtime**.

```
SELECT customer_num, call_code, call_dtime,
       res_dtime - call_dtime span
   FROM cust_calls
   ORDER BY customer_num;
```

Figure 2-94. Query

The **span** column is labeled in the output.

```
customer_num call_code call_dtime              span

         106 D         1998-06-12 08:20        0 00:05
         110 L         1998-07-07 10:24        0 00:06
         116 I         1997-11-28 13:34        0 03:13
         116 I         1997-12-21 11:24        5 20:55
         119 B         1998-07-01 15:00        0 17:21
         121 O         1998-07-10 14:05        0 00:01
         127 I         1998-07-31 14:30
```

Figure 2-95. Query result

CASE expressions

A CASE expression is a conditional expression, which is similar to the concept of the CASE statement in programming languages. You can use a CASE expression when you want to change the way data is represented. The CASE expression allows a statement to return one of several possible results, depending on which of several condition tests evaluates to TRUE.

TEXT or BYTE values are not allowed in a CASE expression.

Consider a column that represents marital status numerically as `1,2,3,4` with the corresponding values meaning single, married, divorced, widowed. In some cases, you might prefer to store the short values (`1,2,3,4`) for database efficiency, but employees in human resources might prefer the more descriptive values (single, married, divorced, widowed). The CASE expression makes such conversions between different sets of values easy.

In IBM Informix, the CASE expression also supports extended data types and cast expressions.

The following example shows a CASE expression with multiple WHEN clauses that returns more descriptive values for the **manu_code** column of the **stock** table. If none of the WHEN conditions is true, NULL is the default result. (You can omit the ELSE NULL clause.)

```
SELECT
   CASE
      WHEN manu_code = "HRO" THEN "Hero"
      WHEN manu_code = "SHM" THEN "Shimara"
      WHEN manu_code = "PRC" THEN "ProCycle"
      WHEN manu_code = "ANZ" THEN "Anza"
      ELSE NULL
   END
   FROM stock;
```

You must include at least one WHEN clause within the CASE expression; subsequent WHEN clauses and the ELSE clause are optional. If no WHEN condition evaluates to true, the resulting value is NULL. You can use the IS NULL expression to handle NULL results. For information on handling NULL values, see the *IBM Informix Guide to SQL: Syntax*.

The following query shows a simple CASE expression that returns a character string value to flag any orders from the **orders** table that have not been shipped to the customer.

```
SELECT order_num, order_date,
      CASE
         WHEN ship_date IS NULL
         THEN "order not shipped"
      END
   FROM orders;
```

Figure 2-96. Query

```
order_num order_date (expression)

       1001 05/20/1998
       1002 05/21/1998
       1003 05/22/1998
       1004 05/22/1998
       1005 05/24/1998
       1006 05/30/1998 order not shipped
       1007 05/31/1998
⋮
       1019 07/11/1998
       1020 07/11/1998
       1021 07/23/1998
       1022 07/24/1998
       1023 07/24/1998
```

Figure 2-97. Query result

For information about how to use the CASE expression to update a column, see "CASE expression to update a column" on page 6-19.

Sorting on derived columns

When you want to use ORDER BY on an expression, you can use either the display label assigned to the expression or an integer, as Figure 2-98 and Figure 2-100 show.

```
SELECT customer_num, call_code, call_dtime,
       res_dtime - call_dtime span
   FROM cust_calls
   ORDER BY span;
```

Figure 2-98. Query

The query retrieves the same data from the **cust_calls** table as Figure 2-94 on page 2-35. In the query, the ORDER BY clause causes the data to be displayed in ascending order of the derived values in the **span** column, as the result shows.

```
customer_num call_code call_dtime              span

         127 I         1998-07-31 14:30
         121 O         1998-07-10 14:05        0 00:01
         106 D         1998-06-12 08:20        0 00:05
         110 L         1998-07-07 10:24        0 00:06
         116 I         1997-11-28 13:34        0 03:13
         119 B         1998-07-01 15:00        0 17:21
         116 I         1997-12-21 11:24        5 20:55
```

Figure 2-99. Query result

The following query uses an integer to represent the result of the operation `res_dtime - call_dtime` and retrieves the same rows that appear in the above result.

```
SELECT customer_num, call_code, call_dtime,
       res_dtime - call_dtime span
   FROM cust_calls
   ORDER BY 4;
```

Figure 2-100. Query

Rowid values in SELECT statements

The database server assigns a unique *rowid* to rows in nonfragmented tables. The rowid is, in effect, a hidden column in every table. The sequential values of rowid have no special significance and can vary depending on the location of the physical data in the chunk. You can use a rowid to locate the internal record number that is associated with a row in a table. Rows in fragmented tables do not automatically contain the rowid column.

It is recommended that you use primary keys as a method of access in your applications rather than rowids. Because primary keys are defined in the ANSI specification of SQL, using them to access data makes your applications more portable. In addition, the database server requires less time to access data in a fragmented table when it uses a primary key than it requires to access the same data when it uses rowid.

For more information about rowids, see the *IBM Informix Database Design and Implementation Guide* and your *IBM Informix Administrator's Guide*.

The following query uses the rowid and the wildcard asterisk symbol (*) in the Projection clause to retrieve each row in the **manufact** table and its corresponding rowid.

```
SELECT rowid, * FROM manufact;
```

Figure 2-101. Query

```
rowid manu_code manu_name       lead_time

  257 SMT       Smith             3
  258 ANZ       Anza              5
  259 NRG       Norge             7
  260 HSK       Husky             5
  261 HRO       Hero              4
  262 SHM       Shimara          30
  263 KAR       Karsten          21
  264 NKL       Nikolus           8
  265 PRC       ProCycle          9
```

Figure 2-102. Query result

Never store a rowid in a permanent table or attempt to use it as a foreign key. If a table is dropped and then reloaded from external data, all the rowids will be different.

Multiple-table SELECT statements

To select data from two or more tables, specify the table names in the FROM clause. Add a WHERE clause to create a join condition between at least one related column in each table. This WHERE clause creates a temporary composite table in which each pair of rows that satisfies the join condition is linked to form a single row.

A *simple join* combines information from two or more tables based on the relationship between one column in each table. A *composite join* is a join between two or more tables based on the relationship between two or more columns in each table.

To create a join, you must specify a relationship, called a *join condition*, between at least one column from each table. Because the columns are being compared, they must have compatible data types. When you join large tables, performance improves when you index the columns in the join condition.

Data types are described in the *IBM Informix Guide to SQL: Reference* and the *IBM Informix Database Design and Implementation Guide*. Indexing is discussed in detail in the *IBM Informix Administrator's Guide*.

Create a Cartesian product

When you perform a multiple-table query that does not explicitly state a join condition among the tables, you create a *Cartesian product*. A Cartesian product consists of every possible combination of rows from the tables. This result is usually large and unwieldy.

The following query selects from two tables and produces a Cartesian product.

```
SELECT * FROM customer, state;
```

Figure 2-103. Query

Although only 52 rows exist in the **state** table and 28 rows in the **customer** table, the effect of the query is to multiply the rows of one table by the rows of the other and retrieve an impractical 1,456 rows, as the result shows.

```
customer_num  101
fname         Ludwig
lname         Pauli
company       All Sports Supplies
address1      213 Erstwild Court
address2
city          Sunnyvale
state         CA
zipcode       94086
phone         408-789-8075
code          AK
sname         Alaska

customer_num  101
fname         Ludwig
lname         Pauli
company       All Sports Supplies
address1      213 Erstwild Court
address2
city          Sunnyvale
state         CA
zipcode       94086
phone         408-789-8075
code          HI
sname         Hawaii

customer_num  101
fname         Ludwig
lname         Pauli
company       All Sports Supplies
address1      213 Erstwild Court
address2
city          Sunnyvale
state         CA
zipcode       94086
phone         408-789-8075
code          CA
sname         California
⋮
```

Figure 2-104. Query result

In addition, some of the data that is displayed in the concatenated rows is contradictory. For example, although the **city** and **state** from the **customer** table indicate an address in California, the **code** and **sname** from the **state** table might be for a different state.

Create a join

Conceptually, the first stage of any join is the creation of a Cartesian product. To refine or constrain this Cartesian product and eliminate meaningless combinations of rows of data, include a WHERE clause with a valid join condition in your SELECT statement.

This section illustrates *cross joins*, *equi-joins*, *natural joins*, and *multiple-table joins*. Additional complex forms, such as *self-joins* and *outer joins*, are discussed in Chapter 5, "Compose advanced SELECT statements," on page 5-1.

Cross join

A *cross join* combines all rows in all tables selected and creates a Cartesian product. The results of a cross join can be very large and difficult to manage.

The following query uses ANSI join syntax to create a cross join.

```
SELECT * FROM customer CROSS JOIN  state;
```

Figure 2-105. Query

The results of the query are identical to the results of Figure 2-103 on page 2-39. In addition, you can filter a cross join by specifying a WHERE clause.

For more information about Cartesian products, see "Create a Cartesian product" on page 2-38. For more information about ANSI syntax, see "ANSI join syntax" on page 5-11.

Equi-join

An *equi-join* is a join based on equality or matching column values. This equality is indicated with an equal sign (=) as the comparison operator in the WHERE clause, as the following query shows.

```
SELECT * FROM manufact, stock
   WHERE manufact.manu_code = stock.manu_code;
```

Figure 2-106. Query

The query joins the **manufact** and **stock** tables on the **manu_code** column. It retrieves only those rows for which the values of the two columns are equal, some of which the result shows.

```
manu_code    SMT
manu_name    Smith
lead_time       3
stock_num    1
manu_code    SMT
description  baseball gloves
unit_price   $450.00
unit         case
unit_descr   10 gloves/case

manu_code    SMT
manu_name    Smith
lead_time       3
stock_num    5
manu_code    SMT
description  tennis racquet
unit_price   $25.00
unit         each
unit_descr   each

manu_code    SMT
manu_name    Smith
lead_time       3
stock_num    6
manu_code    SMT
description  tennis ball
unit_price   $36.00
unit         case
unit_descr   24 cans/case

manu_code    ANZ
manu_name    Anza
lead_time       5
stock_num    5
manu_code    ANZ
description  tennis racquet
unit_price   $19.80
unit         each
unit_descr   each
⋮
```

Figure 2-107. Query result

In this equi-join, the result includes the **manu_code** column from both the **manufact** and **stock** tables because the select list requested every column.

You can also create an equi-join with additional constraints, where the comparison condition is based on the inequality of values in the joined columns. These joins use a relational operator in addition to the equal sign (=) in the comparison condition that is specified in the WHERE clause.

To join tables that contain columns with the same name, qualify each column name with the name of its table and a period symbol (.), as the following query shows.

```
SELECT order_num, order_date, ship_date, cust_calls.*
   FROM orders, cust_calls
   WHERE call_dtime >= ship_date
      AND cust_calls.customer_num = orders.customer_num
   ORDER BY orders.customer_num;
```

Figure 2-108. Query

The query joins the **customer_num** column and then selects only those rows where the **call_dtime** in the **cust_calls** table is greater than or equal to the **ship_date** in the **orders** table. The result shows the combined rows that it returns.

```
order_num      1004
order_date     05/22/1998
ship_date      05/30/1998
customer_num   106
call_dtime     1998-06-12 08:20
user_id        maryj
call_code      D
call_descr     Order received okay, but two of the cans of
                       ANZ tennis balls within the case were empty
res_dtime      1998-06-12 08:25
res_descr      Authorized credit for two cans to customer,
               issued apology. Called ANZ buyer to report
               the qa problem.

order_num      1008
order_date     06/07/1998
ship_date      07/06/1998
customer_num   110
call_dtime     1998-07-07 10:24
user_id        richc
call_code      L
call_descr     Order placed one month ago (6/7) not received.
res_dtime      1998-07-07 10:30
res_descr      Checked with shipping (Ed Smith). Order out
               yesterday-was waiting for goods from ANZ.
               Next time will call with delay if necessary.

order_num      1023
order_date     07/24/1998
ship_date      07/30/1998
customer_num   127
call_dtime     1998-07-31 14:30
user_id        maryj
call_code      I
call_descr     Received Hero watches (item # 304) instead
                of ANZ watches
res_dtime
res_descr      Sent memo to shipping to send ANZ item 304
               to customer and pickup HRO watches. Should
               be done tomorrow, 8/1
```

Figure 2-109. Query result

Natural join

A *natural join* is a type of equi-join and is structured so that the join column does not display data redundantly, as the following query shows.

```
SELECT manu_name, lead_time, stock.*
   FROM manufact, stock
   WHERE manufact.manu_code = stock.manu_code;
```

Figure 2-110. Query

Like the example for equi-join, the query joins the **manufact** and **stock** tables on the **manu_code** column. Because the Projection list is more closely defined, the **manu_code** is listed only once for each row retrieved, as the result shows.

```
manu_name    Smith
lead_time       3
stock_num    1
manu_code    SMT
description  baseball gloves
unit_price   $450.00
unit         case
unit_descr   10 gloves/case

manu_name    Smith
lead_time       3
stock_num    5
manu_code    SMT
description  tennis racquet
unit_price   $25.00
unit         each
unit_descr   each

manu_name    Smith
lead_time       3
stock_num    6
manu_code    SMT
description  tennis ball
unit_price   $36.00
unit         case
unit_descr   24 cans/case

manu_name    Anza
lead_time       5
stock_num    5
manu_code    ANZ
description  tennis racquet
unit_price   $19.80
unit         each
unit_descr   each
⋮
```

Figure 2-111. Query result

All joins are *associative*; that is, the order of the joining terms in the WHERE clause does not affect the meaning of the join.

Both statements in the following query create the same natural join.

```
SELECT catalog.*, description, unit_price, unit, unit_descr
   FROM catalog, stock
   WHERE catalog.stock_num = stock.stock_num
      AND catalog.manu_code = stock.manu_code
      AND catalog_num = 10017;

SELECT catalog.*, description, unit_price, unit, unit_descr
   FROM catalog, stock
   WHERE catalog_num = 10017
      AND catalog.manu_code = stock.manu_code
      AND catalog.stock_num = stock.stock_num;
```

Figure 2-112. Query

Each statement retrieves the following row.

```
catalog_num  10017
stock_num    101
manu_code    PRC
cat_descr
Reinforced, hand-finished tubular. Polyurethane belted.
Effective against punctures. Mixed tread for super wear
and road grip.
cat_picture  <BYTE value>

cat_advert   Ultimate in Puncture Protection, Tires
             Designed for In-City Riding
description  bicycle tires
unit_price   $88.00
unit         box
unit_descr   4/box
```

Figure 2-113. Query result

Figure 2-112 on page 2-43 includes a TEXT column, **cat_descr**; a BYTE column, **cat_picture**; and a VARCHAR column, **cat_advert**.

Multiple-table join

A *multiple-table join* connects more than two tables on one or more associated columns; it can be an equi-join or a natural join.

The following query creates an equi-join on the **catalog**, **stock**, and **manufact** tables.

```
SELECT * FROM catalog, stock, manufact
   WHERE catalog.stock_num = stock.stock_num
      AND stock.manu_code = manufact.manu_code
      AND catalog_num = 10025;
```

Figure 2-114. Query

The query retrieves the following rows.

```
catalog_num  10025
stock_num    106
manu_code    PRC
cat_descr
Hard anodized alloy with pearl finish; 6mm hex bolt hard ware.
Available in lengths of 90-140mm in 10mm increments.
cat_picture  <BYTE value>

cat_advert   ProCycle Stem with Pearl Finish
stock_num    106
manu_code    PRC
description  bicycle stem
unit_price   $23.00
unit         each
unit_descr   each
manu_code    PRC
manu_name    ProCycle
lead_time       9
```

Figure 2-115. Query result

The **manu_code** is repeated three times, once for each table, and **stock_num** is repeated twice.

To avoid the considerable duplication of a multiple-table query such as Figure 2-114 on page 2-44, include specific columns in the projection list to define the SELECT statement more closely, as the following query shows.

```
SELECT catalog.*, description, unit_price, unit,
      unit_descr, manu_name, lead_time
   FROM catalog, stock, manufact
   WHERE catalog.stock_num = stock.stock_num
       AND stock.manu_code = manufact.manu_code
       AND catalog_num = 10025;
```

Figure 2-116. Query

The query uses a wildcard to select all columns from the table with the most columns and then specifies columns from the other two tables. The result shows the natural join that the query produces. It displays the same information as the previous example, but without duplication.

```
catalog_num  10025
stock_num    106
manu_code    PRC
cat_descr
Hard anodized alloy with pearl finish. 6mm hex bolt
hardware. Available in lengths of 90-140mm in 10mm increments.
cat_picture  <BYTE value>

cat_advert   ProCycle Stem with Pearl Finish
description  bicycle stem
unit_price   $23.00
unit         each
unit_descr   each
manu_name    ProCycle
lead_time       9
```

Figure 2-117. Query result

Some query shortcuts

You can use aliases, the INTO TEMP clause, and display labels to speed your way through joins and multiple-table queries and to produce output for other uses.

Aliases

You can assign aliases to the tables in the FROM clause of a SELECT statement to make multiple-table queries shorter and more readable. You can use an alias wherever the table name would be used, for instance, as a prefix to the column names in the other clauses.

```
SELECT s.stock_num, s.manu_code, s.description,
       s.unit_price, c.catalog_num,
       c.cat_advert, m.lead_time
   FROM stock s, catalog c, manufact m
   WHERE s.stock_num = c.stock_num
      AND s.manu_code = c.manu_code
      AND s.manu_code = m.manu_code
      AND s.manu_code IN ('HRO', 'HSK')
      AND s.stock_num BETWEEN 100 AND 301
   ORDER BY catalog_num;
```

Figure 2-118. Query

The associative nature of the SELECT statement allows you to use an alias before you define it. In the query above, the aliases **s** for the **stock** table, **c** for the **catalog** table, and **m** for the **manufact** table are specified in the FROM clause and used throughout the SELECT and WHERE clauses as column prefixes.

Compare the length of Figure 2-118 on page 2-45 with the following query, which does not use aliases.

```
SELECT stock.stock_num, stock.manu_code, stock.description,
       stock.unit_price, catalog.catalog_num,
       catalog.cat_advert,
       manufact.lead_time
   FROM stock, catalog, manufact
   WHERE stock.stock_num = catalog.stock_num
      AND stock.manu_code = catalog.manu_code
      AND stock.manu_code = manufact.manu_code
      AND stock.manu_code IN ('HRO', 'HSK')
      AND stock.stock_num BETWEEN 100 AND 301
   ORDER BY catalog_num;
```

Figure 2-119. Query

Figure 2-118 on page 2-45 and Figure 2-119 are equivalent and retrieve the data that the following query shows.

```
stock_num    110
manu_code    HRO
description  helmet
unit_price   $260.00
catalog_num  10033
cat_advert   Lightweight Plastic with Vents Assures Cool
             Comfort Without Sacrificing Protection
lead_time       4

stock_num    110
manu_code    HSK
description  helmet
unit_price   $308.00
catalog_num  10034
cat_advert   Teardrop Design Used by Yellow Jerseys; You
             Can Time the Difference
lead_time       5
⋮
```

Figure 2-120. Query result

You cannot use the ORDER BY clause for the TEXT column **cat_descr** or the BYTE column **cat_picture**.

You can use aliases to shorten your queries on tables that are not in the current database.

The following query joins columns from two tables that reside in different databases and systems, neither of which is the current database or system.

```
SELECT order_num, lname, fname, phone
FROM masterdb@central:customer c, sales@western:orders o
   WHERE c.customer_num = o.customer_num
      AND order_num <= 1010;
```

Figure 2-121. Query

By assigning the aliases c and o to the long *database@system:table* names, **masterdb@central:customer** and **sales@western:orders**, respectively, you can use the aliases to shorten the expression in the WHERE clause and retrieve the data, as the result shows.

```
order_num lname           fname           phone

    1001 Higgins         Anthony         415-368-1100
    1002 Pauli           Ludwig          408-789-8075
    1003 Higgins         Anthony         415-368-1100
    1004 Watson          George          415-389-8789
    1005 Parmelee        Jean            415-534-8822
    1006 Lawson          Margaret        415-887-7235
    1007 Sipes           Arnold          415-245-4578
    1008 Jaeger          Roy             415-743-3611
    1009 Keyes           Frances         408-277-7245
    1010 Grant           Alfred          415-356-1123
```

Figure 2-122. Query result

For more information on how to access tables that are not in the current database, see "Access other database servers" on page 7-1 and the *IBM Informix Guide to SQL: Syntax*.

You can also use synonyms as shorthand references to the long names of tables that are not in the current database as well as current tables and views. For details on how to create and use synonyms, see the *IBM Informix Database Design and Implementation Guide*.

The INTO TEMP clause

By adding an INTO TEMP clause to your SELECT statement, you can temporarily save the results of a multiple-table query in a separate table that you can query or manipulate without modifying the database. Temporary tables are dropped when you end your SQL session or when your program or report terminates.

The following query creates a temporary table called **stockman** and stores the results of the query in it. Because all columns in a temporary table must have names, the alias **adj_price** is required.

```
SELECT DISTINCT stock_num, manu_name, description,
             unit_price, unit_price * 1.05  adj_price
   FROM stock, manufact
   WHERE manufact.manu_code = stock.manu_code
   INTO TEMP stockman;
SELECT * from stockman;
```

Figure 2-123. Query

```
stock_num manu_name       description     unit_price   adj_price

        1 Hero            baseball gloves    $250.00    $262.5000
        1 Husky           baseball gloves    $800.00    $840.0000
        1 Smith           baseball gloves    $450.00    $472.5000
        2 Hero            baseball           $126.00    $132.3000
        3 Husky           baseball bat       $240.00    $252.0000
        4 Hero            football           $480.00    $504.0000
        4 Husky           football           $960.00   $1008.0000
⋮
      306 Shimara         tandem adapter     $190.00    $199.5000
      307 ProCycle        infant jogger      $250.00    $262.5000
      308 ProCycle        twin jogger        $280.00    $294.0000
      309 Hero            ear drops           $40.00     $42.0000
      309 Shimara         ear drops           $40.00     $42.0000
      310 Anza            kick board          $84.00     $88.2000
      310 Shimara         kick board          $80.00     $84.0000
      311 Shimara         water gloves        $48.00     $50.4000
      312 Hero            racer goggles       $72.00     $75.6000
      312 Shimara         racer goggles       $96.00    $100.8000
      313 Anza            swim cap            $60.00     $63.0000
      313 Shimara         swim cap            $72.00     $75.6000
```

Figure 2-124. Query result

You can query this table and join it with other tables, which avoids a multiple sort and lets you move more quickly through the database. For more information on temporary tables, see the *IBM Informix Guide to SQL: Syntax* and the *IBM Informix Administrator's Guide*.

Summary

This chapter presented syntax examples and results for basic kinds of SELECT statements that are used to query a relational database. The section "Single-table SELECT statements" on page 2-6 shows how to perform the following actions:

- Select columns and rows from a table with the Projection and FROM clauses
- Select rows from a table with the Projection, FROM, and WHERE clauses
- Use the DISTINCT or UNIQUE keyword in the Projection clause to eliminate duplicate rows from query results
- Sort retrieved data with the ORDER BY clause and the DESC keyword
- Select and order data values that contain non-English characters
- Use the BETWEEN, IN, MATCHES, and LIKE keywords and various relational operators in the WHERE clause to create comparison conditions
- Create comparison conditions that include values, exclude values, find a range of values (with keywords, relational operators, and subscripting), and find a subset of values
- Use exact-text comparisons, variable-length wildcards, and restricted and unrestricted wildcards to perform variable text searches
- Use the logical operators AND, OR, and NOT to connect search conditions or Boolean expressions in a WHERE clause
- Use the ESCAPE keyword to protect special characters in a query
- Search for NULL values with the IS NULL and IS NOT NULL keywords in the WHERE clause

- Use the FIRST clause to specify that a query returns only a specified number of the rows that match the conditions of the SELECT statement
- Use arithmetic operators in the Projection clause to perform computations on number fields and display derived data
- Assign display labels to computed columns as a formatting tool for reports

This chapter also introduced simple join conditions that enable you to select and display data from two or more tables. The section "Multiple-table SELECT statements" on page 2-38 describes how to perform the following actions:

- Create a Cartesian product
- Create a CROSS JOIN, which creates a Cartesian product
- Include a WHERE clause with a valid join condition in your query to constrain a Cartesian product
- Define and create a natural join and an equi-join
- Join two or more tables on one or more columns
- Use aliases as a shortcut in multiple-table queries
- Retrieve selected data into a separate, temporary table with the INTO TEMP clause to perform computations outside the database

Chapter 3. Select data from complex types

This chapter describes how to query *complex data types*. A complex data type is built from a combination of other data types with an SQL type constructor. An SQL statement can access individual components within the complex type. Complex data types are *row types* or *collection types*.

ROW types have instances that combine one or more related data fields. The two kinds of ROW types are *named* and *unnamed*.

Collection types have instances where each collection value contains a group of elements of the same data type, which can be any fundamental or complex data type. A collection can consist of a LIST, SET, or MULTISET datatype.

Important: There is no cross-database support for complex data types. They can only be manipulated in local databases.

For a more complete description of the data types that the database server supports, see the chapter on data types in the *IBM Informix Guide to SQL: Reference*.

For information about how to create and use complex types, see the *IBM Informix Database Design and Implementation Guide*, *IBM Informix Guide to SQL: Reference*, and *IBM Informix Guide to SQL: Syntax*.

Select row-type data

This section describes how to query data that is defined as row-type data. A ROW type is a complex type that combines one or more related data fields.

The two kinds of ROW types are as follows:

Named ROW type
A named ROW type can define tables, columns, fields of another row-type column, program variables, statement local variables, and routine return values.

Unnamed ROW type
An unnamed ROW type can define columns, fields of another row-type column, program variables, statement local variables, routine return values, and constants.

The examples used throughout this section use the named ROW types **zip_t**, **address_t**, and **employee_t**, which define the **employee** table. The following figure shows the SQL syntax that creates the ROW types and table.

```
CREATE ROW TYPE zip_t
(
   z_code    CHAR(5),
   z_suffix  CHAR(4)
)

CREATE ROW TYPE address_t
(
   street    VARCHAR(20),
   city      VARCHAR(20),
   state     CHAR(2),
   zip       zip_t
)

CREATE ROW TYPE employee_t
(
name      VARCHAR(30),
address   address_t,
salary    INTEGER
)

CREATE TABLE employee OF TYPE employee_t
```

Figure 3-1. SQL syntax that creates the ROW types and table.

The named ROW types **zip_t**, **address_t** and **employee_t** serve as templates for the fields and columns of the typed table, **employee**. A *typed table* is a table that is defined on a named ROW type. The **employee_t** type that serves as the template for the **employee** table uses the **address_t** type as the data type of the **address** field. The **address_t** type uses the **zip_t** type as the data type of the **zip** field.

The following figure shows the SQL syntax that creates the **student** table. The **s_address** column of the **student** table is defined on an unnamed ROW type. (The **s_address** column could also have been defined as a named ROW type.)

```
CREATE TABLE student
(
s_name      VARCHAR(30),
s_address   ROW(street VARCHAR (20), city VARCHAR(20),
              state CHAR(2), zip VARCHAR(9)),
              grade_point_avg DECIMAL(3,2)
)
```

Figure 3-2. SQL syntax that creates the student table.

Select columns of a typed table

A query on a typed table is no different from a query on any other table. For example, the following query uses the asterisk symbol (*) to specify a SELECT statement that returns all columns of the **employee** table.

```
SELECT * FROM employee
```

Figure 3-3. Query

The SELECT statement on the **employee** table returns all rows for all columns.

```
name        Paul, J.
address     ROW(102 Ruby, Belmont, CA, 49932, 1000)
salary      78000

name        Davis, J.
address     ROW(133 First, San Jose, CA, 85744, 4900)
salary      75000
⋮
```

Figure 3-4. Query result

The following query shows how to construct a query that returns rows for the **name** and **address** columns of the **employee** table.

```
SELECT name, address FROM employee
```

Figure 3-5. Query

```
name        Paul, J.
address     ROW(102 Ruby, Belmont, CA, 49932, 1000)

name        Davis, J.
address     ROW(133 First, San Jose, CA, 85744, 4900)
⋮
```

Figure 3-6. Query result

Select columns that contain row-type data

A *row-type column* is a column that is defined on a named ROW type or unnamed ROW type. You use the same SQL syntax to query a named ROW type and an unnamed row-type column.

A query on a row-type column returns data from all the fields of the ROW type. A *field* is a component data type within a ROW type. For example, the **address** column of the **employee** table contains the **street**, **city**, **state**, and **zip** fields. The following query shows how to construct a query that returns all fields of the **address** column.

```
SELECT address FROM employee
```

Figure 3-7. Query

```
address     ROW(102 Ruby, Belmont, CA, 49932, 1000)
address     ROW(133 First, San Jose, CA, 85744, 4900)
address     ROW(152 Topaz, Willits, CA, 69445, 1000))
⋮
```

Figure 3-8. Query result

To access individual fields that a column contains, use single-dot notation to project the individual fields of the column. For example, suppose you want to access specific fields from the **address** column of the **employee** table. The following SELECT statement projects the **city** and **state** fields from the **address** column.

```
SELECT address.city, address.state FROM employee
```

Figure 3-9. Query

```
city            state

Belmont         CA
San Jose        CA
Willits         CA
⋮
```

Figure 3-10. Query result

You construct a query on an unnamed row-type column in the same way you construct a query on a named row-type column. For example, suppose you want to access data from the **s_address** column of the **student** table in Figure 3-2 on page 3-2. You can use *dot notation* to query the individual fields of a column that are defined on an unnamed row type. The following query shows how to construct a SELECT statement on the **student** table that returns rows for the **city** and **state** fields of the **s_address** column.

```
SELECT s_address.city, s_address.state FROM student
```

Figure 3-11. Query

```
city            state

Belmont         CA
Mount Prospect  IL
Greeley         CO
⋮
```

Figure 3-12. Query result

Field projections

Do not confuse fields with columns. Columns are only associated with tables, and column projections use conventional dot notation of the form `name_1.name2` for a table and column, respectively. A *field* is a component data type within a ROW type. With ROW types (and the capability to assign a ROW type to a single column), you can project individual fields of a column with single dot notation of the form: `name_a.name_b.name_c.name_d`. IBM Informix database servers use the following precedence rules to interpret dot notation:

1. table_name_a . column_name_b . field_name_c . field_name_d
2. column_name_a . field_name_b . field_name_c . field_name_d

When the meaning of a particular identifier is ambiguous, the database server uses precedence rules to determine which database object the identifier specifies. Consider the following two statements:

```
CREATE TABLE b (c ROW(d INTEGER, e CHAR(2)))
CREATE TABLE c (d INTEGER)
```

In the following SELECT statement, the expression `c.d` references column **d** of table **c** (rather than field **d** of column **c** in table **b**) because a table identifier has a higher precedence than a column identifier:

```
SELECT * FROM b,c WHERE c.d = 10
```

To avoid referencing the wrong database object, you can specify the full notation for a field projection. Suppose, for example, you want to reference field **d** of column **c** in table **b** (not column **d** of table **c**). The following statement specifies the table, column, and field identifiers of the object you want to reference:

```
SELECT * FROM b,c WHERE b.c.d = 10
```

Important: Although precedence rules reduce the chance of the database server misinterpreting field projections, it is recommended that you use unique names for all table, column, and field identifiers.

Field projections to select nested fields

Typically the row type is a column, but you can use any row-type expression for field projection. When the row-type expression itself contains other row types, the expression contains nested fields. To access nested fields within an expression or individual fields, use dot notation. To access all the fields of the row type, use an asterisk (*). This section describes both methods of row-type access.

For a discussion of how to use dot notation and asterisk notation with row-type expressions, see the Expression segment in the *IBM Informix Guide to SQL: Syntax*.

Select individual fields of a row type:
Consider the **address** column of the **employee** table, which contains the fields **street**, **city**, **state**, and **zip**. In addition, the **zip** field contains the nested fields: **z_code** and **z_suffix**. (You might want to review the row type and table definitions of Figure 3-1 on page 3-2.) A query on the **zip** field returns rows for the **z_code** and **z_suffix** fields. However, you can specify that a query returns only specific nested fields. The following query shows how to use dot notation to construct a SELECT statement that returns rows for the **z_code** field of the **address** column only.

```
SELECT address.zip.z_code FROM employee
```

Figure 3-13. Query

```
z_code

39444
6500
76055
19004
⋮
```

Figure 3-14. Query result

Asterisk notation to access all fields of a row type

Asterisk notation is supported only within the select list of a SELECT statement. When you specify the column name for a row-type column in a projection list, the database server returns values for all fields of the column. You can also use asterisk notation when you want to project all the fields within a ROW type.

The following query uses asterisk notation to return all fields of the **address** column in the **employee** table.

```
SELECT address.* FROM employee;
```

Figure 3-15. Query

```
address   ROW(102 Ruby, Belmont, CA, 49932, 1000)
address   ROW(133 First, San Jose, CA, 85744, 4900)
address   ROW(152 Topaz, Willits, CA, 69445, 1000))
⋮
```

Figure 3-16. Query result

The asterisk notation makes it easier to perform some SQL tasks. Suppose you create a function **new_row()** that returns a row-type value and you want to call this function and insert the row that is returned into a table. The database server provides no easy way to handle such operations. However, the following query shows how to use asterisk notation to return all fields of **new_row()** and insert the returned fields into the **tab_2** table.

```
INSERT INTO tab_2 SELECT new_row(exp).* FROM tab_1
```

Figure 3-17. Query

For information about how to use the INSERT statement, see Chapter 6, "Modify data," on page 6-1.

Important: An expression that uses the `.*` notation is evaluated only once.

Select from a collection

This section describes how to query columns that are defined on collection types. A *collection type* is a complex data type in which each collection value contains a group of elements of the same data type. For a detailed description of collection data types, see the *IBM Informix Database Design and Implementation Guide*. For information about how to access the individual elements that a collection contains, see "Handle collections in SELECT statements" on page 5-27.

The following figure shows the **manager** table, which is used in examples throughout this section. The **manager** table contains both simple and nested collection types. A *simple collection* is a collection type that does not contain any fields that are themselves collection types. The **direct_reports** column of the **manager** table is a simple collection. A *nested collection* is a collection type that contains another collection type. The **projects** column of the **manager** table is a nested collection.

```
CREATE TABLE manager
(
   mgr_name        VARCHAR(30),
   department      VARCHAR(12),
   direct_reports  SET(VARCHAR(30) NOT NULL),
   projects        LIST(ROW(pro_name VARCHAR(15),
                     pro_members SET(VARCHAR(20) NOT NULL)
                     ) NOT NULL)
)
```

Figure 3-18. The manager table

A query on a column that is a collection type returns, for each row in the table, all the elements that the particular collection contains. For example, the following query shows a query that returns data in the **department** column and all elements in the **direct_reports** column for each row of the **manager** table.

```
SELECT department, direct_reports FROM manager
```

Figure 3-19. Query

```
department      marketing
direct_reports  SET {Smith, Waters, Adams, Davis, Kurasawa}

department      engineering
ddirect_reports  SET {Joshi, Davis, Smith, Waters, Fosmire, Evans, Jones}

department      publications
direct_reports  SET {Walker, Fremont, Porat, Johnson}

department      accounting
direct_reports  SET {Baker, Freeman, Jacobs}
⋮
```

Figure 3-20. Query result

The output of a query on a collection type always includes the type constructor that specifies whether the collection is a SET, MULTISET, or LIST. For example, in the result, the SET constructor precedes the elements of each collection. Braces ({}) demarcate the elements of a collection; commas separate individual elements of a collection.

Select nested collections

The **projects** column of the **manager** table (see Figure 3-18 on page 3-6) is a nested collection. A query on a nested collection type returns all the elements that the particular collection contains. The following query shows a query that returns all elements from the **projects** column for a specified row. The WHERE clause limits the query to a single row in which the value in the **mgr_name** column is `Sayles`.

```
SELECT projects
   FROM manager
   WHERE mgr_name = 'Sayles'
```

Figure 3-21. Query

The query result shows a **project** column collection for a single row of the **manager** table. The query returns the names of those projects that the manager `Sayles` oversees. The collection contains, for each element in the LIST, the project name (**pro_name**) and the SET of individuals (**pro_members**) who are assigned to each project.

```
projects  LIST {ROW(voyager_project, SET{Simonian, Waters, Adams, Davis})}

projects  LIST {ROW(horizon_project, SET{Freeman, Jacobs, Walker, Cannan})}

projects  LIST {ROW(sapphire_project, SET{Villers, Reeves, Doyle, Strongin})}
⋮
```

Figure 3-22. Query result

The IN keyword to search for elements in a collection

You can use the IN keyword in the WHERE clause of an SQL statement to determine whether a collection contains a certain element. For example, the following query shows how to construct a query that returns values for **mgr_name** and **department** where `Adams` is an element of a collection in the **direct_reports** column.

```
SELECT mgr_name, department
   FROM manager
   WHERE 'Adams' IN direct_reports
```

Figure 3-23. Query

```
mgr_name     Sayles
department   marketing
```

Figure 3-24. Query result

Although you can use a WHERE clause with the IN keyword to search for a particular element in a simple collection, the query always returns the complete collection. For example, the following query returns all the elements of the collection where `Adams` is an element of a collection in the **direct_reports** column.

```
SELECT mgr_name, direct_reports
   FROM manager
   WHERE 'Adams' IN direct_reports
```

Figure 3-25. Query

```
mgr_name        Sayles
direct_reports  SET {Smith, Waters, Adams, Davis, Kurasawa}
```

Figure 3-26. Query result

As the result shows, a query on a collection column returns the entire collection, not a particular element within the collection.

You can use the IN keyword in a WHERE clause to reference a simple collection only. You cannot use the IN keyword to reference a collection that contains fields that are themselves collections. For example, you cannot use the IN keyword to reference the **projects** column in the **manager** table because **projects** is a nested collection.

You can combine the NOT and IN keywords in the WHERE clause of a SELECT statement to search for collections that do not contain a certain element. For example, the following query shows a query that returns values for **mgr_name** and **department** where Adams is not an element of a collection in the **direct_reports** column.

```
SELECT mgr_name, department
   FROM manager
   WHERE 'Adams' NOT IN direct_reports
```

Figure 3-27. Query

```
mgr_name     Williams
department   engineering

mgr_name     Lyman
department   publications

mgr_name     Cole
department   accounting
```

Figure 3-28. Query result

For information about how to count the elements in a collection column, see “Cardinality function” on page 4-12.

Select rows within a table hierarchy

This section describes how to query rows from tables within a table hierarchy. For more information about how to create and use a table hierarchy, see the *IBM Informix Database Design and Implementation Guide*.

The following figure shows the statements that create the type and table hierarchies that the examples in this section use.

```
CREATE ROW TYPE address_t
(
   street   VARCHAR (20),
   city     VARCHAR(20),
   state    CHAR(2),
   zip      VARCHAR(9)
)

CREATE ROW TYPE person_t
(
   name     VARCHAR(30),
   address  address_t,
   soc_sec  CHAR(9)
)

CREATE ROW TYPE employee_t
(
salary       INTEGER
)
UNDER person_t

CREATE ROW TYPE sales_rep_t
(
   rep_num     SERIAL8,
   region_num  INTEGER
)
UNDER employee_t

CREATE TABLE person OF TYPE person_t

CREATE TABLE employee OF TYPE employee_t
UNDER person

CREATE TABLE sales_rep OF TYPE sales_rep_t
UNDER employee
```

Figure 3-29. Statements that create the type and table hierarchies.

The following figure shows the hierarchical relationships of the row types and tables in the previous figure.

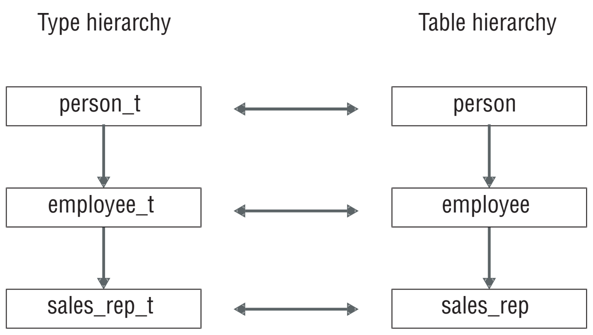


Figure 3-30. Type and table hierarchies

Select rows of the supertable without the ONLY keyword

A table hierarchy allows you to construct, in a single SQL statement, a query whose scope is a supertable and its subtables. A query on a supertable returns rows from both the supertable and its subtables. The following query shows a query on the **person** table, which is the root supertable in the table hierarchy.

```
SELECT * FROM person
```

Figure 3-31. Query

Figure 2-31 on page 2-12 returns all columns in the supertable and those columns in subtables (**employee** and **sales_rep**) that are inherited from the supertable. A query on a supertable does not return columns from subtables that are not in the supertable. The query result shows the **name**, **address**, and **soc_sec** columns in the **person**, **employee**, and **sales_rep** tables.

```
name        Rogers, J.
address     ROW(102 Ruby Ave, Belmont, CA, 69055)
soc_sec     454849344

name        Sallie, A.
address     ROW(134 Rose St, San Carlos, CA, 69025)
soc_sec     348441214
⋮
```

Figure 3-32. Query result

Select rows from a supertable with the ONLY keyword

Although a SELECT statement on a supertable returns rows from both the supertable and its subtables, you cannot tell which rows come from the supertable and which rows come from the subtables. To limit the results of a query to the supertable only, you must include the ONLY keyword in the SELECT statement. For example, the following query returns rows in the **person** table only.

```
SELECT * FROM ONLY(person);
```

Figure 3-33. Query

```
name        Rogers, J.
address     ROW(102 Ruby Ave, Belmont, CA, 69055)
soc_sec     454849344
⋮
```

Figure 3-34. Query result

An alias for a supertable

An *alias* is a word that immediately follows the name of a table in the FROM clause. You can specify an alias for a typed table in a SELECT or UPDATE statement and then use the alias (in the same SELECT or UPDATE statement) as an expression by itself. If you create an alias for a supertable, the alias can represent values from the supertable or the subtables that inherit from the supertable. In DB-Access, the following query returns row values for all instances of the **person**, **employee**, and **sales_rep** tables.

```
SELECT p FROM person p;
```

Figure 3-35. Query

Informix ESQL/C does not recognize this construct. In an Informix ESQL/C program, the query returns an error.

Summary

This chapter introduced sample syntax and results for selecting data from complex types using SELECT statements to query a relational database. The section "Select row-type data" on page 3-1 shows how to perform the following actions:

- Select row-type data from typed tables and columns
- Use row-type expressions for field projections

The section "Select from a collection" on page 3-6 shows how to perform the following actions:

- Query columns that are defined on collection types
- Search for elements in a collection
- Query columns that are defined on nested collection types

The section "Select rows within a table hierarchy" on page 3-9 shows how to perform the following actions:

- Query a supertable with or without the ONLY keyword
- Specify an alias for a supertable

Chapter 4. Functions in SELECT statements

In addition to column names and operators, an expression can also include one or more functions. This chapter shows how to use functions in SELECT statements to perform more complex database queries and data manipulation.

For information about the syntax of the following SQL functions and other SQL functions, see the Expressions segment in the *IBM Informix Guide to SQL: Syntax*.

Tip: You can also use functions that you create yourself. For information about user-defined functions, see Chapter 11, "Create and use SPL routines," on page 11-1, and *IBM Informix User-Defined Routines and Data Types Developer's Guide*.

Functions in SELECT statements

You can use any basic type of expression (column, constant, function, aggregate function, and procedure), or combination thereof, in the select list.

A function expression uses a function that is evaluated for each row in the query. All function expressions require arguments. This set of expressions contains the time function and the length function when they are used with a column name as an argument.

Aggregate functions

An aggregate function returns one value for a set of queried rows. The aggregate functions take on values that depend on the set of rows that the WHERE clause of the SELECT statement returns. In the absence of a WHERE clause, the aggregate functions take on values that depend on all the rows that the FROM clause forms.

You cannot use aggregate functions for expressions that contain the following data types:
- TEXT
- BYTE
- CLOB
- BLOB
- Collection data types (LIST, MULTISET, and SET)
- ROW types
- Opaque data types (except with user-defined aggregate functions that support opaque types)

Aggregates are often used to summarize information about groups of rows in a table. This use is discussed in Chapter 5, "Compose advanced SELECT statements," on page 5-1. When you apply an aggregate function to an entire table, the result contains a single row that summarizes all the selected rows.

All IBM Informix database servers support the following aggregate functions.

The AVG function

The following query computes the average **unit_price** of all rows in the **stock** table.

```
SELECT AVG (unit_price) FROM stock;
```

Figure 4-1. Query

```
  (avg)

$197.14
```

Figure 4-2. Query result

The following query computes the average **unit_price** of just those rows in the **stock** table that have a **manu_code** of SHM.

```
SELECT AVG (unit_price) FROM stock WHERE manu_code = 'SHM';
```

Figure 4-3. Query

```
  (avg)

$204.93
```

Figure 4-4. Query result

The COUNT function

The following query counts and displays the total number of rows in the **stock** table.

```
SELECT COUNT(*) FROM stock;
```

Figure 4-5. Query

```
(count(*))

   73
```

Figure 4-6. Query result

The following query includes a WHERE clause to count specific rows in the **stock** table, in this case, only those rows that have a **manu_code** of SHM.

```
SELECT COUNT (*) FROM stock WHERE manu_code = 'SHM';
```

Figure 4-7. Query

```
(count(*))

   17
```

Figure 4-8. Query result

By including the keyword DISTINCT (or its synonym UNIQUE) and a column name in the following query, you can tally the number of different manufacturer codes in the **stock** table.

```
SELECT COUNT (DISTINCT manu_code) FROM stock;
```

Figure 4-9. Query

```
(count)

   9
```

Figure 4-10. Query result

The MAX and MIN functions

You can combine aggregate functions in the same SELECT statement. For example, you can include both the **MAX** and the **MIN** functions in the select list, as the following query shows.

```
SELECT MAX (ship_charge), MIN (ship_charge) FROM orders;
```

Figure 4-11. Query

The query finds and displays both the highest and lowest **ship_charge** in the **orders** table.

```
 (max)     (min)

$25.20     $5.00
```

Figure 4-12. Query result

The RANGE function

The **RANGE** function computes the difference between the maximum and the minimum values for the selected rows.

You can apply the **RANGE** function only to numeric columns. The following query finds the range of prices for items in the **stock** table.

```
SELECT RANGE(unit_price) FROM stock;
```

Figure 4-13. Query

```
(range)

955.50
```

Figure 4-14. Query result

As with other aggregates, the **RANGE** function applies to the rows of a group when the query includes a GROUP BY clause, which the following query shows.

```
SELECT RANGE(unit_price) FROM stock
   GROUP BY manu_code;
```

Figure 4-15. Query

```
(range)

820.20
595.50
720.00
225.00
632.50
  0.00
460.00
645.90
425.00
```

Figure 4-16. Query result

The STDEV function

The **STDEV** function computes the standard deviation for the selected rows. It is the square root of the **VARIANCE** function.

You can apply the **STDEV** function only to numeric columns. The following query finds the standard deviation on a population:

```
SELECT STDEV(age) FROM u_pop WHERE age > 21;
```

As with the other aggregates, the **STDEV** function applies to the rows of a group when the query includes a GROUP BY clause, as the following example shows:

```
SELECT STDEV(age) FROM u_pop
   GROUP BY state
   WHERE STDEV(age) > 21;
```

Nulls are ignored unless every value in the specified column is null. If every column value is null, the **STDEV** function returns a null for that column. For more information about the **STDEV** function, see the Expression segment in the *IBM Informix Guide to SQL: Syntax*.

The SUM function

The following query calculates the total **ship_weight** of orders that were shipped on July 13, 1998.

```
SELECT SUM (ship_weight) FROM orders
   WHERE ship_date = '07/13/1998';
```

Figure 4-17. Query

```
(sum)

130.5
```

Figure 4-18. Query result

The VARIANCE function

The **VARIANCE** function returns the variance for a sample of values as an unbiased estimate of the variance for all rows selected. It computes the following value:

```
(SUM(Xi**2) - (SUM(Xi)**2)/N)/(N-1)
```

In this example, `Xi` is each value in the column and `N` is the total number of values in the column. You can apply the **VARIANCE** function only to numeric columns. The following query finds the variance on a population:

```
SELECT VARIANCE(age) FROM u_pop WHERE age > 21;
```

As with the other aggregates, the **VARIANCE** function applies to the rows of a group when the query includes a GROUP BY clause, which the following example shows:

```
SELECT VARIANCE(age) FROM u_pop
   GROUP BY birth
   WHERE VARIANCE(age) > 21;
```

Nulls are ignored unless every value in the specified column is null. If every column value is null, the **VARIANCE** function returns a null for that column. For more information about the **VARIANCE** function, see the Expression segment in the *IBM Informix Guide to SQL: Syntax*.

Apply functions to expressions

The following query shows how you can apply functions to expressions and supply display labels for their results.

```
SELECT MAX (res_dtime - call_dtime) maximum,
   MIN (res_dtime - call_dtime) minimum,
   AVG (res_dtime - call_dtime) average
   FROM cust_calls;
```

Figure 4-19. Query

The query finds and displays the maximum, minimum, and average amounts of time (in days, hours, and minutes) between the reception and resolution of a customer call and labels the derived values appropriately. The query result shows these qualities of time.

```
maximum         minimum         average

5 20:55         0 00:01         1 02:56
```

Figure 4-20. Query result

Time functions

You can use the time functions **DAY**, **MONTH**, **WEEKDAY**, and **YEAR** in either the Projection clause or the WHERE clause of a query. These functions return a value that corresponds to the expressions or arguments that you use to call the function. You can also use the **CURRENT** or **SYSDATE** function to return a value with the current date and time, or use the **EXTEND** function to adjust the precision of a DATE or DATETIME value.

The DAY and CURRENT functions

The following query returns the day of the month for the **call_dtime** and **res_dtime** columns in two *expression* columns.

```
SELECT customer_num, DAY (call_dtime), DAY (res_dtime)
   FROM cust_calls;
```

Figure 4-21. Query

```
customer_num  (expression) (expression)

         106           12          12
         110            7           7
         119            1           2
         121           10          10
         127           31
         116           28          28
         116           21          27
```

Figure 4-22. Query result

The following query uses the **DAY** and **CURRENT** functions to compare column values to the current day of the month. It selects only those rows where the value is earlier than the current day. In this example, the CURRENT day is 15.

```
SELECT customer_num, DAY (call_dtime), DAY (res_dtime)
   FROM cust_calls
   WHERE DAY (call_dtime) < DAY (CURRENT);
```

Figure 4-23. Query

```
customer_num  (expression) (expression)
         106          12           12
         110           7            7
         119           1            2
         121          10           10
```

Figure 4-24. Query result

The following query uses the **CURRENT** function to select all calls except those that came in today.

```
SELECT customer_num, call_code, call_descr
   FROM cust_calls
   WHERE call_dtime < CURRENT YEAR TO DAY;
```

Figure 4-25. Query

```
customer_num  106
call_code     D
call_descr    Order was received, but two of the cans of ANZ tennis balls
              within the case were empty

customer_num  110
call_code     L
call_descr     Order placed one month ago (6/7) not received.
⋮
customer_num  116
call_code     I
call_descr    Second complaint from this customer! Received two cases
              right-handed outfielder gloves (1 HRO) instead of one case
              lefties.
```

Figure 4-26. Query result

The **SYSDATE** function closely resembles the **CURRENT** function, but the default precision of its returned value is DATETIME YEAR TO FRACTION(5), rather than the default DATETIME YEAR TO FRACTION(3) precision of **CURRENT** when no DATETIME qualifier is specified.

The MONTH function

The following query uses the **MONTH** function to extract and show what month the customer call was received and resolved, and it uses display labels for the resulting columns. However, it does not make a distinction between years.

```
SELECT customer_num,
   MONTH (call_dtime) call_month,
   MONTH (res_dtime) res_month
   FROM cust_calls;
```

Figure 4-27. Query

```
customer_num   call_month    res_month

         106            6            6
         110            7            7
         119            7            7
         121            7            7
         127            7
         116           11           11
         116           12           12
```

Figure 4-28. Query result

The following query uses the **MONTH** function plus **DAY** and **CURRENT** to show what month the customer call was received and resolved if **DAY** is earlier than the current day.

```
SELECT customer_num,
   MONTH (call_dtime) called,
   MONTH (res_dtime) resolved
   FROM cust_calls
   WHERE DAY (res_dtime) < DAY (CURRENT);
```

Figure 4-29. Query

```
customer_num     called   resolved

         106          6          6
         119          7          7
         121          7          7
```

Figure 4-30. Query result

The WEEKDAY function

The following query uses the **WEEKDAY** function to indicate which day of the week calls are received and resolved (0 represents Sunday, 1 is Monday, and so on), and the expression columns are labeled.

```
SELECT customer_num,
   WEEKDAY (call_dtime) called,
   WEEKDAY (res_dtime) resolved
   FROM cust_calls
   ORDER BY resolved;
```

Figure 4-31. Query

```
customer_num     called   resolved

         127         3
         110         0          0
         119         1          2
         121         3          3
         116         3          3
         106         3          3
         116         5          4
```

Figure 4-32. Query result

The following query uses the **COUNT** and **WEEKDAY** functions to count how many calls were received on a weekend. This kind of statement can give you an idea of customer-call patterns or indicate whether overtime pay might be required.

```
SELECT COUNT(*)
   FROM cust_calls
   WHERE WEEKDAY (call_dtime) IN (0,6);
```

Figure 4-33. Query

```
(count(*))

         4
```

Figure 4-34. Query result

The YEAR function

The following query retrieves rows where the **call_dtime** is earlier than the beginning of the current year.

```
SELECT customer_num, call_code,
   YEAR (call_dtime) call_year,
   YEAR (res_dtime) res_year
   FROM cust_calls
   WHERE YEAR (call_dtime) < YEAR (TODAY);
```

Figure 4-35. Query

```
customer_num call_code call_year res_year

         116 I              1997     1997
         116 I              1997     1997
```

Figure 4-36. Query result

Format DATETIME values

In the following query, the **EXTEND** function displays only the specified subfields to restrict the two DATETIME values.

```
SELECT customer_num,
   EXTEND (call_dtime, month to minute) call_time,
   EXTEND (res_dtime, month to minute) res_time
   FROM cust_calls
   ORDER BY res_time;
```

Figure 4-37. Query

The query returns the month-to-minute range for the columns labeled **call_time** and **res_time** and gives an indication of the work load.

```
customer_num call_time   res_time

         127 07-31 14:30
         106 06-12 08:20 06-12 08:25
         119 07-01 15:00 07-02 08:21
         110 07-07 10:24 07-07 10:30
         121 07-10 14:05 07-10 14:06
         116 11-28 13:34 11-28 16:47
         116 12-21 11:24 12-27 08:19
```

Figure 4-38. Query result

The **TO_CHAR** function can also format DATETIME values. See "The TO_CHAR function" on page 4-10 for information about this built-in function, which can also accept DATE values or numeric values as an argument, and returns a formatted character string.

Besides the built-in time functions that these examples illustrate, IBM Informix also supports the **ADD_MONTHS**, **LAST_DAY**, **MDY**, **MONTHS_BETWEEN**, and **NEXT_DAY** functions. In addition to these functions, the **TRUNC** and **ROUND** functions can return values that change the precision of DATE or DATETIME arguments. These additional time functions are described in the *IBM Informix Guide to SQL: Syntax*.

Date-conversion functions

You can use a date-conversion function anywhere you use an expression.

The following conversion functions convert between date and character values:

The DATE function

The **DATE** function converts a character string to a DATE value. In the following query, the **DATE** function converts a character string to a DATE value to allow for comparisons with DATETIME values. The query retrieves DATETIME values only when **call_dtime** is later than the specified **DATE**.

```
SELECT customer_num, call_dtime, res_dtime
   FROM cust_calls
   WHERE call_dtime > DATE ('12/31/97');
```

Figure 4-39. Query

```
customer_num call_dtime       res_dtime

         106 1998-06-12 08:20 1998-06-12 08:25
         110 1998-07-07 10:24 1998-07-07 10:30
         119 1998-07-01 15:00 1998-07-02 08:21
         121 1998-07-10 14:05 1998-07-10 14:06
         127 1998-07-31 14:30
```

Figure 4-40. Query result

The following query converts DATETIME values to DATE format and displays the values, with labels, only when **call_dtime** is greater than or equal to the specified date.

```
SELECT customer_num,
   DATE (call_dtime) called,
   DATE (res_dtime) resolved
   FROM cust_calls
   WHERE call_dtime >= DATE ('1/1/98');
```

Figure 4-41. Query

```
customer_num called      resolved

         106 06/12/1998   06/12/1998
         110 07/07/1998   07/07/1998
         119 07/01/1998   07/02/1998
         121 07/10/1998   07/10/1998
         127 07/31/1998
```

Figure 4-42. Query result

The TO_CHAR function

The **TO_CHAR** function converts DATETIME or DATE values to character string values. The **TO_CHAR** function evaluates a DATETIME value according to the date-formatting directive that you specify and returns an NVARCHAR value. For a complete list of the supported date-formatting directives, see the description of the **GL_DATETIME** environment variable in the *IBM Informix GLS User's Guide*.

You can also use the **TO_CHAR** function to convert a DATETIME or DATE value to an LVARCHAR value.

The following query uses the **TO_CHAR** function to convert a DATETIME value to a more readable character string.

```
SELECT customer_num,
   TO_CHAR(call_dtime, "%A %B %d %Y") call_date
   FROM cust_calls
   WHERE call_code = "B";
```

Figure 4-43. Query

```
customer_num  119
call_date     Friday July 01 1998
```

Figure 4-44. Query result

The following query uses the **TO_CHAR** function to convert DATE values to more readable character strings.

```
SELECT order_num,
   TO_CHAR(ship_date,"%A %B %d %Y") date_shipped
   FROM orders
   WHERE paid_date IS NULL;
```

Figure 4-45. Query

```
order_num           1004
date_shipped        Monday May 30 1998

order_num           1006
date_shipped

order_num           1007
date_shipped        Sunday June 05 1998

order_num           1012
date_shipped        Wednesday June 29 1998

order_num           1016
date_shipped        Tuesday July 12 1998

order_num           1017
date_shipped        Wednesday July 13 1998
```

Figure 4-46. Query result

The **TO_CHAR** function can also format numeric values. For more information about the built-in **TO_CHAR** function, see the *IBM Informix Guide to SQL: Syntax*.

The TO_DATE function

The **TO_DATE** function accepts an argument of a character data type and converts this value to a DATETIME value. The **TO_DATE** function evaluates a character string according to the date-formatting directive that you specify and returns a DATETIME value. For a complete list of the supported date-formatting directives, see the description of the **GL_DATETIME** environment variable in the *IBM Informix GLS User's Guide*.

You can also use the **TO_DATE** function to convert an LVARCHAR value to a DATETIME value.

The following query uses the **TO_DATE** function to convert character string values to DATETIME values whose format you specify.

```
SELECT customer_num, call_descr
  FROM cust_calls
  WHERE call_dtime = TO_DATE("2008-07-07 10:24",
  "%Y-%m-%d %H:%M");
```

Figure 4-47. Query

```
customer_num   110

call_descr     Order placed one month ago (6/7) not received.
```

Figure 4-48. Query result

You can use the **DATE** or **TO_DATE** function to convert a character string to a DATE value. One advantage of the **TO_DATE** function is that it allows you to specify a format for the value returned. (You can use the **TO_DATE** function, which always returns a DATETIME value, to convert a character string to a DATE value because the database server implicitly handles conversions between DATE and DATETIME values.)

Cardinality function

The **CARDINALITY** function counts the number of elements that a collection contains. You can use the **CARDINALITY** function with simple or nested collections. Any duplicates in a collection are counted as individual elements. The following query shows a query that returns, for every row in the **manager** table, **department** values and the number of elements in each **direct_reports** collection.

```
SELECT department, CARDINALITY(direct_reports) FROM manager;
```

Figure 4-49. Query

```
department   marketing 5

department   engineering 7

department   publications 4

department   accounting 3
```

Figure 4-50. Query result

You can also evaluate the number of elements in a collection from within a predicate expression, as the following query shows.

```
SELECT department, CARDINALITY(direct_reports) FROM manager
   WHERE CARDINALITY(direct_reports) < 6
   GROUP BY department;
```

Figure 4-51. Query

```
department   accounting 3

department   marketing 5

department   publications 4
```

Figure 4-52. Query result

Smart large object functions

The database server provides four SQL functions that you can call from within an SQL statement to import and export smart large objects. The following table shows the smart-large-object functions.

Table 4-1. SQL functions for smart large objects

Function name	**Purpose**
FILETOBLOB()	Copies a file into a BLOB column
FILETOCLOB()	Copies a file into a CLOB column
LOCOPY()	Copies BLOB or CLOB data into another BLOB or CLOB column
LOTOFILE()	Copies a BLOB or CLOB into a file

For detailed information and the syntax of smart-large-object functions, see the Expression segment in the *IBM Informix Guide to SQL: Syntax*.

You can use any of the functions that the table shows in SELECT, UPDATE, and INSERT statements. For examples of how to use the preceding functions in INSERT and UPDATE statements, see Chapter 6, “Modify data,” on page 6-1.

Suppose you create the **inmate** and **fbi_list** tables, as the following figure shows.

```
CREATE TABLE inmate
(
   id_num   INT,
   picture  BLOB,
   felony   CLOB
);

CREATE TABLE fbi_list
(
   id       INTEGER,
   mugshot  BLOB
) PUT mugshot IN (sbspace1);
```

Figure 4-53. Create the inmate and fbi_list tables.

The following SELECT statement uses the **LOTOFILE()** function to copy data from the **felony** column into the `felon_322.txt` file that is located on the client computer:

```
SELECT id_num, LOTOFILE(felony, 'felon_322.txt', 'client')
   FROM inmate
   WHERE id = 322;
```

The first argument for **LOTOFILE()** specifies the name of the column from which data is to be exported. The second argument specifies the name of the file into which data is to be copied. The third argument specifies whether the target file is located on the client computer ('client') or server computer ('server').

The following rules apply for specifying the path of a file name in a function argument, depending on whether the file resides on the client or server computer:

- If the source file resides on the server computer, you must specify the full path name to the file (not the path name relative to the current working directory).
- If the source file resides on the client computer, you can specify either the full or relative path name to the file.

String-manipulation functions

String-manipulation functions accept arguments of type CHAR, NCHAR, VARCHAR, NVARCHAR, or LVARCHAR. You can use a string-manipulation function anywhere you use an expression.

The following functions convert between upper and lowercase letters in a character string:

- **LOWER**
- **UPPER**
- **INITCAP**

The following functions manipulate character strings in various ways:

- **REPLACE**
- **SUBSTR**
- **SUBSTRING**
- **LPAD**
- **RPAD**

Restriction: You cannot overload any of the string-manipulation functions to handle extended data types.

The LOWER function

Use the **LOWER** function to replace every uppercase letter in a character string with a lowercase letter. The **LOWER** function accepts an argument of a character data type and returns a value of the same data type as the argument you specify.

The following query uses the **LOWER** function to convert any uppercase letters in a character string to lowercase letters.

```
SELECT manu_code, LOWER(manu_code)
   FROM items
   WHERE order_num = 1018
```

Figure 4-54. Query

```
manu_code   (expression)

PRC          prc
KAR          kar
PRC          prc
SMT          smt
HRO          hro
```

Figure 4-55. Query result

The UPPER function

Use the **UPPER** function to replace every lowercase letter in a character string with an uppercase letter. The **UPPER** function accepts an argument of a character data type and returns a value of the same data type as the argument you specify.

The following query uses the **UPPER** function to convert any lowercase letters in a character string to uppercase letters.

```
SELECT call_code, UPPER(code_descr) FROM call_type
```

Figure 4-56. Query

```
call_code    (expression)

B            BILLING ERROR
D            DAMAGED GOODS
I            INCORRECT MERCHANDISE SENT
L            LATE SHIPMENT
O            OTHER
```

Figure 4-57. Query result

The INITCAP function

Use the **INITCAP** function to replace the first letter of every word in a character string with an uppercase letter. The **INITCAP** function assumes a new word whenever the function encounters a letter that is preceded by any character other than a letter. The **INITCAP** function accepts an argument of a character data type and returns a value of the same data type as the argument you specify.

The following query uses the **INITCAP** function to convert the first letter of every word in a character string to an uppercase letter.

```
SELECT INITCAP(description) FROM stock
   WHERE manu_code = "ANZ";
```

Figure 4-58. Query

```
(expression)

Tennis Racquet
Tennis Ball
Volleyball
Volleyball Net
Helmet
Golf Shoes
3 Golf Balls
Running Shoes
Watch
Kick Board
Swim Cap
```

Figure 4-59. Query result

The REPLACE function

Use the **REPLACE** function to replace a certain set of characters in a character string with other characters.

In the following query, the **REPLACE** function replaces the unit column value `each` with `item` for every row that the query returns. The first argument of the **REPLACE** function is the expression to be evaluated. The second argument specifies the characters that you want to replace. The third argument specifies a new character string to replace the characters removed.

```
SELECT stock_num, REPLACE(unit,"each", "item") cost_per, unit_price
   FROM stock
   WHERE manu_code = "HRO";
```

Figure 4-60. Query

```
stock_num      cost_per   unit_price

1              case         $250.00
2              case         $126.00
4              case         $480.00
7              case         $600.00
110            case         $260.00
205            case         $312.00
301            item          $42.50
302            item           $4.50
304            box          $280.00
305            case          $48.00
309            case          $40.00
312            box           $72.00
```

Figure 4-61. Query result

The SUBSTRING and SUBSTR functions

You can use the **SUBSTRING** and **SUBSTR** functions to return a portion of a character string. You specify the *start position* and *length* (optional) to determine which portion of the character string the function returns.

Restriction: The units of measurement in the arguments to these two functions are bytes, rather than logical characters. This is of no importance in the default locale, nor in other single-byte locales, but you should not invoke **SUBSTRING** or **SUBSTR** in locales in which the logical characters of the code set can differ in their storage lengths.

The SUBSTRING function

You can use the **SUBSTRING** function to return some portion of a character string. You specify the *start position* and *length* (optional) to determine which portion of the character string the function returns. You can specify a positive or negative number for the start position. A start position of 1 specifies that the **SUBSTRING** function begins from the first position in the string. When the start position is zero (0) or a negative number, the **SUBSTRING** function counts backward from the beginning of the string.

The following query shows an example of the **SUBSTRING** function, which returns the first four characters for any **sname** column values that the query returns. In this example, the **SUBSTRING** function starts at the beginning of the string and returns four characters counting forward from the start position.

```
SELECT sname, SUBSTRING(sname FROM 1 FOR 4) FROM state
   WHERE code = "AZ";
```

Figure 4-62. Query

```
sname           (expression)

Arizona         Ariz
```

Figure 4-63. Query result

In the following query, the **SUBSTRING** function specifies a start position of `6` but does not specify the length. The function returns a character string that extends from the sixth position to the end of the string.

```
SELECT sname, SUBSTRING(sname FROM 6) FROM state
   WHERE code = "WV";
```

Figure 4-64. Query

```
sname           (expression)

West Virginia   Virginia
```

Figure 4-65. Query result

In the following query, the **SUBSTRING** function returns only the first character for any **sname** column value that the query returns. For the **SUBSTRING** function, a start position of `-2` counts backward three positions (`0, -1, -2`) from the start position of the string (for a start position of `0`, the function counts backward one position from the beginning of the string).

```
SELECT sname, SUBSTRING(sname FROM -2 FOR 4) FROM state
   WHERE code = "AZ";
```

Figure 4-66. Query

```
sname          (expression)

Arizona        A
```

Figure 4-67. Query result

The SUBSTR function

The **SUBSTR** function serves the same purpose as the **SUBSTRING** function, but the syntax of the two functions differs.

To return a portion of a character string, specify the *start position* and *length* (optional) to determine which portion of the character string the **SUBSTR** function returns. The start position that you specify for the **SUBSTR** function can be a positive or a negative number. However, the **SUBSTR** function treats a negative number in the start position differently than does the **SUBSTRING** function. When the start position is a negative number, the **SUBSTR** function counts backward from the end of the character string, which depends on the length of the string, not the character length of a word or visible characters that the string contains. The **SUBSTR** function recognizes zero (`0`) or `1` in the start position as the first position in the string.

The following query shows an example of the **SUBSTR** function that includes a negative number for the start position. Given a start position of `-15`, the **SUBSTR** function counts backward 15 positions from the end of the string to find the start position and then returns the next five characters.

```
SELECT sname, SUBSTR(sname, -15, 5) FROM state
   WHERE code = "CA";
```

Figure 4-68. Query

```
sname          (expression)

California     Calif
```

Figure 4-69. Query result

To use a negative number for the start position, you need to know the length of the value that is evaluated. The **sname** column is defined as CHAR(15), so a **SUBSTR** function that accepts an argument of type **sname** can use a start position of `0`, `1`, or `-15` for the function to return a character string that begins from the first position in the string.

The following query returns the same result as Figure 4-68.

```
SELECT sname, SUBSTR(sname, 1, 5) FROM state
   WHERE code = "CA";
```

Figure 4-70. Query

The LPAD function

Use the **LPAD** function to return a copy of a string that has been left padded with a sequence of characters that are repeated as many times as necessary or truncated, depending on the specified length of the padded portion of the string. Specify the source string, the length of the string to be returned, and the character string to serve as padding.

The data type of the source string and the character string that serves as padding can be any data type that converts to VARCHAR or NVARCHAR.

The following query shows an example of the **LPAD** function with a specified length of 21 bytes. Because the source string has a length of 15 bytes (**sname** is defined as CHAR(15)), the **LPAD** function pads the first six positions to the left of the source string.

```
SELECT sname, LPAD(sname, 21, "-")
   FROM state
   WHERE code = "CA" OR code = "AZ";
```

Figure 4-71. Query

```
sname           (expression)

California      ------California
Arizona         ------Arizona
```

Figure 4-72. Query result

The RPAD function

Use the **RPAD** function to return a copy of a string that has been right padded with a sequence of characters that are repeated as many times as necessary or truncated, depending on the specified length of the padded portion of the string. Specify the source string, the length of the string to be returned, and the character string to serve as padding.

The data type of the source string and the character string that serves as padding can be any data type that converts to VARCHAR or NVARCHAR.

The following query shows an example of the **RPAD** function with a specified length of 21 bytes. Because the source string has a length of 15 bytes (**sname** is defined as CHAR(15)), the **RPAD** function pads the first six positions to the right of the source string.

```
SELECT sname, RPAD(sname, 21, "-")
   FROM state
   WHERE code = "WV" OR code = "AZ";
```

Figure 4-73. Query

```
sname           (expression)
West Virginia   West Virginia  ------
Arizona         Arizona        ------
```

Figure 4-74. Query result

In addition to these functions, the **LTRIM** and **RTRIM** functions can return a value that drops specified leading or trailing padding characters from their string argument, and the ASCII function can return the numeric value of the codepoint within the ASCII character set of the first character in its string argument. These built-in functions for operations on string values are described in the*IBM Informix Guide to SQL: Syntax*.

Other functions

You can also use the **LENGTH**, **USER**, **CURRENT**, **SYSDATE**, and **TODAY** functions anywhere in an SQL expression that you would use a constant. In addition, you can include the **DBSERVERNAME** function in a SELECT statement to display the name of the database server where the current database resides.

You can use these functions to select an expression that consists entirely of constant values or an expression that includes column data. In the first instance, the result is the same for all rows of output.

In addition, you can use the **HEX** function to return the hexadecimal encoding of an expression, the **ROUND** function to return the rounded value of an expression, and the **TRUNC** function to return the truncated value of an expression. For more information on the preceding functions, see the *IBM Informix Guide to SQL: Syntax*.

The LENGTH function

In the following query, the **LENGTH** function calculates the number of bytes in the combined **fname** and **lname** columns for each row where the length of **company** is greater than 15.

```
SELECT customer_num,
   LENGTH (fname) + LENGTH (lname) namelength
   FROM customer
   WHERE LENGTH (company) > 15;
```

Figure 4-75. Query

```
customer_num    namelength

         101            11
         105            13
         107            11
         112            14
         115            11
         118            10
         119            10
         120            10
         122            12
         124            11
         125            10
         126            12
         127            10
         128            11
```

Figure 4-76. Query result

Although the **LENGTH** function might not be useful when you work with DB-Access, it can be important to determine the string length for programs and reports. The **LENGTH** function returns the clipped length of a CHARACTER or VARCHAR string and the full number of bytes in a TEXT or BYTE string.

IBM Informix also supports the **CHAR_LENGTH** function, which returns the number of logical characters in its string argument, rather than the number of bytes. This function is useful in locales where a single logical character might require more than a single byte of storage. For more information about the **CHAR_LENGTH** function, see the *IBM Informix Guide to SQL: Syntax* and the *IBM Informix GLS User's Guide*.

The USER function

Use the **USER** function when you want to define a restricted view of a table that contains only rows that include your user ID. For information about how to create views, see the *IBM Informix Database Design and Implementation Guide* and the GRANT and CREATE VIEW statements in the *IBM Informix Guide to SQL: Syntax*.

The following query returns the user name (login account name) of the user who executes the query. It is repeated once for each row in the table.

```
SELECT * FROM cust_calls
   WHERE user_id = USER;
```

Figure 4-77. Query

If the user name of the current user is **richc**, the query retrieves only those rows in the **cust_calls** table where `user_id = richc`.

```
customer_num  110
call_dtime    1998-07-07 10:24
user_id       richc
call_code     L
call_descr    Order placed one month ago (6/7) not received.
res_dtime     1998-07-07 10:30
res_descr     Checked with shipping (Ed Smith). Order sent yesterday-we
              were waiting for goods from ANZ. Next time will call with
              delay if necessary

customer_num  119
call_dtime    1998-07-01 15:00
user_id       richc
call_code     B
call_descr    Bill does not reflect credit from previous order
res_dtime     1998-07-02 08:21
res_descr     Spoke with Jane Akant in Finance. She found the error and is
              sending new bill to customer
```

Figure 4-78. Query result

The TODAY function

The **TODAY** function returns the current system date. If the following query is issued when the current system date is July 10, 1998, it returns this one row.

```
SELECT * FROM orders WHERE order_date = TODAY;
```

Figure 4-79. Query

```
order_num      1018
order_date     07/10/1998
customer_num   121
ship_instruct  SW corner of Biltmore Mall
backlog        n
po_num         S22942
ship_date      07/13/1998
ship_weight    70.50
ship_charge    $20.00
paid_date      08/06/1998
```

Figure 4-80. Query result

The DBSERVERNAME and SITENAME functions

You can include the function **DBSERVERNAME** (or its synonym, **SITENAME**) in a SELECT statement to find the name of the database server. You can query the **DBSERVERNAME** for any table that has rows, including system catalog tables.

In the following query, you assign the label **server** to the **DBSERVERNAME** expression and also select the **tabid** column from the **systables** system catalog table. This table describes database tables, and **tabid** is the table identifier.

```
SELECT DBSERVERNAME server, tabid
   FROM systables
   WHERE tabid <= 4;
```

Figure 4-81. Query

```
 server           tabid

montague             1
montague             2
montague             3
montague             4
```

Figure 4-82. Query result

The WHERE clause restricts the numbers of rows displayed. Otherwise, the database server name would be displayed once for each row of the **systables** table.

The HEX function

In the following query, the **HEX** function returns the hexadecimal format of two columns in the **customer** table, as the result shows.

```
SELECT HEX (customer_num) hexnum, HEX (zipcode) hexzip
   FROM customer;
```

Figure 4-83. Query

```
hexnum     hexzip

0x00000065 0x00016F86
0x00000066 0x00016FA5
0x00000067 0x0001705F
0x00000068 0x00016F4A
0x00000069 0x00016F46
0x0000006A 0x00016F6F
⋮
```

Figure 4-84. Query result

The DBINFO function

You can call the **DBINFO** function in a SELECT statement to find any of the following information:

- The name of a dbspace corresponding to a tblspace number or expression
- The last SERIAL, SERIAL8 or BIGSERIAL value inserted into a table
- The number of rows processed by the SELECT, INSERT, DELETE, UPDATE, MERGE, EXECUTE FUNCTION, EXECUTE PROCEDURE, or EXECUTE ROUTINE statement
- The session ID of the current session
- The name of the current database to which the session is connected
- Whether an INSERT, UPDATE, or DELETE statement is being performed as part of a replicated transaction.
- The name of the host computer on which the database server runs
- The type of operating system and the word length of the host computer
- The local time zone and the current date and time in Coordinated Universal Time (UTC) format
- The DATETIME value corresponding to a specified integer column or to a specified UTC time value (as an integer number of seconds since 1970-01-01 00:00:00+00:00)
- The exact version of the database server to which a client application is connected, or a specified component of the full version string.

You can use the **DBINFO** function anywhere within SQL statements and within SPL routines.

The following query shows how you might use the **DBINFO** function to find out the name of the host computer on which the database server runs.

```
SELECT FIRST 1 DBINFO('dbhostname') FROM systables;
```

Figure 4-85. Query

```
(constant)

lyceum
```

Figure 4-86. Query result

Without the FIRST 1 clause to restrict the values in the **tabid**, the host name of the computer on which the database server runs would be repeated for each row of the **systables** table. The following query shows how you might use the DBINFO function to find out the complete version number and the type of the current database server.

```
SELECT FIRST 1 DBINFO('version','full') FROM systables;
```

Figure 4-87. Query

For more information about how to use the **DBINFO** function to find information about your current database server, database session, or database, see the *IBM Informix Guide to SQL: Syntax*.

The DECODE function

You can use the **DECODE** function to convert an expression of one value to another value. The **DECODE** function has the following form:

```
DECODE(test, a, a_value, b, b_value, ..., n, n_value, exp_m )
```

The **DECODE** function returns *a_value* when *a* equals *test*, and returns *b_value* when *b* equals *test*, and, in general, returns *n_value* when *n* equals *test*.

If several expressions match *test*, **DECODE** returns *n_value* for the first expression found. If no expression matches *test*, **DECODE** returns *exp_m*; if no expression matches *test* and there is no *exp_m*, **DECODE** returns NULL.

Restriction: The **DECODE** function does not support arguments of type TEXT or BYTE.

Suppose an **employee** table exists that includes **emp_id** and **evaluation** columns. Suppose also that execution of the following query on the **employee** table returns the rows that the result shows.

```
SELECT emp_id, evaluation FROM employee;
```

Figure 4-88. Query

```
emp_id          evaluation

012233          great
012344          poor
012677          NULL
012288          good
012555          very good
```

Figure 4-89. Query result

In some cases, you might want to convert a set of values. For example, suppose you want to convert the descriptive values of the **evaluation** column in the preceding example to corresponding numeric values. The following query shows how you might use the **DECODE** function to convert values from the **evaluation** column to numeric values for each row in the **employee** table.

```
SELECT emp_id, DECODE(evaluation, "poor", 0, "fair", 25, "good",
50, "very good", 75, "great", 100, -1) AS evaluation
   FROM employee;
```

Figure 4-90. Query

```
emp_id         evaluation

012233          100
012344          0
012677          -1
012288          50
012555          75
⋮
```

Figure 4-91. Query result

You can specify any data type for the arguments of the **DECODE** function provided that the arguments meet the following requirements:

- The arguments *test*, *a*,*b*, ..., *n* all have the same data type or evaluate to a common compatible data type.
- The arguments *a_value*, *b_value*, ..., *n_value* all have the same data type or evaluate to a common compatible data type.

The NVL function

You can use the **NVL** function to convert an expression that evaluates to NULL to a value that you specify. The **NVL** function accepts two arguments: the first argument takes the name of the expression to be evaluated; the second argument specifies the value that the function returns when the first argument evaluates to NULL. If the first argument does not evaluate to NULL, the function returns the value of the first argument. Suppose a **student** table exists that includes **name** and **address** columns. Suppose also that execution of the following query on the **student** table returns the rows that the result shows.

```
SELECT name, address FROM student;
```

Figure 4-92. Query

```
name               address

John Smith         333 Vista Drive
Lauren Collier     1129 Greenridge Street
Fred Frith         NULL
Susan Jordan       NULL
```

Figure 4-93. Query result

The following query includes the **NVL** function, which returns a new value for each row in the table where the **address** column contains a NULL value.

```
SELECT name, NVL(address, "address is unknown") AS address
   FROM student;
```

Figure 4-94. Query

```
name             address

John Smith       333 Vista Drive
Lauren Collier   1129 Greenridge Street
Fred Frith       address is unknown
Susan Jordan     address is unknown
```

Figure 4-95. Query result

You can specify any data type for the arguments of the **NVL** function provided that the two arguments evaluate to a common compatible data type.

If both arguments of the **NVL** function evaluate to NULL, the function returns NULL.

IBM Informix also supports the **NULLIF** function, which resembles the **NVL** function, but has different semantics. **NULLIF** returns NULL if its two arguments are equal, or returns its first argument if its arguments are not equal. For more information about the **NULLIF** function, see the *IBM Informix Guide to SQL: Syntax*.

SPL routines in SELECT statements

Previous examples in this chapter show SELECT statement expressions that consist of column names, operators, and SQL functions. This section shows expressions that contain an SPL routine call.

SPL routines contain special Stored Procedure Language (SPL) statements as well as SQL statements. For more information on SPL routines, see Chapter 11, "Create and use SPL routines," on page 11-1.

IBM Informix allows you to write external routines in C and in Java™. For more information, see *IBM Informix User-Defined Routines and Data Types Developer's Guide*.

When you include an SPL routine expression in a projection list, the SPL routine must be one that returns a single value (one column of one row). For example, the following statement is valid only if **test_func()** returns a single value:

```
SELECT col_a, test_func(col_b) FROM tab1
   WHERE col_c = "Davis";
```

SPL routines that return more than a single value are not supported in the Projection clause of SELECT statements. In the preceding example, if **test_func()** returns more than one value, the database server returns an error message.

SPL routines provide a way to extend the range of functions available by allowing you to perform a subquery on each row you select.

For example, suppose you want a listing of the customer number, the customer's last name, and the number of orders the customer has made. The following query shows one way to retrieve this information. The **customer** table has **customer_num** and **lname** columns but no record of the number of orders each customer has made. You could write a **get_orders** routine, which queries the **orders** table for each **customer_num** and returns the number of corresponding orders (labeled **n_orders**).

```
SELECT customer_num, lname, get_orders(customer_num) n_orders
   FROM customer;
```

Figure 4-96. Query

The result shows the output from this SPL routine.

```
customer_num    lname    n_orders

         101    Pauli           1
         102    Sadler          9
         103    Currie          9
         104    Higgins         4
⋮
         123    Hanlon          1
         124    Putnum          1
         125    Henry           0
         126    Neelie          1
         127    Satifer         1
         128    Lessor          0
```

Figure 4-97. Query result

Use SPL routines to encapsulate operations that you frequently perform in your queries. For example, the condition in the following query contains a routine, **conv_price**, that converts the unit price of a stock item to a different currency and adds any import tariffs.

```
SELECT stock_num, manu_code, description FROM stock
   WHERE conv_price(unit_price, ex_rate = 1.50,
   tariff = 50.00) < 1000;
```

Figure 4-98. Query

Data encryption functions

You can use the SET ENCRYPTION PASSWORD statement with built-in SQL encryption functions that use Advanced Encryption Standard (AES) and Triple DES (3DES) encryption to secure your sensitive data. When you use encryption, only those users who have the correct password will be able to read, copy, or modify the data.

Use the SET ENCRYPTION PASSWORD statement with the following built-in encryption and decryption functions:

- **ENCRYPT_AES**
  ```
  ENCRYPT_AES(data-string-expression
  [, password-string-expression [, hint-string-expression ]])
  ```
- **ENCRYPT_TDES**
  ```
  ENCRYPT_TDES (data-string-expression
   [, password-string-expression [, hint-string-expression ]])
  ```
- **DECRYPT_CHAR**
  ```
  DECRYPT_CHAR(EncryptedData [, PasswordOrPhrase])
  ```
- **DECRYPT_BINARY**
  ```
  DECRYPT_BINARY(EncryptedData [, PasswordOrPhrase])
  ```
- **GETHINT**
  ```
  GETHINT(EncryptedData)
  ```

If you have used the SET ENCRYPTION PASSWORD statement to specify a default password, then the database server applies that password in subsequent calls to encryption and decryption functions that you invoke in the same session.

Use **ENCRYPT_AES** and **ENCRYPT_TDES** to define encrypted data and use **DECRYPT_CHAR** and **DECRYPT_BINARY** to query encrypted data. Use **GETHINT** to display the password hint string, if set, on the server.

You can use these SQL built-in functions to implement column-level or cell-level encryption.
- Use column-level encryption to encrypt all values in a given column with the same password.
- Use cell-level encryption to encrypt data within the column with different passwords.

Tip: If you intend to select encrypted data from a large table, specify an unencrypted column on which to select the rows. You can create indexes or foreign-key constraints on columns that contain encrypted data, but to do so is an inefficient use of resources, because such indexes and foreign-key constraints are not used by the query optimizer.

Using column-level data encryption to secure credit card data

The following example uses column-level encryption to secure credit card data.

To use column-level data encryption to secure credit card data:
1. Create the table: `create table customer (id char(30), creditcard lvarchar(67));`
2. Insert the encryption data:
   a. Set session password: `SET ENCRYPTION PASSWORD "credit card number is encrypted";`
   b. Encrypt data.
   ```
       INSERT INTO customer VALUES
   ("Alice",  encrypt_aes("1234567890123456"));
       INSERT INTO customer VALUES
   ("Bob", encrypt_aes("2345678901234567"));
   ```
3. Query encryption data with decryption function.
   ```
   SET ENCRYPTION PASSWORD "credit card number is encrypted";
   SELECT id FROM customer
      WHERE DECRYPT_CHAR(creditcard) = "2345678901234567";
   ```

Important: Encrypted data values occupy more storage space than the corresponding unencrypted data. A column whose width is sufficient to store plain text might need to be increased before it can support column-level encryption or cell-level encryption. If you attempt to insert an encrypted value into a column whose declared width is shorter than the encrypted string, the column stores a truncated value that cannot be decrypted.

For more information on encryption security, see *IBM Informix Administrator's Guide*.

For more information on the syntax and storage requirements of built-in encryption and decryption functions, see *IBM Informix Guide to SQL: Syntax*.

Summary

This chapter introduced sample syntax and results for functions in basic SELECT statements to query a relational database and to manipulate the returned data. "Functions in SELECT statements" on page 4-1 shows how to perform the following actions:

- Use the aggregate functions in the Projection clause to calculate and retrieve specific data.
- Include the time functions **DATE**, **DAY**, **MDY**, **MONTH**, **WEEKDAY**, **YEAR**, **CURRENT**, and **EXTEND** plus the **TODAY**, **LENGTH**, and **USER** functions in your SELECT statements.
- Use conversion functions in the SELECT clause to convert between date and character values.
- Use string-manipulation functions in the SELECT clause to convert between upper and lower case letters or to manipulate character strings in various ways.

"SPL routines in SELECT statements" on page 4-26 shows how to include SPL routines in your SELECT statements.

"Data encryption functions" on page 4-27 shows how the use of the SET ENCRYPTION statement and built-in encryption and decryption functions can prevent users who cannot provide a password from viewing or modifying sensitive data.

Chapter 5. Compose advanced SELECT statements

This section increases the scope of what you can do with the SELECT statement and enables you to perform more complex database queries and data manipulation. Chapter 2, “Compose SELECT statements,” on page 2-1, focused on five of the clauses in the SELECT statement syntax. This section adds the GROUP BY clause and the HAVING clause. You can use the GROUP BY clause with aggregate functions to organize rows returned by the FROM clause. You can include a HAVING clause to place conditions on the values that the GROUP BY clause returns.

This section also extends the earlier discussion of joins. It illustrates *self-joins*, which enable you to join a table to itself, and four kinds of *outer joins*, in which you apply the keyword OUTER to treat two or more joined tables unequally. It also introduces correlated and uncorrelated subqueries and their operational keywords, shows how to combine queries with the UNION operator, and defines the set operations known as union, intersection, and difference.

Examples in this section show how to use some or all of the SELECT statement clauses in your queries. The clauses must appear in the following order:
1. Projection
2. FROM
3. WHERE
4. GROUP BY
5. HAVING
6. ORDER BY
7. INTO TEMP

For an example of a SELECT statement that uses all these clauses in the correct order, see Figure 5-15 on page 5-6.

An additional SELECT statement clause, INTO, which you can use to specify program and host variables in SQL APIs, is described in Chapter 8, “SQL programming,” on page 8-1, as well as in the publications that come with the product.

This section also describes nested SELECT statements, in which subqueries are specified within the Projection, FROM, or WHERE clauses of the main query. Other sections show how SELECT statements can define and manipulate collections, and how to perform set operations on query results.

The GROUP BY and HAVING clauses

The optional GROUP BY and HAVING clauses add functionality to your SELECT statement. You can include one or both in a basic SELECT statement to increase your ability to manipulate aggregates.

The GROUP BY clause combines similar rows, producing a single result row for each group of rows that have the same values, for each column listed in the Projection clause. The HAVING clause sets conditions on those groups after you form them. You can use a GROUP BY clause without a HAVING clause, or a HAVING clause without a GROUP BY clause.

The GROUP BY clause

The GROUP BY clause divides a table into sets. This clause is most often combined with aggregate functions that produce summary values for each of those sets. Some examples in Chapter 2, "Compose SELECT statements," on page 2-1 show the use of aggregate functions applied to a whole table. This section illustrates aggregate functions applied to groups of rows.

Using the GROUP BY clause without aggregates is much like using the DISTINCT (or UNIQUE) keyword in the SELECT clause. The following query is described in "Select specific columns" on page 2-10.

```
SELECT DISTINCT customer_num FROM orders;
```

Figure 5-1. Query

You could also write the statement as the following query shows.

```
SELECT customer_num FROM orders
   GROUP BY customer_num;
```

Figure 5-2. Query

Figure 5-1 and Figure 5-2 return the following rows.

```
customer_num

         101
         104
         106
         110
⋮
         124
         126
         127
```

Figure 5-3. Query result

The GROUP BY clause collects the rows into sets so that each row in each set has the same customer numbers. With no other columns selected, the result is a list of the unique **customer_num** values.

The power of the GROUP BY clause is more apparent when you use it with aggregate functions.

The following query retrieves the number of items and the total price of all items for each order.

```
SELECT order_num, COUNT (*) number, SUM (total_price) price
   FROM items
   GROUP BY order_num;
```

Figure 5-4. Query

The GROUP BY clause causes the rows of the **items** table to be collected into groups, each group composed of rows that have identical **order_num** values (that is, the items of each order are grouped together). After the database server forms the groups, the aggregate functions COUNT and SUM are applied within each group.

Figure 5-4 on page 5-2 returns one row for each group. It uses labels to give names to the results of the COUNT and SUM expressions, as the result shows.

```
order_num      number         price

     1001           1          $250.00
     1002           2         $1200.00
     1003           3          $959.00
     1004           4         $1416.00
 .
 .
 .
     1021           4         $1614.00
     1022           3          $232.00
     1023           6          $824.00
```

Figure 5-5. Query result

The result collects the rows of the **items** table into groups that have identical order numbers and computes the COUNT of rows in each group and the SUM of the prices.

You cannot include a TEXT, BYTE, CLOB, or BLOB column in a GROUP BY clause. To *group*, you must be able to *sort*, and no natural sort order exists for these data types.

Unlike the ORDER BY clause, the GROUP BY clause does not order data. Include an ORDER BY clause *after* your GROUP BY clause if you want to sort data in a particular order or sort on an aggregate in the projection list.

The following query is the same as Figure 5-4 on page 5-2 but includes an ORDER BY clause to sort the retrieved rows in ascending order of **price**, as the result shows.

```
SELECT order_num, COUNT(*) number, SUM (total_price) price
   FROM items
   GROUP BY order_num
   ORDER BY price;
```

Figure 5-6. Query

```
  order_num      number         price

     1010          2           $84.00
     1011          1           $99.00
     1013          4          $143.80
     1022          3          $232.00
     1001          1          $250.00
     1020          2          $438.00
     1006          5          $448.00
⋮
     1002          2         $1200.00
     1004          4         $1416.00
     1014          2         $1440.00
     1019          1         $1499.97
     1021          4         $1614.00
     1007          5         $1696.00
```

Figure 5-7. Query result

The topic "Select specific columns" on page 2-10 describes how to use an integer in an ORDER BY clause to indicate the position of a column in the projection list. You can also use an integer in a GROUP BY clause to indicate the position of column names or display labels in the GROUP BY list.

The following query returns the same rows as Figure 5-6 on page 5-3 shows.

```
SELECT order_num, COUNT(*) number, SUM (total_price) price
   FROM items
   GROUP BY 1
   ORDER BY 3;
```

Figure 5-8. Query

When you build a query, all non-aggregate columns that are in the projection list in the Projection clause must also be included in the GROUP BY clause. A SELECT statement with a GROUP BY clause must return only one row per group. Columns that are listed after GROUP BY are certain to reflect only one distinct value within a group, and that value can be returned. However, a column not listed after GROUP BY might contain different values in the rows that are contained in the group.

The following query shows how to use the GROUP BY clause in a SELECT statement that joins tables.

```
SELECT o.order_num, SUM (i.total_price)
   FROM orders o, items i
   WHERE o.order_date > '01/01/98'
      AND o.customer_num = 110
      AND o.order_num = i.order_num
   GROUP BY o.order_num;
```

Figure 5-9. Query

The query joins the **orders** and **items** tables, assigns table aliases to them, and returns the rows.

```
  order_num            (sum)

       1008          $940.00
       1015          $450.00
```

Figure 5-10. Query result

The HAVING clause

To complement a GROUP BY clause, use a HAVING clause to apply one or more qualifying conditions to groups after they are formed. The effect of the HAVING clause on groups is similar to the way the WHERE clause qualifies individual rows. One advantage of using a HAVING clause is that you can include aggregates in the search condition, whereas you cannot include aggregates in the search condition of a WHERE clause.

Each HAVING condition compares one column or aggregate expression of the group with another aggregate expression of the group or with a constant. You can use HAVING to place conditions on both column values and aggregate values in the group list.

The following query returns the average total price per item on all orders that have more than two items. The HAVING clause tests each group as it is formed and selects those that are composed of more than two rows.

```
SELECT order_num, COUNT(*) number, AVG (total_price) average
   FROM items
   GROUP BY order_num
   HAVING COUNT(*) > 2;
```

Figure 5-11. Query

```
  order_num      number          average

       1003           3          $319.67
       1004           4          $354.00
       1005           4          $140.50
       1006           5           $89.60
       1007           5          $339.20
       1013           4           $35.95
       1016           4          $163.50
       1017           3          $194.67
       1018           5          $226.20
       1021           4          $403.50
       1022           3           $77.33
       1023           6          $137.33
```

Figure 5-12. Query result

If you use a HAVING clause without a GROUP BY clause, the HAVING condition applies to all rows that satisfy the search condition. In other words, all rows that satisfy the search condition make up a single group.

The following query, a modified version of Figure 5-11 on page 5-5, returns just one row, the average of all **total_price** values in the table, as the result shows.

```
SELECT AVG (total_price) average
   FROM items
   HAVING count(*) > 2;
```

Figure 5-13. Query

```
         average

         $270.97
```

Figure 5-14. Query result

If Figure 5-13, like Figure 5-11 on page 5-5, had included the non-aggregate column **order_num** in the Projection clause, you would have to include a GROUP BY clause with that column in the group list. In addition, if the condition in the HAVING clause was not satisfied, the output would show the column heading and a message would indicate that no rows were found.

The following query contains all the SELECT statement clauses that you can use in the IBM Informix version of interactive SQL (the INTO clause that names host variables is available only in an SQL API).

```
SELECT o.order_num, SUM (i.total_price) price,
     paid_date - order_date span
   FROM orders o, items i
   WHERE o.order_date > '01/01/98'
      AND o.customer_num > 110
      AND o.order_num = i.order_num
   GROUP BY 1, 3
   HAVING COUNT (*) < 5
   ORDER BY 3
   INTO TEMP temptab1;
```

Figure 5-15. Query

The query joins the **orders** and **items** tables; employs display labels, table aliases, and integers that are used as column indicators; groups and orders the data; and puts the results in a temporary table, as the result shows.

```
  order_num            price        span

       1017          $584.00
       1016          $654.00
       1012         $1040.00
       1019         $1499.97          26
       1005          $562.00          28
       1021         $1614.00          30
       1022          $232.00          40
       1010           $84.00          66
       1009          $450.00          68
       1020          $438.00          71
```

Figure 5-16. Query result

Create advanced joins

The topic “Create a join” on page 2-39 shows how to include a WHERE clause in a SELECT statement to join two or more tables on one or more columns. It illustrates natural joins and equi-joins.

This section discusses how to use two more complex kinds of joins, self-joins and outer joins. As described for simple joins, you can define aliases for tables and assign display labels to expressions to shorten your multiple-table queries. You can also issue a SELECT statement with an ORDER BY clause that sorts data into a temporary table.

Self-joins

A join does not always have to involve two different tables. You can join a table to itself, creating a *self-join*. Joining a table to itself can be useful when you want to compare values in a column to other values in the same column.

To create a self-join, list a table twice in the FROM clause, and assign it a different alias each time. Use the aliases to refer to the table in the Projection and WHERE clauses as if it were two separate tables. (Aliases in SELECT statements are discussed in “Aliases” on page 2-45 and in the *IBM Informix Guide to SQL: Syntax*.)

Just as in joins between tables, you can use arithmetic expressions in self-joins. You can test for null values, and you can use an ORDER BY clause to sort the values in a specified column in ascending or descending order.

The following query finds pairs of orders where the **ship_weight** differs by a factor of five or more and the **ship_date** is not null. The query then orders the data by **ship_date**.

```
SELECT x.order_num, x.ship_weight, x.ship_date,
       y.order_num, y.ship_weight, y.ship_date
   FROM orders x, orders y
   WHERE x.ship_weight >= 5 * y.ship_weight
      AND x.ship_date IS NOT NULL
      AND y.ship_date IS NOT NULL
   ORDER BY x.ship_date;
```

Figure 5-17. Query

Table 5-1. Query result

order_num	ship_weight	ship_date	order_num	ship_weight	ship_date
1004	95.80	05/30/1998	1011	10.40	07/03/1998
1004	95.80	05/30/1998	1020	14.00	07/16/1998
1004	95.80	05/30/1998	1022	15.00	07/30/1998
1007	125.90	06/05/1998	1015	20.60	07/16/1998
1007	125.90	06/05/1998	1020	14.00	07/16/1998

If you want to store the results of a self-join into a temporary table, append an INTO TEMP clause to the SELECT statement and assign display labels to at least one set of columns to rename them. Otherwise, the duplicate column names cause an error and the temporary table is not created.

The following query, which is similar to Figure 5-17 on page 5-7, labels all columns selected from the **orders** table and puts them in a temporary table called **shipping**.

```
SELECT x.order_num orders1, x.po_num purch1,
       x.ship_date ship1, y.order_num orders2,
       y.po_num purch2, y.ship_date ship2
   FROM orders x, orders y
   WHERE x.ship_weight >= 5 * y.ship_weight
      AND x.ship_date IS NOT NULL
      AND y.ship_date IS NOT NULL
   ORDER BY orders1, orders2
   INTO TEMP shipping;
```

Figure 5-18. Query

If you query with SELECT * from table **shipping**, you see the following rows.

```
    orders1 purch1     ship1         orders2 purch2    ship2

       1004 8006       05/30/1998       1011 B77897    07/03/1998
       1004 8006       05/30/1998       1020 W2286     07/16/1998
       1004 8006       05/30/1998       1022 W9925     07/30/1998
       1005 2865       06/09/1998       1011 B77897    07/03/1998
⋮
       1019 Z55709     07/16/1998       1020 W2286     07/16/1998
       1019 Z55709     07/16/1998       1022 W9925     07/30/1998
       1023 KF2961     07/30/1998       1011 B77897    07/03/1998
```

Figure 5-19. Query result

You can join a table to itself more than once. The maximum number of self-joins depends on the resources available to you.

The self-join in the following query creates a list of those items in the **stock** table that are supplied by three manufacturers. The self-join includes the last two conditions in the WHERE clause to eliminate duplicate manufacturer codes in rows that are retrieved.

```
SELECT s1.manu_code, s2.manu_code, s3.manu_code,
       s1.stock_num, s1.description
   FROM stock s1, stock s2, stock s3
   WHERE s1.stock_num = s2.stock_num
      AND s2.stock_num = s3.stock_num
      AND s1.manu_code < s2.manu_code
      AND s2.manu_code < s3.manu_code
   ORDER BY stock_num;
```

Figure 5-20. Query

```
manu_code manu_code manu_code stock_num description

HRO       HSK       SMT               1 baseball gloves
ANZ       NRG       SMT               5 tennis racquet
ANZ       HRO       HSK             110 helmet
ANZ       HRO       PRC             110 helmet
ANZ       HRO       SHM             110 helmet
ANZ       HSK       PRC             110 helmet
ANZ       HSK       SHM             110 helmet
ANZ       PRC       SHM             110 helmet
HRO       HSK       PRC             110 helmet
HRO       HSK       SHM             110 helmet
HRO       PRC       SHM             110 helmet
⋮
KAR       NKL       PRC             301 running shoes
KAR       NKL       SHM             301 running shoes
KAR       PRC       SHM             301 running shoes
NKL       PRC       SHM             301 running shoes
```

Figure 5-21. Query result

If you want to select rows from a payroll table to determine which employees earn more than their manager, you might construct the self-join as the following SELECT statement shows:

```
SELECT emp.employee_num, emp.gross_pay, emp.level,
       emp.dept_num, mgr.employee_num, mgr.gross_pay,
       mgr.dept_num, mgr.level
   FROM payroll emp, payroll mgr
   WHERE emp.gross_pay > mgr.gross_pay
      AND emp.level < mgr.level
      AND emp.dept_num = mgr.dept_num
   ORDER BY 4;
```

The following query uses a *correlated subquery* to retrieve and list the 10 highest-priced items ordered.

```
SELECT order_num, total_price
   FROM items a
   WHERE 10 >
      (SELECT COUNT (*)
         FROM items b
         WHERE b.total_price < a.total_price)
   ORDER BY total_price;
```

Figure 5-22. Query

The query returns the 10 rows.

```
order_num    total_price

   1018      $15.00
   1013      $19.80
   1003      $20.00
   1005      $36.00
   1006      $36.00
   1013      $36.00
   1010      $36.00
   1013      $40.00
   1022      $40.00
   1023      $40.00
```

Figure 5-23. Query result

You can create a similar query to find and list the 10 employees in the company who have the most seniority.

For more information about correlated subqueries, refer to "Subqueries in SELECT statements" on page 5-17.

Outer joins

This section shows how to create and use outer joins in a SELECT statement. "Create a join" on page 2-39 discusses inner joins. Whereas an inner join treats two or more joined tables equally, an outer join treats two or more joined tables asymmetrically. An outer join makes one of the tables dominant (also called the outer table) over the other subordinate tables (also called inner tables).

In an inner join or in a simple join, the result contains only the combinations of rows that satisfy the join conditions. Rows that do not satisfy the join conditions are discarded.

In an outer join, the result contains the combinations of rows that satisfy the join conditions and the rows from the dominant table that would otherwise be discarded because no matching row was found in the subordinate table. The rows from the dominant table that do not have matching rows in the subordinate table contain NULL values in the columns selected from the subordinate table.

An outer join allows you to apply join filters to the inner table before the join condition is applied.

Earlier versions of the database server supported only the IBM Informix extension to the ANSI-SQL standard syntax for outer joins. This syntax is still supported. However, the ANSI-SQL standard syntax provides for more flexibility with creating queries. It is recommended that you use the ANSI-SQL standard syntax to create new queries. Whichever form of syntax you use, you must use it for all outer joins in a single query block.

Before you rely on outer joins, determine whether one or more inner joins can work. You can often use an inner join when you do not need supplemental information from other tables.

Restriction: You cannot combine IBM Informix and ANSI outer-join syntax in the same query block.

For information on the syntax of outer joins, see the *IBM Informix Guide to SQL: Syntax*.

IBM Informix extension to outer join syntax

The IBM Informix extension to outer-join syntax begins an outer join with the OUTER keyword. When you use the Informix syntax, you must include the join condition in the WHERE clause. When you use the Informix syntax for an outer join, the database server supports the following three basic types of outer joins:

- A simple outer join on two tables
- An outer join for a simple join to a third table
- An outer join of two tables to a third table

An outer join must have a Projection clause, a FROM clause, and a WHERE clause. The join conditions are expressed in a WHERE clause. To transform a simple join into an outer join, insert the keyword OUTER directly before the name of the subordinate tables in the FROM clause. As shown later in this section, you can include the OUTER keyword more than once in your query.

No Informix extension to outer-join syntax is equivalent to the ANSI right outer join.

ANSI join syntax

The following ANSI joins are supported:

- Left outer join
- Right outer join

The ANSI outer-join syntax begins an outer join with the LEFT JOIN, LEFT OUTER JOIN, RIGHT JOIN, or RIGHT OUTER JOIN keywords. The OUTER keyword is optional. Queries can specify a join condition and optional join filters in the ON clause. The WHERE clause specifies a post-join filter. In addition, you can explicitly specify the type of join using the LEFT or right clause. ANSI join syntax also allows the dominant or subordinate part of an outer join to be the result set of another join, when you begin the join with a left parenthesis.

If you use ANSI syntax for an outer join, you must use the ANSI syntax for all outer joins in a single query block.

Tip: The examples in this section use table aliases for brevity. “Aliases” on page 2-45 discusses table aliases.

Left outer join

In the syntax of a left outer join, the dominant table of the outer join appears to the left of the keyword that begins the outer join. A left outer join returns all of the rows for which the join condition is true and, in addition, returns all other rows from the dominant table and displays the corresponding values from the subservient table as NULL.

The following query uses ANSI syntax LEFT OUTER JOIN to achieve the same results as Figure 5-30 on page 5-14, which uses the IBM Informix outer-join syntax:

```
SELECT c.customer_num, c.lname, c.company, c.phone,
       u.call_dtime, u.call_descr
   FROM customer c LEFT OUTER JOIN cust_calls u
   ON c.customer_num = u.customer_num;
```

Figure 5-24. Query

In this example, you can use the ON clause to specify the join condition. You can add an additional filter in the WHERE clause to limit your result set; such a filter is a post-join filter.

The following query returns only rows in which customers have not made any calls to customer service. In this query, the database server applies the filter in the WHERE clause after it performs the outer join on the **customer_num** column of the **customer** and **cust_calls** tables.

```
SELECT c.customer_num, c.lname, c.company, c.phone,
   u.call_dtime, u.call_descr
   FROM customer c LEFT OUTER JOIN cust_calls u
   ON c.customer_num = u.customer_num
   WHERE u.customer_num IS NULL;
```

Figure 5-25. Query

In addition to the previous examples, the following examples show various types of query constructions that are available with ANSI join syntax:

```
SELECT *
FROM (t1 LEFT OUTER JOIN (t2 LEFT OUTER JOIN t3 ON t2.c1=t3.c1)
   ON t1.c1=t3.c1) JOIN (t4 LEFT OUTER JOIN t5 ON t4.c1=t5.c1)
   ON t1.c1=t4.c1;

SELECT *
FROM (t1 LEFT OUTER JOIN (t2 LEFT OUTER JOIN t3 ON t2.c1=t3.c1)
   ON t1.c1=t3.c1),
   (t4 LEFT OUTER JOIN t5 ON t4.c1=t5.c1)
   WHERE t1.c1 = t4.c1;

SELECT *
FROM (t1 LEFT OUTER JOIN (t2 LEFT OUTER JOIN t3 ON t2.c1=t3.c1)
   ON t1.c1=t3.c1) LEFT OUTER JOIN (t4 JOIN t5 ON t4.c1=t5.c1)
   ON t1.c1=t4.c1;

SELECT *
FROM t1 LEFT OUTER JOIN (t2 LEFT OUTER JOIN t3 ON t2.c1=t3.c1)
   ON t1.c1=t2.c1;

SELECT *
FROM t1 LEFT OUTER JOIN (t2 LEFT OUTER JOIN t3 ON t2.c1=t3.c1)
   ON t1.c1=t3.c1;

SELECT *
FROM (t1 LEFT OUTER JOIN t2 ON t1.c1=t2.c1)
   LEFT OUTER JOIN t3 ON t2.c1=t3.c1;

SELECT *
FROM (t1 LEFT OUTER JOIN t2 ON t1.c1=t2.c1)
   LEFT OUTER JOIN t3 ON t1.c1=t3.c1;

SELECT *
FROM t9, (t1 LEFT JOIN t2 ON t1.c1=t2.c1),
   (t3 LEFT JOIN t4 ON t3.c1=10), t10, t11,
   (t12 LEFT JOIN t14 ON t12.c1=100);

SELECT * FROM
  ((SELECT c1,c2 FROM t3) AS vt3(v31,v32)
    LEFT OUTER JOIN
        ( (SELECT c1,c2 FROM t1) AS vt1(vc1,vc2)
        LEFT OUTER JOIN
        (SELECT c1,c2 FROM t2) AS vt2(vc3,vc4)
         ON vt1.vc1 = vt2.vc3)
ON vt3.v31 = vt2.vc3);
```

The last example above illustrates joins on derived tables. It specifies a left outer join on the results of a subquery in the FROM clause of the outer query with the results of another left outer join on two other subquery results. See the section "Subqueries in the FROM clause" on page 5-20 for less complex examples of the ANSI-compliant syntax for subqueries.

Right outer join

In the syntax of a right outer join, the dominant table of the outer join appears to the right of the keyword that begins the outer join. A right outer join returns all of the rows for which the join condition is true and, in addition, returns all other rows from the dominant table and displays the corresponding values from the subservient table as NULL.

The following query is an example of a right outer join on the **customer** and **orders** tables.

```
SELECT c.customer_num, c.fname, c.lname, o.order_num,
o.order_date, o.customer_num
FROM customer c RIGHT OUTER JOIN orders o
ON (c.customer_num = o.customer_num);
```

Figure 5-26. Query

The query returns all rows from the dominant table **orders** and, as necessary, displays the corresponding values from the subservient table **customer** as NULL.

```
customer_num   fname    lname order_num   order_date  customer_num
        104  Anthony  Wiggins      1001   05/30/1998           104
        101  Ludwig     Pauli      1002   05/30/1998           101
        104 Anthony   Wiggins      1003   05/30/1998           104
     <NULL>  <NULL>    <NULL>      1004   06/05/1998           106
```

Figure 5-27. Query result

Simple join

The following query is an example of a simple join on the **customer** and **cust_calls** tables.

```
SELECT c.customer_num, c.lname, c.company,
     c.phone, u.call_dtime, u.call_descr
   FROM customer c, cust_calls u
   WHERE c.customer_num = u.customer_num;
```

Figure 5-28. Query

The query returns only those rows in which the customer has made a call to customer service, as the result shows.

```
customer_num  106
lname         Watson
company       Watson & Son
phone         415-389-8789
call_dtime    1998-06-12 08:20
call_descr    Order was received, but two of the cans of
              ANZ tennis balls within the case were empty
⋮
customer_num  116
lname         Parmelee
company       Olympic City
phone         415-534-8822
call_dtime    1997-12-21 11:24
call_descr    Second complaint from this customer! Received
              two cases right-handed outfielder gloves (1 HRO)
              instead of one case lefties.
```

Figure 5-29. Query result

Simple outer join on two tables

The following query uses the same Projection clause, tables, and comparison condition as the preceding example, but this time it creates a simple outer join in IBM Informix extension syntax.

```
SELECT c.customer_num, c.lname, c.company,
     c.phone, u.call_dtime, u.call_descr
   FROM customer c, OUTER cust_calls u
   WHERE c.customer_num = u.customer_num;
```

Figure 5-30. Query

The addition of the keyword OUTER before the **cust_calls** table makes it the subservient table. An outer join causes the query to return information on all customers, whether or not they have made calls to customer service. All rows from the dominant **customer** table are retrieved, and NULL values are assigned to columns of the subservient **cust_calls** table, as the result shows.

```
customer_num  101
lname         Pauli
company       All Sports Supplies
phone         408-789-8075
call_dtime
call_descr

customer_num  102
lname         Sadler
company       Sports Spot
phone         415-822-1289
call_dtime
call_descr
⋮
customer_num  107
lname         Ream
company       Athletic Supplies
phone         415-356-9876
call_dtime
call_descr

customer_num  108
lname         Quinn
company       Quinn's Sports
phone         415-544-8729
call_dtime
call_descr
```

Figure 5-31. Query result

Outer join for a simple join to a third table

Using the IBM Informix syntax, the following query shows an outer join that is the result of a simple join to a third table. This second type of outer join is known as a *nested simple join*.

```
SELECT c.customer_num, c.lname, o.order_num,
     i.stock_num, i.manu_code, i.quantity
   FROM customer c, OUTER (orders o, items i)
   WHERE c.customer_num = o.customer_num
      AND o.order_num = i.order_num
      AND manu_code IN ('KAR', 'SHM')
   ORDER BY lname;
```

Figure 5-32. Query

The query first performs a simple join on the **orders** and **items** tables, retrieving information on all orders for items with a **manu_code** of KAR or SHM. It then performs an outer join to combine this information with data from the dominant **customer** table. An optional ORDER BY clause reorganizes the data into the following form.

```
customer_num lname            order_num stock_num manu_code quantity

         114 Albertson
         118 Baxter
         113 Beatty
⋮
         105 Vector
         121 Wallack               1018       302 KAR              3
         106 Watson
```

Figure 5-33. Query result

Outer join of two tables to a third table

Using the IBM Informix extension syntax, the following query shows an outer join that is the result of an outer join of each of two tables to a third table. In this third type of outer join, join relationships are possible only between the dominant table and the subservient tables.

```
SELECT c.customer_num, c.lname, o.order_num,
     order_date, call_dtime
   FROM customer c, OUTER orders o, OUTER cust_calls x
   WHERE c.customer_num = o.customer_num
      AND c.customer_num = x.customer_num
   ORDER BY lname
   INTO TEMP service;
```

Figure 5-34. Query

The query individually joins the subservient tables **orders** and **cust_calls** to the dominant **customer** table; it does not join the two subservient tables. An INTO TEMP clause selects the results into a temporary table for further manipulation or queries, as the result shows.

```
customer_num lname            order_num order_date call_dtime

         114 Albertson
         118 Baxter
         113 Beatty
         103 Currie
         115 Grant                 1010 06/17/1998
⋮
         117 Sipes                 1012 06/18/1998
         105 Vector
         121 Wallack               1018 07/10/1998 1998-07-10 14:05
         106 Watson                1004 05/22/1998 1998-06-12 08:20
         106 Watson                1014 06/25/1998 1998-06-12 08:20
```

Figure 5-35. Query result

If Figure 5-34 had tried to create a join condition between the two subservient tables **o** and **x**, as the following query shows, an error message would indicate the creation of a two-sided outer join.

```
WHERE o.customer_num = x.customer_num
```

Figure 5-36. Query

Joins that combine outer joins

To achieve multiple levels of nesting, you can create a join that employs any combination of the three types of outer joins. Using the ANSI syntax, the following query creates a join that is the result of a combination of a simple outer join on two tables and a second outer join.

```
SELECT c.customer_num, c.lname, o.order_num,
     stock_num, manu_code, quantity
   FROM customer c, OUTER (orders o, OUTER items i)
   WHERE c.customer_num = o.customer_num
      AND o.order_num = i.order_num
      AND manu_code IN ('KAR', 'SHM')
   ORDER BY lname;
```

Figure 5-37. Query

The query first performs an outer join on the **orders** and **items** tables, retrieving information on all orders for items with a **manu_code** of KAR or SHM. It then performs a second outer join that combines this information with data from the dominant **customer** table.

```
customer_num lname            order_num stock_num manu_code quantity

         114 Albertson
         118 Baxter
         113 Beatty
         103 Currie
         115 Grant                 1010
⋮
         117 Sipes                 1012
         117 Sipes                 1007
         105 Vector
         121 Wallack               1018       302 KAR              3
         106 Watson                1014
         106 Watson                1004
```

Figure 5-38. Query result

You can specify the join conditions in two ways when you apply an outer join to the result of an outer join to a third table. The two subservient tables are joined, but you can join the dominant table to either subservient table without affecting the results if the dominant table and the subservient table share a common column.

Subqueries in SELECT statements

A *subquery* (the inner SELECT statement, where one SELECT statement is nested within another) can return zero or more rows or expressions. Each subquery must be delimited by parentheses, and must contain a Projection clause and a FROM clause. A subquery can itself contain other subqueries.

The database server supports subqueries in the following contexts:

- A SELECT statement nested in the Projection clause of another SELECT statement
- a SELECT statement nested in the WHERE clause of another SELECT statement
- a SELECT statement nested in the FROM clause of another SELECT statement.

You can also specify a subquery in various clauses of the INSERT, DELETE, MERGE, or UPDATE statements where a subquery is valid.

Subqueries in the Projection clause or in the WHERE clause can be *correlated* or *uncorrelated*. A subquery is correlated when the value that it produces depends on a value produced by the outer SELECT statement that contains it. For more information, see "Correlated subqueries."

Any other kind of subquery is considered uncorrelated. Only uncorrelated subqueries are valid in the FROM clause of the SELECT statement.

Correlated subqueries

A *correlated subquery* is a subquery that refers to a column of a table that is not listed in its FROM clause. The column can be in the Projection clause or in the WHERE clause. To find the table to which the correlated subquery refers, search the columns until a correlation is found.

In general, correlated subqueries diminish performance. Use the table name or alias in the subquery so that there is no doubt as to which table the column is in.

The database server will use the outer query to get values. For example, if the table **taba** has the column **col1** and table **tabb** has the column **col2** and they contain the following:

```
taba.col1       aa,bb,null
tabb.col2       bb, null
```

And the query is:

```
select * from taba where col1 in (select col1 from tabb);
```

Then the results might be meaningless. The database server will provide all values in **taba.col1** and then compare them to **taba.col1** (outer query WHERE clause). This will return all rows. You usually use the subquery to return column values from the inner table. Had the query been written as:

```
select * from taba where col1 in (select tabb.col1 from tabb);
```

Then the `error -217 column not found` would have resulted.

The important feature of a correlated subquery is that, because it depends on a value from the outer SELECT, it must be executed repeatedly, once for every value that the outer SELECT produces. An uncorrelated subquery is executed only once.

Using subqueries to combine SELECT statements

You can construct a SELECT statement with a subquery to replace two separate SELECT statements.

Subqueries in SELECT statements allow you to perform various tasks, including the following actions:

- Compare an expression to the result of another SELECT statement

- Determine whether the results of another SELECT statement include a specific expression
- Determine whether another SELECT statement returns any rows

An optional WHERE clause in a subquery is often used to narrow the search condition.

A subquery selects and returns values to the first or outer SELECT statement. A subquery can return no value, a single value, or a set of values, as follows:

- If a subquery returns no value, the query does not return any rows. Such a subquery is equivalent to a NULL value.
- If a subquery returns one value, the value is in the form of either one aggregate expression or exactly one row and one column. Such a subquery is equivalent to a single number or character value.
- If a subquery returns a list or set of values, the values can represent one row or one column.
- In the FROM clause of the outer query, a subquery can represent a set of rows (sometimes called a *derived table* or a *table expression*).

Subqueries in a Projection clause

A subquery can occur in the Projection clause of another SELECT statement. The following query shows how you might use a subquery in a Projection clause to return the total shipping charges (from the **orders** table) for each customer in the **customer** table. You could also write this query as a join between two tables.

```
SELECT customer.customer_num,
   (SELECT SUM(ship_charge)
       FROM orders
       WHERE customer.customer_num = orders.customer_num)
         AS total_ship_chg
   FROM customer;
```

Figure 5-39. Query

```
customer_num total_ship_chg

         101        $15.30
         102
         103
         104        $38.00
         105

⋮
         123         $8.50
         124        $12.00
         125
         126        $13.00
         127        $18.00
         128
```

Figure 5-40. Query result

Subqueries in the FROM clause

This topic describes subqueries that occur as nested SELECT statements in the FROM clause of an outer SELECT statement. Such subqueries are sometimes called *derived tables* or *table expressions* because the outer query uses the results of the subquery as a data source.

The following query uses asterisk notation in the outer query to return the results of a subquery that retrieves all fields of the **address** column in the **employee** table.

```
SELECT * FROM (SELECT address.* FROM employee);
```

Figure 5-41. Query

```
address   ROW(102 Ruby, Belmont, CA, 49932, 1000)
address   ROW(133 First, San Jose, CA, 85744, 4900)
address   ROW(152 Topaz, Willits, CA, 69445, 1000))
⋮
```

Figure 5-42. Query result

This illustrates how to specify a derived table, but it is a trivial example of this syntax, because the outer query does not manipulate any values in the table expression that the subquery in the FROM clause returns. (See Figure 3-15 on page 3-6 for a simple query that returns the same results.)

The following query is a more complex example in which the outer query selects only the first qualifying row of a derived table that a subquery in the FROM clause specifies as a simple join on the **customer** and **cust_calls** tables.

```
SELECT LIMIT 1 * FROM
   (SELECT c.customer_num, c.lname, c.company,
           c.phone, u.call_dtime, u.call_descr
                 FROM customer c, cust_calls u
                 WHERE c.customer_num = u.customer_num
    ORDER BY u.call_dtime DESC);
```

Figure 5-43. Query

The query returns only those rows in which the customer has made a call to customer service, as the result shows.

```
customer_num  106
lname         Watson
company       Watson & Son
phone         415-389-8789
call_dtime    1998-06-12 08:20
call_descr    Order was received, but two of the cans of
              ANZ tennis balls within the case were empty
```

Figure 5-44. Query result

In the preceding example, the subquery includes an ORDER BY clause that specifies a column that appears in Projection list of the subquery, but the query would also be valid if the Projection list had omitted the **u.call_dtime** column. The FROM clause is the only context in which a subquery can specify the ORDER BY clause.

Subqueries in WHERE clauses

This section describes subqueries that occur as a SELECT statement that is nested in the WHERE clause of another SELECT statement.

You can use any relational operator with ALL and ANY to compare something to every one of (ALL) or to any one of (ANY) the values that the subquery produces. You can use the keyword SOME in place of ANY. The operator IN is equivalent to = ANY. To create the opposite search condition, use the keyword NOT or a different relational operator.

The EXISTS operator tests a subquery to see if it found any values; that is, it asks if the result of the subquery is not null. You cannot use the EXISTS keyword in a subquery that contains a column with a TEXT or BYTE data type.

For the syntax that you use to create a condition with a subquery, see the *IBM Informix Guide to SQL: Syntax*.

The following keywords introduce a subquery in the WHERE clause of a SELECT statement.

The ALL keyword

Use the keyword ALL preceding a subquery to determine whether a comparison is true for every value returned. If the subquery returns no values, the search condition is *true*. (If it returns no values, the condition is true of all the zero values.)

The following query lists the following information for all orders that contain an item for which the total price is less than the total price on every item in order number 1023.

```
SELECT order_num, stock_num, manu_code, total_price
   FROM items
   WHERE total_price < ALL
      (SELECT total_price FROM items
         WHERE order_num = 1023);
```

Figure 5-45. Query

```
order_num stock_num manu_code total_price

     1003         9 ANZ            $20.00
     1005         6 SMT            $36.00
     1006         6 SMT            $36.00
     1010         6 SMT            $36.00
     1013         5 ANZ            $19.80
     1013         6 SMT            $36.00
     1018       302 KAR            $15.00
```

Figure 5-46. Query result

The ANY keyword

Use the keyword ANY (or its synonym SOME) before a subquery to determine whether a comparison is true for at least one of the values returned. If the subquery returns no values, the search condition is *false*. (Because no values exist, the condition cannot be true for one of them.)

The following query finds the order number of all orders that contain an item for which the total price is greater than the total price of any one of the items in order number 1005.

```
SELECT DISTINCT order_num
   FROM items
   WHERE total_price > ANY
      (SELECT total_price
         FROM items
         WHERE order_num = 1005);
```

Figure 5-47. Query

```
order_num

       1001
       1002
       1003
       1004
⋮
       1020
       1021
       1022
       1023
```

Figure 5-48. Query result

Single-valued subqueries

You do not need to include the keyword ALL or ANY if you know the subquery can return exactly one value to the outer-level query. A subquery that returns exactly one value can be treated like a function. This kind of subquery often uses an aggregate function because aggregate functions always return single values.

The following query uses the aggregate function **MAX** in a subquery to find the **order_num** for orders that include the maximum number of volleyball nets.

```
SELECT order_num FROM items
   WHERE stock_num = 9
      AND quantity =
         (SELECT MAX (quantity)
            FROM items
            WHERE stock_num = 9);
```

Figure 5-49. Query

```
  order_num

       1012
```

Figure 5-50. Query result

The following query uses the aggregate function **MIN** in the subquery to select items for which the total price is higher than 10 times the minimum price.

```
SELECT order_num, stock_num, manu_code, total_price
   FROM items x
   WHERE total_price >
      (SELECT 10 * MIN (total_price)
         FROM items
         WHERE order_num = x.order_num);
```

Figure 5-51. Query

```
order_num stock_num manu_code  total_price

     1003         8 ANZ           $840.00
     1018       307 PRC           $500.00
     1018       110 PRC           $236.00
     1018       304 HRO           $280.00
```

Figure 5-52. Query result

Correlated subqueries

A *correlated subquery* is a subquery that refers to a column of a table that is not in its FROM clause. The column can be in the Projection clause or in the WHERE clause.

In general, correlated subqueries diminish performance. It is recommended that you qualify the column name in subqueries with the name or alias of the table, in order to remove any doubt regarding in which table the column resides.

The following query is an example of a correlated subquery that returns a list of the 10 latest shipping dates in the **orders** table. It includes an ORDER BY clause after the subquery to order the results because (except in the FROM clause) you cannot include ORDER BY within a subquery.

```
SELECT po_num, ship_date FROM orders main
   WHERE 10 >
      (SELECT COUNT (DISTINCT ship_date)
         FROM orders sub
         WHERE sub.ship_date < main.ship_date)
   AND ship_date IS NOT NULL
   ORDER BY ship_date, po_num;
```

Figure 5-53. Query

The subquery is correlated because the number that it produces depends on **main.ship_date**, a value that the outer SELECT produces. Thus, the subquery must be re-executed for every row that the outer query considers.

The query uses the **COUNT** function to return a value to the main query. The ORDER BY clause then orders the data. The query locates and returns the 16 rows that have the 10 latest shipping dates, as the result shows.

```
po_num     ship_date

4745       06/21/1998
278701     06/29/1998
429Q       06/29/1998
8052       07/03/1998
B77897     07/03/1998
LZ230      07/06/1998
B77930     07/10/1998
PC6782     07/12/1998
DM354331   07/13/1998
S22942     07/13/1998
MA003      07/16/1998
W2286      07/16/1998
Z55709     07/16/1998
C3288      07/25/1998
KF2961     07/30/1998
W9925      07/30/1998
```

Figure 5-54. Query result

If you use a correlated subquery, such as Figure 5-53 on page 5-23, on a large table, you should index the **ship_date** column to improve performance. Otherwise, this SELECT statement is inefficient, because it executes the subquery once for every row of the table. For information about indexing and performance issues, see the *IBM Informix Administrator's Guide* and your *IBM Informix Performance Guide*.

You cannot use a correlated subquery in the FROM clause, however, as the following invalid example illustrates:

```
SELECT item_num, stock_num FROM items,
   (SELECT stock_num FROM catalog
       WHERE stock_num = items.item_num) AS vtab;
```

The subquery in this example fails with error -24138:

```
ALL COLUMN REFERENCES IN A TABLE EXPRESSION MUST REFER
TO TABLES IN THE FROM CLAUSE OF THE TABLE EXPRESSION.
```

The database server issues this error because the **items.item_num** column in the subquery also appears in the Projection clause of the outer query, but the FROM clause of the inner query specifies only the **catalog** table. The term *table expression* in the error message text refers to the set of column values or expressions that are returned by a subquery in the FROM clause, where only uncorrelated subqueries are valid.

The EXISTS keyword

The keyword EXISTS is known as an *existential qualifier* because the subquery is true only if the outer SELECT, as the following query shows, finds at least one row.

```
SELECT UNIQUE manu_name, lead_time
   FROM manufact
   WHERE EXISTS
      (SELECT * FROM stock
         WHERE description MATCHES '*shoe*'
            AND manufact.manu_code = stock.manu_code);
```

Figure 5-55. Query

You can often construct a query with EXISTS that is equivalent to one that uses IN. The following query uses an IN predicate to construct a query that returns the same result as the query above.

```
SELECT UNIQUE manu_name, lead_time
   FROM stock, manufact
   WHERE manufact.manu_code IN
      (SELECT manu_code FROM stock
         WHERE description MATCHES '*shoe*')
            AND stock.manu_code = manufact.manu_code;
```

Figure 5-56. Query

Figure 5-55 on page 5-24 and Figure 5-56 return rows for the manufacturers that produce a kind of shoe, as well as the lead time for ordering the product. The result shows the return values.

```
manu_name       lead_time

Anza                5
Hero                4
Karsten            21
Nikolus             8
ProCycle            9
Shimara            30
```

Figure 5-57. Query result

Add the keyword NOT to IN or to EXISTS to create a search condition that is the opposite of the condition in the preceding queries. You can also substitute !=ALL for NOT IN.

The following query shows two ways to do the same thing. One way might allow the database server to do less work than the other, depending on the design of the database and the size of the tables. To find out which query might be better, use the SET EXPLAIN command to get a listing of the query plan. SET EXPLAIN is discussed in your *IBM Informix Performance Guide* and *IBM Informix Guide to SQL: Syntax*.

```
SELECT customer_num, company FROM customer
  WHERE customer_num NOT IN
    (SELECT customer_num FROM orders
       WHERE customer.customer_num = orders.customer_num);

SELECT customer_num, company FROM customer
  WHERE NOT EXISTS
    (SELECT * FROM orders
       WHERE customer.customer_num = orders.customer_num);
```

Figure 5-58. Query

Each statement in the query above returns the following rows, which identify customers who have not placed orders.

```
customer_num company

         102 Sports Spot
         103 Phil's Sports
         105 Los Altos Sports
         107 Athletic Supplies
         108 Quinn's Sports
         109 Sport Stuff
         113 Sportstown
         114 Sporting Place
         118 Blue Ribbon Sports
         125 Total Fitness Sports
         128 Phoenix University
```

Figure 5-59. Query result

The keywords EXISTS and IN are used for the set operation known as *intersection,* and the keywords NOT EXISTS and NOT IN are used for the set operation known as *difference*. These concepts are discussed in "Set operations" on page 5-32.

The following query performs a subquery on the **items** table to identify all the items in the **stock** table that have not yet been ordered.

```
SELECT * FROM stock
   WHERE NOT EXISTS
      (SELECT * FROM items
         WHERE stock.stock_num = items.stock_num
            AND stock.manu_code = items.manu_code);
```

Figure 5-60. Query

The query returns the following rows.

```
stock_num manu_code description unit_price unit unit_descr

      101  PRC        bicycle tires      $88.00  box   4/box
      102  SHM        bicycle brakes    $220.00  case  4 sets/case
      102  PRC        bicycle brakes    $480.00  case  4 sets/case
      105  PRC        bicycle wheels     $53.00  pair  pair
⋮
      312  HRO        racer goggles      $72.00  box   12/box
      313  SHM        swim cap           $72.00  box   12/box
      313  ANZ        swim cap           $60.00  box   12/box
```

Figure 5-61. Query result

No logical limit exists to the number of subqueries a SELECT statement can have.

Perhaps you want to check whether information has been entered correctly in the database. One way to find errors in a database is to write a query that returns output only when errors exist. A subquery of this type serves as a kind of *audit query,* as the following query shows.

```
SELECT * FROM items
   WHERE total_price != quantity *
      (SELECT unit_price FROM stock
         WHERE stock.stock_num = items.stock_num
            AND stock.manu_code = items.manu_code);
```

Figure 5-62. Query

The query returns only those rows for which the total price of an item on an order is not equal to the stock unit price times the order quantity. If no discount has been applied, such rows were probably entered incorrectly in the database. The query returns rows only when errors occur. If information is correctly inserted into the database, no rows are returned.

```
item_num order_num stock_num manu_code quantity total_price

       1      1004         1 HRO              1     $960.00
       2      1006         5 NRG              5     $190.00
```

Figure 5-63. Query result

Subqueries in DELETE and UPDATE statements

Besides subqueries within the WHERE clause of a SELECT statement, you can use subqueries within other data manipulation language (DML) statements, including the WHERE clause of DELETE and UPDATE statements.

Certain restrictions apply. If the FROM clause of a subquery returns more than one row, and the clause specifies the same table or view that the outer DML statement is modifying, the DML operation will succeed under these circumstances:

- The DML statement is not an INSERT statement.
- No SPL routine within the subquery references the table that is being modified.
- The subquery does not include a correlated column name.
- The subquery is specified using the Condition with Subquery syntax in the WHERE clause of the DELETE or UPDATE statement.

If any of these conditions are not met, the DML operation fails with error -360.

The following example updates the **stock** table by increasing the **unit_price** value by 10% for a subset of prices. The WHERE clause specifies which prices to increase by applying the IN operator to the rows returned by a subquery that selects only the rows of the **stock** table where the **unit_price** value is less than 75.

```
UPDATE stock SET unit_price = unit_price * 1.1
   WHERE unit_price IN
      (SELECT unit_price FROM stock WHERE unit_price < 75);
```

Handle collections in SELECT statements

The database server provides the following SQL features to handle collection expressions:

Collection subquery

A collection subquery takes a virtual table (the result of a subquery) and converts it into a collection.

A collection subquery always returns a collection of type MULTISET. You can use a collection subquery to convert a Query result of relational data into a MULTISET collection. For information about the collection data types, see the *IBM Informix Database Design and Implementation Guide*.

Collection-derived table
A collection-derived table takes a collection and converts it into a virtual table.

Each element of the collection is constructed as a row in the collection-derived table. You can use a collection-derived table to access the individual elements of a collection.

The collection subquery and collection-derived table features represent inverse operations: the collection subquery converts row values from a relational table into a collection whereas the collection-derived table converts the elements of a collection into rows of a relational table.

Collection subqueries

A collection subquery enables users to construct a collection expression from a subquery expression. A collection subquery uses the MULTISET keyword immediately before the subquery to convert the values returned into a MULTISET collection. When you use the MULTISET keyword before a subquery expression, however, the database server does not change the rows of the underlying table but only modifies a copy of those rows. For example, if a collection subquery is passed to a user-defined routine that modifies the collection, then a copy of the collection is modified but not the underlying table.

A collection subquery is an expression that can take either of the following forms:

```
MULTISET(SELECT expression1, expression2... FROM tab_name...)
MULTISET(SELECT ITEM expression FROM tab_name...)
```

Omit the ITEM keyword in a collection subquery

If you omit the ITEM keyword in the collection subquery expression, the collection subquery is a MULTISET whose element type is always an unnamed ROW type. The fields of the unnamed ROW type match the data types of the expressions specified in the Projection clause of the subquery.

Suppose you create the following table that contains a column of type MULTISET:

```
CREATE TABLE tab2
(
   id_num INT,
   ms_col MULTISET(ROW(a INT) NOT NULL)
);
```

The following query shows how you might use a collection subquery in a WHERE clause to convert the rows of INT values that the subquery returns to a collection of type MULTISET. In this example, the database server returns rows when the **ms_col** column of **tab2** is equal to the result of the collection subquery expression

```
SELECT id_num FROM tab2
   WHERE ms_col = (MULTISET(SELECT int_col FROM tab1));
```

Figure 5-64. Query

The query omits the ITEM keyword in the collection subquery, so the INT values the subquery returns are of type MULTISET (ROW(a INT) NOT NULL) that matches the data type of the **ms_col** column of **tab2**.

Specify the ITEM keyword in a collection subquery

When the projection list of the subquery contains a single expression, you can preface the projection list of the subquery with the ITEM keyword to specify that the element type of the MULTISET matches the data type of the subquery result. In other words, when you include the ITEM keyword, the database server does not put a row wrapper around the projection list. For example, if the subquery (that immediately follows the MULTISET keyword) returns INT values, the collection subquery is of type MULTISET(INT NOT NULL).

Suppose you create a function **int_func()** that accepts an argument of type MULTISET(INT NOT NULL). The following query shows a collection subquery that converts rows of INT values to a MULTISET and uses the collection subquery as an argument in the function **int_func()**.

```
EXECUTE FUNCTION int_func(MULTISET(SELECT ITEM int_col
   FROM tab1
   WHERE int_col BETWEEN 1 AND 10));
```

Figure 5-65. Query

The query includes the ITEM keyword in the subquery, so the **int_col** values that the query returns are converted to a collection of type MULTISET (INT NOT NULL). Without the ITEM keyword, the collection subquery would return a collection of type MULTISET (ROW(a INT) NOT NULL).

Collection subqueries in the FROM clause

Collection subqueries are valid in the FROM clause of SELECT statements, where the outer query can use the values returned by the subquery as a source of data.

The query examples in the section “Collection subqueries” on page 5-28 specify collection subqueries by using the TABLE keyword followed (within parentheses) by the MULTISET keyword, followed by a subquery. This syntax is an IBM Informix extension to the ANSI/ISO standard for the SQL language.

In the FROM clause of the SELECT statement, and only in that context, you can substitute syntax that complies with the ANSI/ISO standard for SQL by specifying a subquery, omitting the TABLE and MULTISET keywords and the nested parentheses, to specify a collection subquery.

The following query uses the IBM Informix extension syntax to join two collection subqueries in the FROM clause of the outer query:

```
SELECT * FROM TABLE(MULTISET(SELECT SUM(C1) FROM T1 GROUP BY C1)),
         TABLE(MULTISET(SELECT SUM(C1) FROM T2 GROUP BY C2));
```

Figure 5-66. Query

The following logically equivalent query returns the same results as the query above by using ANSI/ISO-compliant syntax to join two derived tables in the FROM clause of the outer query:

```
SELECT * FROM (SELECT SUM(C1) FROM T1 GROUP BY C1),
              (SELECT SUM(C1) FROM T2 GROUP BY C2);
```

Figure 5-67. Query

An advantage of this query over the TABLE(MULTISET(SELECT ...)) IBM Informix extension version is that it can also be executed by any database server that supports the ANSI/ISO-compliant syntax in the FROM clause. For more information about syntax and restrictions for collection subqueries, see the *IBM Informix Guide to SQL: Syntax*.

Collection-derived tables

A *collection-derived table* enables you to handle the elements of a collection expression as rows in a virtual table. Use the TABLE keyword in the FROM clause of a SELECT statement to create a collection-derived table. The database server supports collection-derived tables in SELECT, INSERT, UPDATE, and DELETE statements.

The following query uses a collection-derived table named **c_table** to access elements from the **sales** column of the **sales_rep** table in the **superstores_demo** database. The **sales** column is a collection of an unnamed row type whose two fields, **month** and **amount**, store sales data. The query returns an element for **sales.amount** when **sales.month** equals 98-03. Because the inner select is itself an expression, it cannot return more than one column value per iteration of the outer query. The outer query specifies how many rows of the **sales_rep** table are evaluated.

```
SELECT (SELECT c_table.amount FROM TABLE (sales_rep.sales) c_table
   WHERE c_table.month = '98-03')
   FROM sales_rep;
```

Figure 5-68. Query

```
(expression)

$47.22
$53.22
```

Figure 5-69. Query result

The following query uses a collection-derived table to access elements from the **sales** collection column where the **rep_num** column equals 102. With a collection-derived table, you can specify aliases for the table and columns. If no table name is specified for a collection-derived table, the database server creates one automatically. This example specifies the derived column list **s_month** and **s_amount** for the collection-derived table **c_table**.

```
SELECT * FROM TABLE((SELECT sales FROM sales_rep
   WHERE sales_rep.rep_num = 102)) c_table(s_month, s_amount);
```

Figure 5-70. Query

```
s_month        s_amount

1998-03          $53.22
1998-04          $18.22
```

Figure 5-71. Query result

The following query creates a collection-derived table but does not specify a derived table or derived column names. The query returns the same result as Figure 5-70 except the derived columns assume the default field names of the **sales** column in the **sales_rep** table.

```
SELECT * FROM TABLE((SELECT sales FROM sales_rep
   WHERE sales_rep.rep_num = 102));
```

Figure 5-72. Query

```
month            amount

1998-03          $53.22
1998-04          $18.22
```

Figure 5-73. Query result

Restriction: A collection-derived table is read-only, so it cannot be the target table of INSERT, UPDATE, or DELETE statements or the underlying table of an updatable cursor or view.

For a complete description of the syntax and restrictions on collection-derived tables, see the *IBM Informix Guide to SQL: Syntax*.

ISO-compliant syntax for collection derived tables

The query examples in the topic "Collection-derived tables" on page 5-30 specify collection-derived tables by using the TABLE keyword followed by a SELECT statement enclosed within double parentheses. This syntax is an IBM Informix extension to the ANSI/ISO standard for the SQL language.

In the FROM clause of the SELECT statement, however, and only in that context, you can instead use syntax that complies with the ANSI/ISO standard for SQL by specifying a subquery, without the TABLE keyword or the nested parentheses, to define a collection-derived table.

The following example is logically equivalent to Figure 5-70 on page 5-30, and specifies the derived column list **s_month** and **s_amount** for the collection-derived table **c_table**.

```
SELECT * FROM (SELECT sales FROM sales_rep
   WHERE sales_rep.rep_num = 102) c_table(s_month, s_amount);
```

Figure 5-74. Query

```
s_month         s_amount

1998-03           $53.22
1998-04           $18.22
```

Figure 5-75. Query result

As in the IBM Informix extension syntax, declaring names for the derived table or for its columns is optional, rather than required. The following query uses ANSI/ISO-compliant syntax for a derived table in the FROM clause of the outer query, and produces the same results as Figure 5-72:

```
SELECT * FROM (SELECT sales FROM sales_rep
   WHERE sales_rep.rep_num = 102);
```

Figure 5-76. Query

```
month           amount

1998-03         $53.22
1998-04         $18.22
```

Figure 5-77. Query result

Set operations

The standard set operations *union*, *intersection*, and *difference* let you manipulate database information. These three operations let you use SELECT statements to check the integrity of your database after you perform an update, insert, or delete. They can be useful when you transfer data to a history table, for example, and want to verify that the correct data is in the history table before you delete the data from the original table.

Union

A union operation uses the UNION operator to combine two queries into a single *compound query*. You can use the UNION operator between two or more SELECT statements to produce a temporary table that contains rows that exist in any or all of the original tables. You can also use the UNION operator in the definition of a view.

You cannot use the UNION operator inside a subquery in the following contexts

- in the Projection clause of the SELECT statement
- in the WHERE clause of the SELECT, INSERT, DELETE, or UPDATE statement.

The UNION operator is valid, however, in a subquery in the FROM clause of the SELECT statement, as in the following example:

```
SELECT * FROM (SELECT col1 FROM tab1 WHERE col1 = 100) AS vtab1(c1),
   (SELECT col1 FROM tab2 WHERE col1 = 10
    UNION ALL
    SELECT col1 FROM tab1 WHERE col1 < 50 ) AS vtab2(vc1);
```

IBM Informix does not support ordering on ROW types. Because a UNION operation requires a sort to remove duplicate values, you cannot use a UNION operator when either query in the union operation includes ROW type data. However, the database server does support UNION ALL with ROW type data, because this type of operation does not require a sort.

The following figure illustrates the UNION set operation.

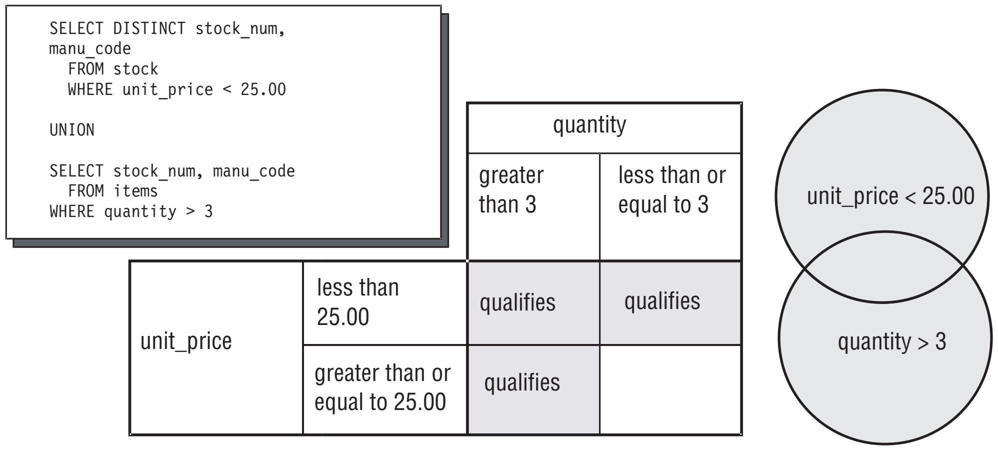

SELECT DISTINCT stock_num, manu_code FROM stock WHERE unit_price < 25.00 UNION SELECT stock_num, manu_code FROM items WHERE quantity > 3
quantity
greater than 3
less than or equal to 3
unit_price
less than 25.00
greater than or equal to 25.00
qualifies
qualifies
qualifies
unit_price < 25.00
quantity > 3

Figure 5-78. The Union set operation

The UNION keyword selects all rows from the two queries, removes duplicates, and returns what is left. Because the results of the queries are combined into a single result, the projection list in each query must have the same number of columns. Also, the corresponding columns that are selected from each table must contain compatible data types (CHARACTER data type columns must be the same length), and these corresponding columns must all allow or all disallow NULL values.

For the complete syntax of the SELECT statement and the UNION operator, see the *IBM Informix Guide to SQL: Syntax*. For information specific to the IBM Informix ESQL/C product and any limitations that involve the INTO clause and compound queries, see the *IBM Informix ESQL/C Programmer's Manual*.

The following query performs a union on the **stock_num** and **manu_code** columns in the **stock** and **items** tables.

```
SELECT DISTINCT stock_num, manu_code FROM stock
   WHERE unit_price < 25.00
UNION
SELECT stock_num, manu_code FROM items
   WHERE quantity > 3;
```

Figure 5-79. Query

The query selects those items that have a unit price of less than $25.00 or that have been ordered in quantities greater than three and lists their **stock_num** and **manu_code**, as the result shows.

```
stock_num manu_code

        5 ANZ
        5 NRG
        5 SMT
        9 ANZ
      103 PRC
      106 PRC
      201 NKL
      301 KAR
      302 HRO
      302 KAR
```

Figure 5-80. Query result

ORDER BY clause with UNION

As the following query shows, when you include an ORDER BY clause, it must follow the final SELECT statement and use an integer, not an identifier, to refer to the ordering column. Ordering takes place after the set operation is complete.

```
SELECT DISTINCT stock_num, manu_code FROM stock
   WHERE unit_price < 25.00
UNION
SELECT stock_num, manu_code FROM items
   WHERE quantity > 3
   ORDER BY 2;
```

Figure 5-81. Query

The compound query above selects the same rows as Figure 5-79 on page 5-33 but displays them in order of the manufacturer code, as the result shows.

```
stock_num manu_code

        5 ANZ
        9 ANZ
      302 HRO
      301 KAR
      302 KAR
      201 NKL
        5 NRG
      103 PRC
      106 PRC
        5 SMT
```

Figure 5-82. Query result

The UNION ALL keywords

By default, the UNION keyword excludes duplicate rows. To retain the duplicate values, add the optional keyword ALL, as the following query shows.

```
SELECT stock_num, manu_code FROM stock
   WHERE unit_price < 25.00
UNION ALL
SELECT stock_num, manu_code FROM items
   WHERE quantity > 3
   ORDER BY 2
   INTO TEMP stock item;
```

Figure 5-83. Query

The query uses the UNION ALL keywords to unite two SELECT statements and adds an INTO TEMP clause after the final SELECT to put the results into a temporary table. It returns the same rows as Figure 5-81 on page 5-34 but also includes duplicate values.

```
stock_num manu_code

        9 ANZ
        5 ANZ
        9 ANZ
        5 ANZ
        9 ANZ
⋮
        5 NRG
        5 NRG
      103 PRC
      106 PRC
        5 SMT
        5 SMT
```

Figure 5-84. Query result

Different column names

Corresponding columns in the Projection clauses for the combined queries must have compatible data types, but the columns do not need to use the same column names.

The following query selects the **state** column from the **customer** table and the corresponding **code** column from the **state** table.

```
SELECT DISTINCT state FROM customer
   WHERE customer_num BETWEEN 120 AND 125
UNION
SELECT DISTINCT code FROM state
   WHERE sname MATCHES '*a';
```

Figure 5-85. Query

The query returns state code abbreviations for customer numbers 120 through 125 and for states whose **sname** ends in `a`.

```
state

AK
AL
AZ
CA
DE
⋮
SD
VA
WV
```

Figure 5-86. Query result

In compound queries, the column names or display labels in the first SELECT statement are the ones that appear in the results. Thus, in the query, the column name **state** from the first SELECT statement is used instead of the column name **code** from the second.

UNION with multiple tables

The following query performs a union on three tables. The maximum number of unions depends on the practicality of the application and any memory limitations.

```
SELECT stock_num, manu_code FROM stock
   WHERE unit_price > 600.00
UNION ALL
SELECT stock_num, manu_code FROM catalog
   WHERE catalog_num = 10025
UNION ALL
SELECT stock_num, manu_code FROM items
   WHERE quantity = 10
   ORDER BY 2;
```

Figure 5-87. Query

The query selects items where the **unit_price** in the **stock** table is greater than $600, the **catalog_num** in the **catalog** table is 10025, or the **quantity** in the **items** table is 10; and the query orders the data by **manu_code**. The result shows the return values.

```
stock_num manu_code

        5 ANZ
        9 ANZ
        8 ANZ
        4 HSK
        1 HSK
      203 NKL
        5 NRG
      106 PRC
      113 SHM
```

Figure 5-88. Query result

A literal in the Projection clause

The following query uses a literal in the projection list to tag the output of part of a union so it can be distinguished later. The tag is given the label **sortkey**. The query uses **sortkey** to order the retrieved rows.

```
SELECT '1' sortkey, lname, fname, company,
     city, state, phone
   FROM customer x
   WHERE state = 'CA'
UNION
SELECT '2' sortkey, lname, fname, company,
     city, state, phone
   FROM customer y
   WHERE state <> 'CA'
   INTO TEMP calcust;
SELECT * FROM calcust
   ORDER BY 1;
```

Figure 5-89. Query

The query creates a list in which the customers from California appear first.

```
sortkey  1
lname    Baxter
fname    Dick
company  Blue Ribbon Sports
city     Oakland
state    CA
phone    415-655-0011

sortkey  1
lname    Beatty
fname    Lana
company  Sportstown
city     Menlo Park
state    CA
phone    415-356-9982
⋮
sortkey  2
lname    Wallack
fname    Jason
company  City Sports
city     Wilmington
state    DE
phone    302-366-7511
```

Figure 5-90. Query result

A FIRST clause

You can use the FIRST clause to select the first rows that result from a union query. The following query uses a FIRST clause to return the first five rows of a union between the **stock** and **items** tables.

```
SELECT FIRST 5 DISTINCT stock_num, manu_code
   FROM stock
   WHERE unit_price < 55.00
UNION
SELECT stock_num, manu_code
   FROM items
   WHERE quantity > 3;
```

Figure 5-91. Query

```
stock_num manu_code

        5 NRG
        5 ANZ
        6 SMT
        6 ANZ
        9 ANZ
```

Figure 5-92. Query result

Intersection

The *intersection* of two sets of rows produces a table that contains rows that exist in both the original tables. Use the keyword EXISTS or IN to introduce subqueries that show the intersection of two sets. The following figure illustrates the intersection set operation.

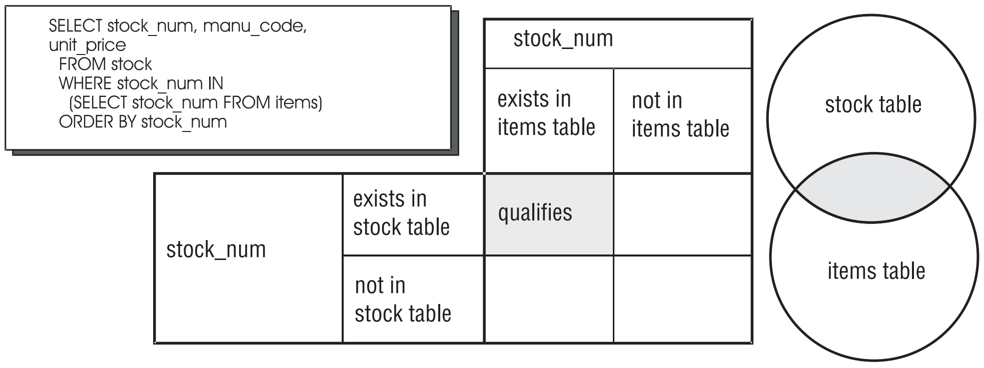


Figure 5-93. The intersection set operation

The following query is an example of a nested SELECT statement that shows the intersection of the **stock** and **items** tables. The result contains all the elements that appear in both sets and returns the following rows.

```
SELECT stock_num, manu_code, unit_price FROM stock
   WHERE stock_num IN
      (SELECT stock_num FROM items)
   ORDER BY stock_num;
```

Figure 5-94. Query

```
stock_num manu_code unit_price

        1 HRO         $250.00
        1 HSK         $800.00
        1 SMT         $450.00
        2 HRO         $126.00
        3 HSK         $240.00
        3 SHM         $280.00
⋮
      306 SHM         $190.00
      307 PRC         $250.00
      309 HRO          $40.00
      309 SHM          $40.00
```

Figure 5-95. Query result

Difference

The *difference* between two sets of rows produces a table that contains rows in the first set that are not also in the second set. Use the keywords NOT EXISTS or NOT IN to introduce subqueries that show the difference between two sets. The following figure illustrates the difference set operation.

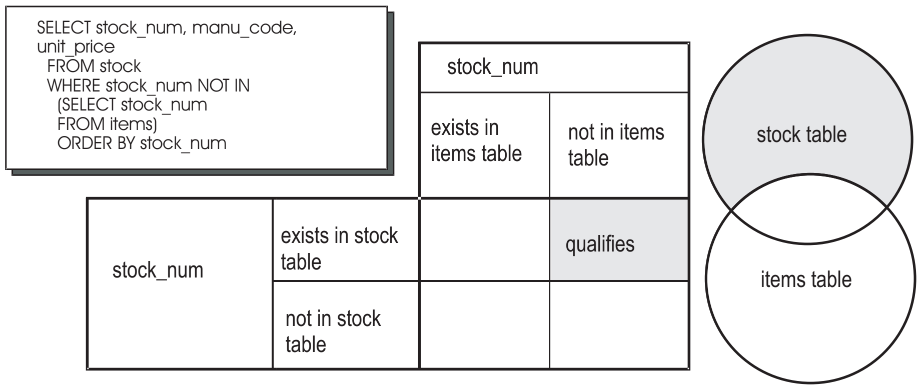


Figure 5-96. The difference set operation

The following query is an example of a nested SELECT statement that shows the difference between the **stock** and **items** tables.

```
SELECT stock_num, manu_code, unit_price FROM stock
   WHERE stock_num NOT IN
      (SELECT stock_num FROM items)
   ORDER BY stock_num;
```

Figure 5-97. Query

The result contains all the elements from only the first set, which returns 17 rows.

```
stock_num manu_code unit_price

      102 PRC         $480.00
      102 SHM         $220.00
      106 PRC          $23.00
⋮
      312 HRO          $72.00
      312 SHM          $96.00
      313 ANZ          $60.00
      313 SHM          $72.00
```

Figure 5-98. Query result

Summary

This chapter builds on concepts introduced in Chapter 2, "Compose SELECT statements," on page 2-1. It provides sample syntax and results for more advanced kinds of SELECT statements, which are used to query a relational database. This chapter presents the following material:

- Introduces the GROUP BY and HAVING clauses, which you can use with aggregates to return groups of rows and apply conditions to those groups
- Shows how to join a table to itself with a self-join to compare values in a column with other values in the same column and to identify duplicates
- Explains how an outer join treats two or more tables asymmetrically, and provides examples of the four kinds of outer join using both the IBM Informix extension and ANSI join syntax.
- Describes how to nest a SELECT statement in the WHERE clause of another SELECT statement to create correlated and uncorrelated subqueries and shows how to use aggregate functions in subqueries
- Describes how to nest SELECT statements in the FROM clause of another SELECT statement to specify uncorrelated subqueries whose results are a data source for the outer SELECT statement
- Demonstrates how to use the keywords ALL, ANY, EXISTS, IN, and SOME to create subqueries, and the effect of adding the keyword NOT or a relational operator
- Describes how to use collection subqueries to convert relational data to a collection of type MULTISET and how to use collection-derived tables to access elements within a collection
- Discusses the union, intersection, and difference set operations
- Shows how to use the UNION and UNION ALL keywords to create compound queries that consist of two or more SELECT statements

Chapter 6. Modify data

This section describes how to modify the data in your databases. Modifying data is fundamentally different from querying data. Querying data involves examining the contents of tables. To modify data involves changing the contents of tables.

Modify data in your database

The following statements modify data:

- DELETE
- INSERT
- MERGE
- UPDATE

Although these SQL statements are relatively simple when compared with the more advanced SELECT statements, use them carefully because they change the contents of the database.

Think about what happens if the system hardware or software fails during a query. Even if the effect on the application is severe, the database itself is unharmed. However, if the system fails while a modification is under way, the state of the database is in doubt. Obviously, a database in an uncertain state has far-reaching implications. Before you delete, insert, or update rows in a database, ask yourself the following questions:

- Is user access to the database and its tables secure; that is, are specific users given limited database and table-level privileges?
- Does the modified data preserve the existing integrity of the database?
- Are systems in place that make the database relatively immune to external events that might cause system or hardware failures?

If you cannot answer yes to each of these questions, do not panic. Solutions to all these problems are built into the IBM Informix database servers. After a description of the statements that modify data, this section discusses these solutions. The *IBM Informix Database Design and Implementation Guide* covers these topics in greater detail.

Delete rows

The DELETE statement removes any row or combination of rows from a table. You cannot recover a deleted row after the transaction is committed. (Transactions are discussed under "Interrupted modifications" on page 6-32. For now, think of a transaction and a statement as the same thing.)

When you delete a row, you must also be careful to delete any rows of other tables whose values depend on the deleted row. If your database enforces referential constraints, you can use the ON DELETE CASCADE option of the CREATE TABLE or ALTER TABLE statements to allow deletes to cascade from one table in a relationship to another. For more information on referential constraints and the ON DELETE CASCADE option, refer to "Referential integrity" on page 6-24.

Delete all rows of a table

The DELETE statement specifies a table and usually contains a WHERE clause that designates the row or rows that are to be removed from the table. If the WHERE clause is left out, all rows are deleted.

Important: Do not execute the following statement.

```
DELETE FROM customer;
```

You can write DELETE statements with or without the FROM keyword.

```
DELETE customer;
```

Because these DELETE statements do not contain a WHERE clause, all rows from the **customer** table are deleted. If you attempt an unconditional delete using the DB-Access menu options, the program warns you and asks for confirmation. However, an unconditional DELETE from within a program can occur without warning.

If you want to delete rows from a table named **from**, you must first set the **DELIMIDENT** environment variable, or qualify the name of the table with the name of its owner:

```
DELETE legree.from;
```

For more information about delimited identifiers and **DELIMIDENT** environment variable, see the descriptions of the Quoted String expression and of the Identifier segment in the *IBM Informix Guide to SQL: Syntax*.

Delete all rows using TRUNCATE

You can use the TRUNCATE statement to quickly remove all rows from a table and also remove all corresponding index data. You cannot recover deleted rows after the transaction is committed. You can use the TRUNCATE statement on tables that contain any type of columns, including smart large objects.

Removing rows with the TRUNCATE statement is faster than removing them with the DELETE statement. It is not necessary to run the UPDATE STATISTICS statement immediately after the TRUNCATE statement. After TRUNCATE executes successfully, IBM Informix automatically updates the statistics and distributions for the table and for its indexes in the system catalog to show no rows in the table or in its dbspace partitions.

For a description of logging, see "Transaction logging" on page 6-33.

TRUNCATE is a data-definition language statement that does not activate DELETE triggers, if any are defined on the table. For an explanation on using triggers, see Chapter 12, "Create and use triggers," on page 12-1.

If the table that the TRUNCATE statement specifies is a typed table, a successful TRUNCATE operation removes all the rows and B-tree structures from that table and from all its subtables within the table hierarchy. TRUNCATE has no equivalent to the ONLY keyword of the DELETE statement to restricts the operation to a single table within the typed table hierarchy.

IBM Informix always logs the TRUNCATE operation, even for a non-logging table. In databases that support transaction logging, only the COMMIT WORK or ROLLBACK WORK statement of SQL is valid after TRUNCATE within the same transaction. For information on the performance impact of using the TRUNCATE statement, see your *IBM Informix Performance Guide*. For the complete syntax, see the *IBM Informix Guide to SQL: Syntax*.

Delete specified rows

The WHERE clause in a DELETE statement has the same form as the WHERE clause in a SELECT statement. You can use it to designate exactly which row or rows should be deleted. You can delete a customer with a specific customer number, as the following example shows:

```
DELETE FROM customer WHERE customer_num = 175;
```

In this example, because the **customer_num** column has a unique constraint, you can ensure that no more than one row is deleted.

Delete selected rows

You can also choose rows that are based on nonindexed columns, as the following example shows:

```
DELETE FROM customer WHERE company = 'Druid Cyclery';
```

Because the column that is tested does not have a unique constraint, this statement might delete more than one row. (Druid Cyclery might have two stores, both with the same name but different customer numbers.)

To find out how many rows a DELETE statement affects, select the count of qualifying rows from the **customer** table for Druid Cyclery.

```
SELECT COUNT(*) FROM customer WHERE company = 'Druid Cyclery';
```

You can also select the rows and display them to ensure that they are the ones you want to delete.

Using a SELECT statement as a test is only an approximation, however, when the database is available to multiple users concurrently. Between the time you execute the SELECT statement and the subsequent DELETE statement, other users could have modified the table and changed the result. In this example, another user might perform the following actions:

- Insert a new row for another customer named Druid Cyclery
- Delete one or more of the Druid Cyclery rows before you insert the new row
- Update a Druid Cyclery row to have a new company name, or update some other customer to have the name Druid Cyclery.

Although it is not likely that other users would do these things in that brief interval, the possibility does exist. This same problem affects the UPDATE statement. Ways of addressing this problem are discussed under “Concurrency and locks” on page 6-36, and in greater detail in Chapter 10, “Programming for a multiuser environment,” on page 10-1.

Another problem you might encounter is a hardware or software failure before the statement finishes. In this case, the database might have deleted no rows, some rows, or all specified rows. The state of the database is unknown, which is undesirable. To prevent this situation, use transaction logging, as “Interrupted modifications” on page 6-32 discusses.

Delete rows that contain row types

When a row contains a column that is defined on a ROW type, you can use dot notation to specify that the only rows deleted are those that contain a specific field value. For example, the following statement deletes only those rows from the **employee** table in which the value of the **city** field in the **address** column is `San Jose`:

```
DELETE FROM employee
   WHERE address.city = 'San Jose';
```

In the preceding statement, the **address** column might be a named ROW type or an unnamed ROW type. The syntax you use to specify field values of a ROW type is the same.

Delete rows that contain collection types

When a row contains a column that is defined on a collection type, you can search for a particular element in a collection and delete the row or rows in which that element is found. For example, the following statement deletes rows in which the **direct_reports** column contains a collection with the element `Baker`:

```
DELETE FROM manager
   WHERE 'Baker' IN direct_reports;
```

Delete rows from a supertable

When you delete the rows of a supertable, the scope of the delete is a supertable and its subtables. Suppose you create a supertable **person** that has two subtables **employee** and **sales_rep** defined under it. The following DELETE statement on the **person** table can delete rows from all the tables **person**, **employee**, and **sales_rep**:

```
DELETE FROM person
   WHERE name ='Walker';
```

To limit a delete to rows of the supertable only, you must use the ONLY keyword in the DELETE statement. For example, the following statement deletes rows of the **person** table only:

```
DELETE FROM ONLY(person)
   WHERE name ='Walker';
```

Important: Use caution when you delete rows from a supertable because the scope of a delete on a supertable includes the supertable and all its subtables.

Complicated delete conditions

The WHERE clause in a DELETE statement can be almost as complicated as the one in a SELECT statement. It can contain multiple conditions that are connected by AND and OR, and it might contain subqueries.

Suppose you discover that some rows of the **stock** table contain incorrect manufacturer codes. Rather than update them, you want to delete them so that they can be re-entered. You know that these rows, unlike the correct ones, have no matching rows in the **manufact** table. The fact that these incorrect rows have no matching rows in the **manufact** table allows you to write a DELETE statement such as the one in the following example:

```
DELETE FROM stock
   WHERE 0 = (SELECT COUNT(*) FROM manufact
        WHERE manufact.manu_code = stock.manu_code);
```

The subquery counts the number of rows of **manufact** that match; the count is 1 for a correct row of **stock** and 0 for an incorrect one. The latter rows are chosen for deletion.

Tip: One way to develop a DELETE statement with a complicated condition is to first develop a SELECT statement that returns precisely the rows to be deleted. Write it as `SELECT *`; when it returns the desired set of rows, change `SELECT *` to read `DELETE` and execute it once more.

The WHERE clause of a DELETE statement cannot use a subquery that tests the same table. That is, when you delete from **stock**, you cannot use a subquery in the WHERE clause that also selects from **stock**.

The key to this rule is in the FROM clause. If a table is named in the FROM clause of a DELETE statement, it cannot also appear in the FROM clause of a subquery of the DELETE statement.

The Delete clause of MERGE

Instead of writing a subquery in the WHERE clause, you can use the MERGE statement to join rows from a source tables and a target table, and then delete from the target the rows that match the join condition. (The source table in a Delete MERGE can also be a collection-derived table whose rows are the result of a query that joins other tables and views, but in the example that follows, the source is a single table.)

As in the previous example, suppose you discover that some rows of the **stock** table contain incorrect manufacturer codes. Rather than update them, you want to delete them so that they can be re-entered. You can use the MERGE statement that specifies **stock** as the target table, **manufact** as the source table, a join condition in the ON clause, and with the Delete clause for the **stock** rows with incorrect manufacturer codes, as in the following example:

```
MERGE INTO stock USING manufact
   ON stock.manu_code != manufact.manu_code
WHEN MATCHED THEN DELETE;
```

In this example, all the rows of the **stock** table for which the join condition in the ON clause is satisfied will be deleted. Here the inequality predicate in the join condition (`stock.manu_code != manufact.manu_code`) evaluates to true for the rows of **stock** in which the **manu_code** column value is not equal to any **manu_code** value in the **manufact** table.

The **source** table that is being joined to the *target* table must be listed in the USING clause.

The MERGE statement can also update rows of the target table, or insert data from the source table into the target table, according to whether or not the row satisfies the condition that the ON clause specifies for joining the target and source tables. A single MERGE statement can also combine both DELETE and INSERT operations, or can combine both UPDATE and INSERT operations without deleting any rows. The source table is unchanged by the MERGE statement. For more information on the syntax and restrictions for Delete merges, Insert merges, and Update merges, see the description of the MERGE statement in the *IBM Informix Guide to SQL: Syntax*.

Insert rows

The INSERT statement adds a new row, or rows, to a table. The statement has two basic functions. It can create a single new row using column values you supply, or it can create a group of new rows using data selected from other tables.

Single rows

In its simplest form, the INSERT statement creates one new row from a list of column values and puts that row in the table. The following statement shows how to add a row to the **stock** table:

```
INSERT INTO stock
   VALUES (115, 'PRC', 'tire pump', 108, 'box', '6/box');
```

The **stock** table has the following columns:

stock_num
A number that identifies the type of merchandise.

manu_code
A foreign key to the **manufact** table.

description
A description of the merchandise.

unit_price
The unit price of the merchandise.

unit The unit of measure

unit_descr
Characterizes the unit of measure.

The values that are listed in the VALUES clause in the preceding example have a one-to-one correspondence with the columns of the **stock** table. To write a VALUES clause, you must know the columns of the tables as well as their sequence from first to last.

Possible column values

The VALUES clause accepts only constant values, not general SQL expressions. You can supply the following values:

- Literal numbers
- Literal DATETIME values
- Literal INTERVAL values
- Quoted strings of characters
- The word NULL for a NULL value
- The word TODAY for the current date
- The word CURRENT (or SYSDATE) for the current date and time
- The word USER for your authorization identifier
- The word DBSERVERNAME (or SITENAME) for the name of the computer where the database server is running

Note: An alternative to the INSERT statement is the MERGE statement, which can use the same VALUES clause syntax as the INSERT statement to insert rows into a table. The MERGE statement performs an outer join of a source table and a target table, and then inserts into the target table any rows in the result set of the join for which the join predicate evaluates to FALSE. The source table is unchanged by the

MERGE statement. Besides inserting rows, the MERGE statement can optionally combine both DELETE and INSERT operations, or combine both UPDATE and INSERT operations. For more information about the syntax and the restrictions on Insert merges, Delete merges, and Update merges, see the description of the MERGE statement in the *IBM Informix Guide to SQL: Syntax*.

Restrictions on column values

Some columns of a table might not allow null values. If you attempt to insert NULL in such a column, the statement is rejected. Other columns in the table might not permit duplicate values. If you specify a value that is a duplicate of one that is already in such a column, the statement is rejected. Some columns might even restrict the possible column values allowed. Use data integrity constraints to restrict columns. For more information, see "Data integrity" on page 6-23.

Restriction: Do not specify the currency symbols for columns that contain money values. Just specify the numeric value of the amount.

The database server can convert between numeric and character data types. You can give a string of numeric characters (for example, `'-0075.6'`) as the value of a numeric column. The database server converts the numeric string to a number. An error occurs only if the string does not represent a number.

You can specify a number or a date as the value for a character column. The database server converts that value to a character string. For example, if you specify TODAY as the value for a character column, a character string that represents the current date is used. (The **DBDATE** environment variable specifies the format that is used.)

Serial data types

A table can have only one column of the SERIAL data type. It can also have either a SERIAL8 column or a BIGSERIAL column.

When you insert values, specify the value zero for the serial column. The database server generates the next actual value in sequence. Serial columns do not allow NULL values.

You can specify a nonzero value for a serial column (as long as it does not duplicate any existing value in that column), and the database server uses the value. That nonzero value might set a new starting point for values that the database server generates. (The next value the database server generates for you is one greater than the maximum value in the column.)

List specific column names

You do not have to specify values for every column. Instead, you can list the column names after the table name and then supply values for only those columns that you named. The following example shows a statement that inserts a new row into the **stock** table:

```
INSERT INTO stock (stock_num,  description,  unit_price,  manu_code)
   VALUES (115,  'tyre pump ',  114,  'SHM');
```

Only the data for the stock number, description, unit price, and manufacturer code is provided. The database server supplies the following values for the remaining columns:

- It generates a serial number for an unlisted serial column.
- It generates a default value for a column with a specific default associated with it.

- It generates a NULL value for any column that allows nulls but it does not specify a default value for any column that specifies NULL as the default value.

  You must list and supply values for all columns that do not specify a default value or do not permit NULL values.

You can list the columns in any order, as long as the values for those columns are listed in the same order. For information about how to designate null or default values for a column, see the *IBM Informix Database Design and Implementation Guide*.

After the INSERT statement in the preceding example is executed, the following new row is inserted into the **stock** table:

```
stock_num manu_code  description  unit_price unit unit_descr

      115       SHM  tyre pump           114
```

Both **unit** and **unit_descr** are blank, which indicates that NULL values exist in those two columns. Because the **unit** column permits NULL values, the number of tire pumps that can be purchased for $114 is not known. Of course, if a default value of `box` were specified for this column, then `box` would be the unit of measure. In any case, when you insert values into specific columns of a table, pay attention to what data is needed for that row.

Insert rows into typed tables

You can insert rows into a typed table in the same way you insert rows into a table not based on a ROW type.

When a typed table contains a row-type column (the named ROW type that defines the typed table contains a nested ROW type), you insert into the row-type column in the same way you insert into a row-type column for a table not based on a ROW type. The following section, “Syntax rules for inserts on columns” on page 6-9, describes how to perform inserts into row-type columns.

This section uses row types **zip_t**, **address_t**, and **employee_t** and typed table **employee** for examples. The following figure shows the SQL syntax that creates the row types and table.

```
CREATE ROW TYPE zip_t
(
   z_code    CHAR(5),
   z_suffix  CHAR(4)
);

CREATE ROW TYPE address_t
(
   street    VARCHAR(20),
   city      VARCHAR(20),
   state     CHAR(2),
   zip       zip_t
);

CREATE ROW TYPE employee_t
(
   name      VARCHAR(30),
   address   address_t,
   salary    INTEGER
);

CREATE TABLE employee OF TYPE employee_t;
```

Figure 6-1. SQL syntax that creates the row types and table.

Syntax rules for inserts on columns

The following syntax rules apply for inserts on columns that are defined on named ROW types or unnamed ROW types:

- Specify the ROW constructor before the field values to be inserted.
- Enclose the field values of the ROW type in parentheses.
- Cast the ROW expression to the appropriate named ROW type (for named ROW types).

Rows that contain named row types

The following statement shows you how to insert a row into the **employee** table in Figure 6-2 on page 6-10:

```
INSERT INTO employee
   VALUES ('Poole, John',
   ROW('402 High St', 'Willits', 'CA',
   ROW(69055,1450))::address_t, 35000 );
```

Because the **address** column of the **employee** table is a named ROW type, you must use a cast operator and the name of the ROW type (**address_t**) to insert a value of type **address_t**.

Rows that contain unnamed row types

Suppose you create the table that the following figure shows. The **student** table defines the **s_address** column as an unnamed row type.

```
CREATE TABLE student
(
s_name     VARCHAR(30),
s_address  ROW(street VARCHAR (20), city VARCHAR(20),
               state CHAR(2), zip VARCHAR(9)),
               grade_point_avg DECIMAL(3,2)
);
```

Figure 6-2. Create the student table.

The following statement shows you how to add a row to the **student** table. To insert into the unnamed row-type column **s_address**, use the ROW constructor but do not cast the row-type value.

```
INSERT INTO student
   VALUES ('Keene, Terry',
      ROW('53 Terra Villa', 'Wheeling', 'IL', '45052'),
      3.75);
```

Specify NULL values for row types

The fields of a row-type column can contain NULL values. You can specify NULL values either at the level of the column or the field.

The following statement specifies a NULL value at the column level to insert NULL values for all fields of the **s_address** column. When you insert a NULL value at the column level, do not include the ROW constructor.

```
INSERT INTO student VALUES ('Brauer, Howie', NULL, 3.75);
```

When you insert a NULL value for particular fields of a ROW type, you must include the ROW constructor. The following INSERT statement shows how you might insert NULL values into particular fields of the **address** column of the **employee** table. (The **address** column is defined as a named ROW type.)

```
INSERT INTO employee
   VALUES (
      'Singer, John',
      ROW(NULL, 'Davis', 'CA',
      ROW(97000, 2000))::address_t, 67000
      );
```

When you specify a NULL value for the field of a ROW type, you do not need to explicitly cast the NULL value when the ROW type occurs in an INSERT statement, an UPDATE statement, or a program variable assignment.

The following INSERT statement shows how you insert NULL values for the **street** and **zip** fields of the **s_address** column for the **student** table:

```
INSERT INTO student
   VALUES(
      'Henry, John',
      ROW(NULL, 'Seattle', 'WA', NULL), 3.82
      );
```

Insert rows into supertables

No special considerations exist when you insert a row into a supertable. An INSERT statement applies only to the table that is specified in the statement. For example, the following statement inserts values into the supertable but does not insert values into any subtables:

```
INSERT INTO person
   VALUES (
      'Poole, John',
      ROW('402 Saphire St.', 'Elmondo', 'CA', '69055'),
      345605900
      );
```

Insert collection values into columns

This section describes how to insert a collection value into a column with DB-Access. It does not discuss how to insert individual elements into a collection column. To access or modify the individual elements of a collection, use an Informix ESQL/C program or SPL routine. For information about how to create an Informix ESQL/C program to insert into a collection, see the *IBM Informix ESQL/C Programmer's Manual*. For information about how to create an SPL routine to insert into a collection, see Chapter 11, "Create and use SPL routines," on page 11-1.

The examples that this section provides are based on the **manager** table in the following figure. The **manager** table contains both simple and nested collection types.

```
CREATE TABLE manager
(
  mgr_name        VARCHAR(30),
  department      VARCHAR(12),
  direct_reports  SET(VARCHAR(30) NOT NULL),
  projects        LIST(ROW(pro_name VARCHAR(15),
                    pro_members SET(VARCHAR(20) NOT NULL))
                    NOT NULL)
);
```

Figure 6-3. Create the manager table.

Insert values into simple collections and nested collections

When you insert values into a row that contains a collection column, you insert the values of all the elements that the collection contains as well as values for the other columns. For example, the following statement inserts a single row into the **manager** table, which includes columns for both simple collections and nested collections:

```
INSERT INTO manager(mgr_name, department,
   direct_reports, projects)
   VALUES
(
'Sayles', 'marketing',
"SET{'Simonian', 'Waters', 'Adams', 'Davis', 'Jones'}",
LIST{
   ROW('voyager_project', SET{'Simonian', 'Waters',
   'Adams', 'Davis'}),
   ROW ('horizon_project', SET{'Freeman', 'Jacobs',
   'Walker', 'Smith', 'Cannan'}),
   ROW ('saphire_project', SET{'Villers', 'Reeves',
   'Doyle', 'Strongin'})
   }
);
```

Insert NULL values into a collection that contains a row type

To insert values into a collection that is a ROW type, you must specify a value for each field in the ROW type.

In general, NULL values are not allowed in a collection. However, if the element type of the collection is a ROW type, you can insert NULL values into individual fields of the row type.

You can also specify an *empty collection*. An empty collection is a collection that contains no elements. To specify an empty collection, use the braces ({}). For example, the following statement inserts data into a row in the **manager** table but specifies that the **direct_reports** and **projects** columns are empty collections:

```
INSERT INTO manager
   VALUES ('Sayles', 'marketing', "SET{}",
   "LIST{ROW(NULL, SET{})}"
);
```

A collection column cannot contain NULL elements. The following statement returns an error because NULL values are specified as elements of collections:

```
INSERT INTO manager
   VALUES ('Cole', 'accounting', "SET{NULL}",
   "LIST{ROW(NULL, ""SET{NULL}"")}"
```

The following syntax rules apply for performing inserts and updates on collection types:
- Use braces ({}) to demarcate the elements that each collection contains.
- If the collection is a nested collection, use braces ({}) to demarcate the elements of both the inner and outer collections.

Insert smart large objects

When you use the INSERT statement to insert an object into a **BLOB** or **CLOB** column, the database server stores the object in an sbspace, rather than the table. The database server provides SQL functions that you can call from within an INSERT statement to import and export BLOB or CLOB data, otherwise known as smart large objects. For a description of these functions, see "Smart large object functions" on page 4-13.

The following INSERT statement uses the **filetoblob()** and **filetoclob()** functions to insert a row of the **inmate** table. (Figure 4-53 on page 4-13 defines the **inmate** table.)

```
INSERT INTO inmate
   VALUES (437, FILETOBLOB('datafile', 'client'),
      FILETOCLOB('tmp/text', 'server'));
```

In the preceding example, the first argument for the **FILETOBLOB()** and **FILETOCLOB()** functions specifies the path of the source file to be copied into the **BLOB** and **CLOB** columns of the **inmate** table, respectively. The second argument for each function specifies whether the source file is located on the client computer ('client') or server computer ('server'). To specify the path of a file name in the function argument, apply the following rules:
- If the source file resides on the server computer, you must specify the full path name to the file (not the path name relative to the current working directory).
- If the source file resides on the client computer, you can specify either the full or relative path name to the file.

Multiple rows and expressions

The other major form of the INSERT statement replaces the VALUES clause with a SELECT statement. This feature allows you to insert the following data:

- Multiple rows with only one statement (each time the SELECT statement returns a row, a row is inserted)
- Calculated values (the VALUES clause permits only constants) because the projection list can contain expressions

For example, suppose a follow-up call is required for every order that has been paid for but not shipped. The INSERT statement in the following example finds those orders and inserts a row in **cust_calls** for each order:

```
INSERT INTO cust_calls (customer_num, call_descr)
   SELECT customer_num, order_num FROM orders
      WHERE paid_date IS NOT NULL
      AND ship_date IS NULL;
```

This SELECT statement returns two columns. The data from these columns (in each selected row) is inserted into the named columns of the **cust_calls** table. Then an order number (from **order_num**, a SERIAL column) is inserted into the call description, which is a character column. Remember that the database server allows you to insert integer values into a character column. It automatically converts the serial number to a character string of decimal digits.

Restrictions on the insert selection

The following list contains the restrictions on the SELECT statement for inserting rows:

- It cannot contain an INTO clause.
- It cannot contain an INTO TEMP clause.
- It cannot contain an ORDER BY clause.
- It cannot refer to the table into which you are inserting rows.

The INTO, INTO TEMP, and ORDER BY clause restrictions are minor. The INTO clause is not useful in this context. (For more information, see Chapter 8, "SQL programming," on page 8-1.) To work around the INTO TEMP clause restriction, first select the data you want to insert into a temporary table and then insert the data from the temporary table with the INSERT statement. Likewise, the lack of an ORDER BY clause is not important. If you need to ensure that the new rows are physically ordered in the table, you can first select them into a temporary table and order it, and then insert from the temporary table. You can also apply a physical order to the table using a clustered index after all insertions are done.

Important: The last restriction is more serious because it prevents you from naming the same table in both the INTO clause of the INSERT statement and the FROM clause of the SELECT statement. Naming the same table in both the INTO clause of the INSERT statement and the FROM clause of the SELECT statement causes the database server to enter an endless loop in which each inserted row is reselected and reinserted.

In some cases, however, you might want to select from the same table into which you must insert data. For example, suppose that you have learned that the Nikolus company supplies the same products as the Anza company, but at half the price. You want to add rows to the **stock** table to reflect the difference between the two companies. Optimally, you want to select data from all the Anza stock rows and reinsert it with the Nikolus manufacturer code. However, you cannot select from the same table into which you are inserting.

To get around this restriction, select the data you want to insert into a temporary table. Then select from that temporary table in the INSERT statement, as the following example shows:

```
SELECT stock_num, 'NIK' temp_manu, description, unit_price/2
      half_price, unit,  unit_descr FROM stock
   WHERE manu_code = 'ANZ'
      AND stock_num < 110
   INTO TEMP anzrows;

INSERT INTO stock SELECT * FROM anzrows;

DROP TABLE anzrows;
```

This SELECT statement takes existing rows from **stock** and substitutes a literal value for the manufacturer code and a computed value for the unit price. These rows are then saved in a temporary table, **anzrows**, which is immediately inserted into the **stock** table.

When you insert multiple rows, a risk exists that one of the rows contains invalid data that might cause the database server to report an error. When such an error occurs, the statement terminates early. Even if no error occurs, a small risk exists that a hardware or software failure might occur while the statement is executing (for example, the disk might fill up).

In either event, you cannot easily tell how many new rows were inserted. If you repeat the statement in its entirety, you might create duplicate rows, or you might not. Because the database is in an unknown state, you cannot know what to do. The solution lies in using transactions, as “Interrupted modifications” on page 6-32 discusses.

Update rows

Use the UPDATE statement to change the contents of one or more existing rows of a table, according to the specifications of the SET clause. This statement takes two fundamentally different forms. One lets you assign specific values to columns by name; the other lets you assign a list of values (that might be returned by a SELECT statement) to a list of columns. In either case, if you are updating rows, and some of the columns have data integrity constraints, the data that you change must conform to the constraints placed on those columns. For more information, refer to “Data integrity” on page 6-23.

Note: An alternative to the UPDATE statement is the MERGE statement, which can use the same SET clause syntax as the UPDATE statement to modify one or more values in existing rows of a table. The MERGE statement performs an outer join of a source table and a target table, and then updates rows in the target table with values from the result set of the join for which the join predicate evaluates to TRUE. Values in the source table are unchanged by the MERGE statement. Besides updating rows, the MERGE statement can optionally combine both UPDATE and INSERT operations, or can combine both DELETE and INSERT operations without updating any rows. For more information about the syntax and the restrictions on Update merges, Delete merges, and Insert merges, see the description of the MERGE statement in the *IBM Informix Guide to SQL: Syntax*.

Select rows to update

Either form of the UPDATE statement can end with a WHERE clause that determines which rows are modified. If you omit the WHERE clause, all rows are modified. To select the precise set of rows that need changing in the WHERE clause can be quite complicated. The only restriction on the WHERE clause is that the table that you update cannot be named in the FROM clause of a subquery.

The first form of an UPDATE statement uses a series of assignment clauses to specify new column values, as the following example shows:

```
UPDATE customer
   SET fname = 'Barnaby', lname = 'Dorfler'
   WHERE customer_num = 103;
```

The WHERE clause selects the row you want to update. In the demonstration database, the **customer.customer_num** column is the primary key for that table, so this statement can update no more than one row.

You can also use subqueries in the WHERE clause. Suppose that the Anza Corporation issues a safety recall of their tennis balls. As a result, any unshipped orders that include stock number 6 from manufacturer ANZ must be put on back order, as the following example shows:

```
UPDATE orders
   SET backlog = 'y'
   WHERE ship_date IS NULL
   AND order_num IN
      (SELECT DISTINCT items.order_num FROM items
         WHERE items.stock_num = 6
         AND items.manu_code = 'ANZ');
```

This subquery returns a column of order numbers (zero or more). The UPDATE operation then tests each row of **orders** against the list and performs the update if that row matches.

Update with uniform values

Each assignment after the keyword SET specifies a new value for a column. That value is applied uniformly to every row that you update. In the examples in the previous section, the new values were constants, but you can assign any expression, including one based on the column value itself. Suppose the manufacturer code HRO has raised all prices by five percent, and you must update the **stock** table to reflect this increase. Use the following statement:

```
UPDATE stock
   SET unit_price = unit_price * 1.05
   WHERE manu_code = 'HRO';
```

You can also use a subquery as part of the assigned value. When a subquery is used as an element of an expression, it must return exactly one value (one column and one row). Perhaps you decide that for any stock number, you must charge a higher price than any manufacturer of that product. You need to update the prices of all unshipped orders. The SELECT statements in the following example specify the criteria:

```
UPDATE items
   SET total_price = quantity *
      (SELECT MAX (unit_price) FROM stock
         WHERE stock.stock_num = items.stock_num)
   WHERE items.order_num IN
      (SELECT order_num FROM orders
         WHERE ship_date IS NULL);
```

The first SELECT statement returns a single value: the highest price in the **stock** table for a particular product. The first SELECT statement is a correlated subquery because, when a value from **items** appears in the WHERE clause for the first SELECT statement, you must execute the query for every row that you update.

The second SELECT statement produces a list of the order numbers of unshipped orders. It is an uncorrelated subquery that is executed once.

Restrictions on updates

Restrictions exist on the use of subqueries when you modify data. In particular, you cannot query the table that is being modified. You can refer to the present value of a column in an expression, as in the example that increments the **unit_price** column by 5 percent. You can also refer to a value of a column in a WHERE clause in a subquery, as in the example that updated the **stock** table, in which the **items** table is updated and **items.stock_num** is used in a join expression.

The need to update and query a table at the same time does not occur often in a well-designed database. (For more information about database design, see the *IBM Informix Database Design and Implementation Guide*.) However, you might want to update and query at the same time when a database is first being developed, before its design has been carefully thought through. A typical problem arises when a table inadvertently and incorrectly contains a few rows with duplicate values in a column that should be unique. You might want to delete the duplicate rows or update only the duplicate rows. Either way, a test for duplicate rows inevitably requires a subquery on the same table that you want to modify, which is not allowed in an UPDATE statement or DELETE statement. Chapter 9, “Modify data through SQL programs,” on page 9-1 discusses how to use an *update cursor* to perform this kind of modification.

Update with selected values

The second form of UPDATE statement replaces the list of assignments with a single bulk assignment, in which a list of columns is set equal to a list of values. When the values are simple constants, this form is nothing more than the form of the previous example with its parts rearranged, as the following example shows:

```
UPDATE customer
   SET (fname, lname) = ('Barnaby', 'Dorfler')
   WHERE customer_num = 103;
```

No advantage exists to writing the statement this way. In fact, it is harder to read because it is not obvious which values are assigned to which columns.

However, when the values to be assigned come from a single SELECT statement, this form makes sense. Suppose that changes of address are to be applied to several customers. Instead of updating the **customer** table each time a change is reported, the new addresses are collected in a single temporary table named **newaddr**. It contains columns for the customer number and the address-related fields of the **customer** table. Now the time comes to apply all the new addresses at once.

```
UPDATE customer
  SET (address1, address2, city, state, zipcode) =
    ((SELECT address1, address2, city, state, zipcode
      FROM newaddr
      WHERE newaddr.customer_num=customer.customer_num))
  WHERE customer_num IN (SELECT customer_num FROM newaddr);
```

A single SELECT statement produces the values for multiple columns. If you rewrite this example in the other form, with an assignment for each updated column, you must write five SELECT statements, one for each column to be updated. Not only is such a statement harder to write, but it also takes much longer to execute.

Tip: In SQL API programs, you can use record or host variables to update values. For more information, refer to Chapter 8, “SQL programming,” on page 8-1.

Update row types

The syntax you use to update a row-type value differs somewhat depending on whether the column is a named ROW type or unnamed ROW type. This section describes those differences and also describes how to specify NULL values for the fields of a ROW type.

Update rows that contain named row types

To update a column that is defined on a named ROW type, you must specify all fields of the ROW type. For example, the following statement updates only the **street** and **city** fields of the **address** column in the **employee** table, but each field of the ROW type must contain a value (NULL values are allowed):

```
UPDATE employee
  SET address = ROW('103 California St',
    San Francisco', address.state, address.zip)::address_t
  WHERE name = 'zawinul, joe';
```

In this example, the values of the **state** and **zip** fields are read from and then immediately reinserted into the row. Only the **street** and **city** fields of the **address** column are updated.

When you update the fields of a column that are defined on a named ROW type, you must use a ROW constructor and cast the row value to the appropriate named ROW type.

Update rows that contain unnamed row types

To update a column that is defined on an unnamed ROW type, you must specify all fields of the ROW type. For example, the following statement updates only the **street** and **city** fields of the **address** column in the **student** table, but each field of the ROW type must contain a value (NULL values are allowed):

```
UPDATE student
   SET s_address = ROW('13 Sunset', 'Fresno',
   s_address.state, s_address.zip)
   WHERE s_name = 'henry, john';
```

To update the fields of a column that are defined on an unnamed ROW type, always specify the ROW constructor before the field values to be inserted.

Specify Null values for the fields of a row type

The fields of a row-type column can contain NULL values. When you insert into or update a row-type field with a NULL value, you must cast the value to the data type of that field.

The following UPDATE statement shows how you might specify NULL values for particular fields of a named row-type column:

```
UPDATE employee
   SET address = ROW(NULL::VARCHAR(20), 'Davis', 'CA',
   ROW(NULL::CHAR(5), NULL::CHAR(4)))::address_t)
   WHERE name = 'henry, john';
```

The following UPDATE statement shows how you specify NULL values for the **street** and **zip** fields of the **address** column for the **student** table.

```
UPDATE student
   SET address = ROW(NULL::VARCHAR(20), address.city,
   address.state, NULL::VARCHAR(9))
   WHERE s_name = 'henry, john';
```

Important: You cannot specify NULL values for a row-type column. You can only specify NULL values for the individual fields of the row type.

Update collection types

When you use DB-Access to update a collection type, you must update the entire collection. The following statement shows how to update the **projects** column. To locate the row that needs to be updated, use the IN keyword to perform a search on the **direct_reports** column.

```
UPDATE manager
SET projects = "LIST
{
   ROW('brazil_project', SET{'Pryor', 'Murphy', 'Kinsley',
      'Bryant'}),
   ROW ('cuba_project', SET{'Forester', 'Barth', 'Lewis',
      'Leonard'})
}"
WHERE 'Williams' IN direct_reports;
```

The first occurrence of the SET keyword in the preceding statement is part of the UPDATE statement syntax.

Important: Do not confuse the SET keyword of an UPDATE statement with the SET constructor that indicates that a collection is a SET data type.

Although you can use the IN keyword to locate specific elements of a simple collection, you cannot update individual elements of a collection column from DB-Access. However, you can create Informix ESQL/C programs and SPL routines to update elements within a collection. For information about how to create an Informix ESQL/C program to update a collection, see the *IBM Informix ESQL/C Programmer's Manual*. For information about how to create SPL routines to update a collection, see the section "Handle collections" on page 11-35.

Update rows of a supertable

When you update the rows of a supertable, the scope of the update is a supertable and its subtables.

When you construct an UPDATE statement on a supertable, you can update all columns in the supertable and columns of subtables that are inherited from the supertable. For example, the following statement updates rows from the **employee** and **sales_rep** tables, which are subtables of the supertable **person**:

```
UPDATE person
   SET salary=65000
   WHERE address.state = 'CA';
```

However, an update on a supertable does not allow you to update columns from subtables that are not in the supertable. For example, in the previous update statement, you cannot update the **region_num** column of the **sales_rep** table because the **region_num** column does not occur in the **employee** table.

When you perform updates on supertables, be aware of the scope of the update. For example, an UPDATE statement on the **person** table that does not include a WHERE clause to restrict which rows to update, modifies all rows of the **person**, **employee**, and **sales_rep** table.

To limit an update to rows of the supertable only, you must use the ONLY keyword in the UPDATE statement. For example, the following statement updates rows of the **person** table only:

```
UPDATE ONLY(person)
   SET address = ROW('14 Jackson St', 'Berkeley',
   address.state, address.zip)
   WHERE name = 'Sallie, A.';
```

Important: Use caution when you update rows of a supertable because the scope of an update on a supertable includes the supertable and all its subtables.

CASE expression to update a column

The CASE expression allows a statement to return one of several possible results, depending on which of several condition tests evaluates to TRUE.

The following example shows how to use a CASE expression in an UPDATE statement to increase the unit price of certain items in the **stock** table:

```
UPDATE stock
   SET unit_price = CASE
      WHEN stock_num = 1
      AND manu_code = "HRO"
      THEN unit_price * 1.2
      WHEN stock_num = 1
      AND manu_code = "SMT"
      THEN unit_price * 1.1
      ELSE 0
      END
```

You must include at least one WHEN clause within the CASE expression; subsequent WHEN clauses and the ELSE clause are optional. If no WHEN condition evaluates to true, the resulting value is null.

SQL functions to update smart large objects

You can use an SQL function that you can call from within an UPDATE statement to import and export smart large objects. For a description of these functions, see page "Smart large object functions" on page 4-13.

The following UPDATE statement uses the **LOCOPY()** function to copy BLOB data from the **mugshot** column of the **fbi_list** table into the **picture** column of the **inmate** table. (Figure 4-53 on page 4-13 defines the **inmate** and **fbi_list** tables.)

```
UPDATE inmate (picture)
    SET picture = (SELECT LOCOPY(mugshot, 'inmate', 'picture')
                 FROM fbi_list WHERE fbi_list.id = 669)
    WHERE inmate.id_num = 437;
```

The first argument for **LOCOPY()** specifies the column (**mugshot**) from which the object is exported. The second and third arguments specify the name of the table (**inmate**) and column (**picture**) whose storage characteristics the newly created object will use. After execution of the UPDATE statement, the **picture** column contains data from the **mugshot** column.

When you specify the path of a file name in the function argument, apply the following rules:

- If the source file resides on the server computer, you must specify the full path name to the file (not the path name relative to the current working directory).
- If the source file resides on the client computer, you can specify either the full or relative path name to the file.

The MERGE statement to update a table

The MERGE statement allows you to apply a Boolean condition to the result of an outer join of a source table and a target table. If the MERGE statement includes the Update clause, rows that satisfy the join condition that you specify after the ON keyword are used in UPDATE operations on the target. The SET clause of the MERGE statement supports the same syntax as the SET clause of the UPDATE statement, and specifies which columns of the target table to update.

The following example illustrates how you can use the Update clause of the MERGE statement to update a target table:

```
MERGE INTO t_target AS t USING t_source AS s ON t.col_a = s.col_a
   WHEN MATCHED THEN UPDATE
      SET t.col_b = t.col_b + s.col_b ;
```

In the preceding example, the name of the target table is **t_target** and the name of the source table is **t_source**. For rows of the join result where **col_a** has the same value in both the source and the target tables, the MERGE statement updates the **t_target** table by adding the value of column **col_b** in the source table to the current value of the **col_b** column in the **t_target** table.

An UPDATE operation of the MERGE statement does not modify the source table, and cannot update any row in the target table more than once.

A single MERGE statement can combine both UPDATE and INSERT operations, or can combine both DELETE and INSERT operations but the delete clause is not required. For a different example of MERGE that includes no Update clause, see the topic “The Delete clause of MERGE” on page 6-5

Privileges on a database and on its objects

You can use the following database privileges to control who accesses a database:

- Database-level privileges
- Table-level privileges
- Routine-level privileges
- Language-level privileges
- Type-level privileges
- Sequence-level privileges
- Fragment-level privileges

This section briefly describes database- and table-level privileges. For more information about database privileges, see the *IBM Informix Database Design and Implementation Guide*. For a list of privileges and a description of the GRANT and REVOKE statements, see the *IBM Informix Guide to SQL: Syntax*.

Database-level privileges

When you create a database, you are the only one who can access it until you, as the owner or database administrator (DBA) of the database, grant database-level privileges to others. The following table shows database-level privileges.

Privilege	Effect
Connect	Allows you to open a database, issue queries, and create and place indexes on temporary tables.
Resource	Allows you to create permanent tables.
DBA	Allows you to perform several additional functions as the DBA.

Table-level privileges

When you create a table in a database that is not ANSI compliant, all users have access privileges to the table until you, as the owner of the table, revoke table-level privileges from specific users. The following table introduces the four privileges that govern how users can access a table.

Privilege	Purpose
Select	Granted on a table-by-table basis and allows you to select rows from a table. (This privilege can be limited to specific columns in a table.)
Delete	Allows you to delete rows.
Insert	Allows you to insert rows.
Update	Allows you to update existing rows (that is, to change their content).

The people who create databases and tables often grant the Connect and Select privileges to **public** so that all users have them. If you can query a table, you have at least the Connect and Select privileges for that database and table.

You need the other table-level privileges to modify data. The owners of tables often withhold these privileges or grant them only to specific users. As a result, you might not be able to modify some tables that you can query freely.

Because these privileges are granted on a table-by-table basis, you can have only Insert privileges on one table and only Update privileges on another, for example. The Update privileges can be restricted even further to specific columns in a table.

For more information on these and other table-level privileges, see the *IBM Informix Database Design and Implementation Guide*.

Display table privileges

If you are the owner of a table (that is, if you created it), you have all privileges on that table. Otherwise, you can determine the privileges you have for a certain table by querying the system catalog. The system catalog consists of system tables that describe the database structure. The privileges granted on each table are recorded in the **systabauth** system table. To display these privileges, you must also know the unique identifier number of the table. This number is specified in the **systables** system table. To display privileges granted on the **orders** table, you might enter the following SELECT statement:

```
SELECT * FROM systabauth
  WHERE tabid = (SELECT tabid FROM systables
                     WHERE tabname = 'orders');
```

The output of the query resembles the following example:

```
grantorgrantee tabid              tabauth

tfecitmutator  101      su-i-x--
tfecitprocrustes101     s--idx--
tfecitpublic   101      s--i-x--
```

The grantor is the user who grants the privilege. The grantor is usually the owner of the table but the owner can be another user that the grantor empowered. The grantee is the user to whom the privilege is granted, and the grantee **public** means any user with Connect privilege. If your user name does not appear, you have only those privileges granted to **public**.

The **tabauth** column specifies the privileges granted. The letters in each row of this column are the initial letters of the privilege names, except that `i` means Insert and `x` means Index. In this example, **public** has Select, Insert, and Index privileges. Only the user **mutator** has Update privileges, and only the user **procrustes** has Delete privileges.

Before the database server performs any action for you (for example, execution of a DELETE statement), it performs a query similar to the preceding one. If you are not the owner of the table, and if the database server cannot find the necessary privilege on the table for your user name or for **public**, it refuses to perform the operation.

Grant privileges to roles

As DBA, you can create roles to standardize the privileges given to a class of users. When you assign privileges to that role, every user of that role has those access privileges. The SQL statements used for defining and manipulating roles include: CREATE ROLE, DROP ROLE, GRANT, REVOKE, and SET ROLE. For more information on the SQL syntax statements for defining and manipulating roles, see the *IBM Informix Guide to SQL: Syntax*.

Default roles automatically apply upon connection to the database for particular users and groups, without requiring the user to issue a SET ROLE statement. For example:

```
GRANT DEFAULT ROLE manager TO larry;
```

For more information on roles and default roles, see “Control database use” on page 1-5 or see the *IBM Informix Administrator's Guide*.

For more information on granting and revoking privileges, see “Grant and revoke privileges in applications” on page 8-21. Also see *IBM Informix Database Design and Implementation Guide*.

Data integrity

The INSERT, UPDATE, and DELETE statements modify data in an existing database. Whenever you modify existing data, the *integrity* of the data can be affected. For example, an order for a nonexistent product could be entered into the **orders** table, a customer with outstanding orders could be deleted from the **customer** table, or the order number could be updated in the **orders** table and not in the **items** table. In each of these cases, the integrity of the stored data is lost.

Data integrity is actually made up of the following parts:

Entity integrity
Each row of a table has a unique identifier.

Semantic integrity
The data in the columns properly reflects the types of information the column was designed to hold.

Referential integrity
The relationships between tables are enforced.

Well-designed databases incorporate these principles so that when you modify data, the database itself prevents you from doing anything that might harm the integrity of the data.

Entity integrity

An entity is any person, place, or thing to be recorded in a database. Each table represents an entity, and each row of a table represents an instance of that entity. For example, if *order* is an entity, the **orders** table represents the idea of an order and each row in the table represents a specific order.

To identify each row in a table, the table must have a primary key. The primary key is a unique value that identifies each row. This requirement is called the *entity integrity constraint*.

For example, the **orders** table primary key is **order_num**. The **order_num** column holds a unique system-generated order number for each row in the table. To access a row of data in the **orders** table, use the following SELECT statement:

```
SELECT * FROM orders WHERE order_num = 1001;
```

Using the order number in the WHERE clause of this statement enables you to access a row easily because the order number uniquely identifies that row. If the table allowed duplicate order numbers, it would be almost impossible to access one single row because all other columns of this table allow duplicate values.

For more information on primary keys and entity integrity, see the *IBM Informix Database Design and Implementation Guide*.

Semantic integrity

Semantic integrity ensures that data entered into a row reflects an allowable value for that row. The value must be within the *domain*, or allowable set of values, for that column. For example, the **quantity** column of the **items** table permits only numbers. If a value outside the domain can be entered into a column, the semantic integrity of the data is violated.

The following constraints enforce semantic integrity:

Data type
The data type defines the types of values that you can store in a column. For example, the data type SMALLINT allows you to enter values from -32,767 to 32,767 into a column.

Default value
The default value is the value inserted into the column when an explicit value is not specified. For example, the **user_id** column of the **cust_calls** table defaults to the login name of the user if no name is entered.

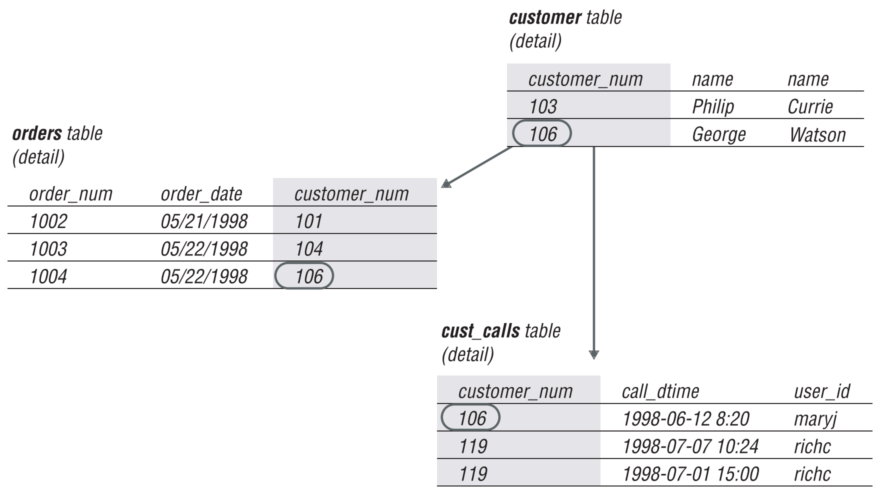
Check constraint
The check constraint specifies conditions on data inserted into a column. Each row inserted into a table must meet these conditions. For example, the **quantity** column of the **items** table might check for quantities greater than or equal to one.

For more information on how to use semantic integrity constraints in database design, see the *IBM Informix Database Design and Implementation Guide*.

Referential integrity

Referential integrity refers to the relationship between tables. Because each table in a database must have a primary key, this primary key can appear in other tables because of its relationship to data within those tables. When a primary key from one table appears in another table, it is called a *foreign key*.

Foreign keys join tables and establish dependencies between tables. tables can form a hierarchy of dependencies in such a way that if you change or delete a row in one table, you destroy the meaning of rows in other tables. For example, the following figure shows that the **customer_num** column of the **customer** table is a primary key for that table and a foreign key in the **orders** and **cust_call** tables. Customer number 106, George Watson, is *referenced* in both the **orders** and **cust_calls** tables. If customer 106 is deleted from the **customer** table, the link between the three tables and this particular customer is destroyed.



customer table (detail)
customer_num name name
103 Philip Currie
106 George Watson
orders table (detail)
order_num order_date customer_num
1002 05/21/1998 101
1003 05/22/1998 104
1004 05/22/1998 106
cust_calls table (detail)
customer_num call_dtime user_id
106 1998-06-12 8:20 maryj
119 1998-07-07 10:24 richc
119 1998-07-01 15:00 richc

Figure 6-4. Referential integrity in the demonstration database

When you delete a row that contains a primary key or update it with a different primary key, you destroy the meaning of any rows that contain that value as a foreign key. Referential integrity is the logical dependency of a foreign key on a primary key. The integrity of a row that contains a foreign key depends on the integrity of the row that it references—the row that contains the matching primary key.

By default, the database server does not allow you to violate referential integrity and gives you an error message if you attempt to delete rows from the parent table before you delete rows from the child table. You can, however, use the ON DELETE CASCADE option to cause deletes from a parent table to trip deletes on child tables. See "The ON DELETE CASCADE option."

To define primary and foreign keys, and the relationship between them, use the CREATE TABLE and ALTER TABLE statements. For more information on these statements, see the *IBM Informix Guide to SQL: Syntax*. For information about how to build a data model with primary and foreign keys, see the *IBM Informix Database Design and Implementation Guide*.

The ON DELETE CASCADE option

To maintain referential integrity when you delete rows from a primary key for a table, use the ON DELETE CASCADE option in the REFERENCES clause of the CREATE TABLE and ALTER TABLE statements. This option allows you to delete a row from a parent table and its corresponding rows in matching child tables with a single delete command.

Lock during cascading deletes

During deletes, locks are held on all qualifying rows of the parent and child tables. When you specify a delete, the delete that is requested from the parent table occurs before any referential actions are performed.

What happens to multiple children tables

If you have a parent table with two child constraints, one child with cascading deletes specified and one child without cascading deletes, and you attempt to delete a row from the parent table that applies to both child tables, the DELETE statement fails, and no rows are deleted from either the parent or child tables.

Logging must be turned on

You must turn on logging in your current database for cascading deletes to work. Logging and cascading deletes are discussed in "Transaction logging" on page 6-33.

Example of cascading deletes

Suppose you have two tables with referential integrity rules applied, a parent table, accounts, and a child table, **sub_accounts**. The following CREATE TABLE statements define the referential constraints:

```
CREATE TABLE accounts (
  acc_num SERIAL primary key,
  acc_type INT,
  acc_descr CHAR(20));

CREATE TABLE sub_accounts (
  sub_acc INTEGER primary key,
  ref_num INTEGER REFERENCES accounts (acc_num)
    ON DELETE CASCADE,
  sub_descr CHAR(20));
```

The primary key of the accounts table, the **acc_num** column, uses a SERIAL data type, and the foreign key of the **sub_accounts** table, the **ref_num** column, uses an INTEGER data type. Combining the SERIAL data type on the primary key and the INTEGER data type on the foreign key is allowed. Only in this condition can you mix and match data types. The SERIAL data type is an INTEGER, and the database automatically generates the values for the column. All other primary and foreign key combinations must match explicitly. For example, a primary key that is defined as CHAR must match a foreign key that is defined as CHAR.

The definition of the foreign key of the **sub_accounts** table, the **ref_num** column, includes the ON DELETE CASCADE option. This option specifies that a delete of any row in the parent table **accounts** will automatically cause the corresponding rows of the child table **sub_accounts** to be deleted.

To delete a row from the accounts table that will cascade a delete to the **sub_accounts** table, you must turn on logging. After logging is turned on, you can delete the account number 2 from both tables, as the following example shows:

```
DELETE FROM accounts WHERE acc_num = 2;
```

Restrictions on cascading deletes

You can use cascading deletes for most deletes, including deletes on self-referencing and cyclic queries. The only exception is correlated subqueries, which are nested SELECT statements in which the value that the subquery (or inner SELECT) produces depends on a value produced by the outer SELECT statement that contains it. If you have implemented cascading deletes, you cannot write deletes that use a child table in the correlated subquery. You receive an error when you attempt to delete from a correlated subquery.

Restriction: You cannot define a DELETE trigger event on a table if the table defines a referential constraint with ON DELETE CASCADE.

Object modes and violation detection

The object modes and violation detection features of the database can help you monitor data integrity. These features are particularly powerful when they are combined during schema changes or when insert, delete, and update operations are performed on large volumes of data over short periods.

Database objects, within the context of a discussion of the object modes feature, are constraints, indexes, and triggers, and each of them have different modes. Do not confuse database objects that are relevant to the object modes feature with generic database objects. Generic database objects are things like tables and synonyms.

Definitions of object modes

You can set disabled, enabled, or filtering modes for a constraint or a unique index. You can set disabled or enabled modes for a trigger or a duplicate index. You can use database object modes to control the effects of INSERT, DELETE, and UPDATE statements.

Enabled mode: Constraints, indexes, and triggers are enabled by default.

When a database object is enabled, the database server recognizes the existence of the database object and takes the database object into consideration while it executes an INSERT, DELETE, or UPDATE statement. Thus, an enabled constraint is enforced, an enabled index updated, and an enabled trigger is executed when the trigger event takes place.

When you enable constraints and unique indexes, if a violating row exists, the data manipulation statement fails (that is no rows change) and the database server returns an error message.

You can identify the reason for the failure when you analyze the information in the violations and diagnostic tables. You can then take corrective action or roll back the operation.

Disabled mode: When a database object is disabled, the database server does not take it into consideration during the execution of an INSERT, DELETE, or UPDATE statement. A disabled constraint is not enforced, a disabled index is not updated, and a disabled trigger is not executed when the trigger event takes place. When you disable constraints and unique indexes, any data manipulation statement that violates the restriction of the constraint or unique index succeed, (that is, the target row is changed), and the database server does not return an error message.

Filtering mode: When a constraint or unique index is in filtering mode, the statement succeeds and the database server enforces the constraint or the unique index requirement during an INSERT, DELETE, or UPDATE statement by writing the failed rows to the violations table associated with the target table. Diagnostic information about the constraint violation is written to the diagnostics table associated with the target table.

Example of modes with data manipulation statements

An example with the INSERT statement can illustrate the differences between the enabled, disabled, and filtering modes. Consider an INSERT statement in which a user tries to add a row that does not satisfy an integrity constraint on a table. For example, assume that user **joe** created a table named **cust_subset**, and this table consists of the following columns: **ssn** (customer's social security number), **fname** (customer's first name), **lname** (customer's last name), and **city** (city in which the customer lives). The **ssn** column has the INT data type. The other three columns have the CHAR data type.

Assume that user **joe** defined the **lname** column as not null but has not assigned a name to the not null constraint, so the database server has implicitly assigned the name **n104_7** to this constraint. Finally, assume that user **joe** created a unique index named **unq_ssn** on the **ssn** column.

Now user **linda** who has the Insert privilege on the **cust_subset** table enters the following INSERT statement on this table:

```
INSERT INTO cust_subset (ssn, fname, city)
   VALUES (973824499, "jane", "los altos");
```

To better understand the distinctions among enabled, disabled, and filtering modes, you can view the results of the preceding INSERT statement in the following three sections.

Results of the insert operation when the constraint is enabled:
If the NOT NULL constraint on the **cust_subset** table is enabled, the INSERT statement fails to insert the new row in this table. Instead user **linda** receives the following error message when she enters the INSERT statement:

```
-292 An implied insert column lname does not accept NULLs.
```

Results of the insert operation when the constraint is disabled:

If the NOT NULL constraint on the **cust_subset** table is disabled, the INSERT statement that user **linda** issues successfully inserts the new row in this table. The new row of the **cust_subset** table has the following column values.

ssn	fname	lname	city
973824499	jane	NULL	los altos

Results of the insert when constraint is in filtering mode:
If the NOT NULL constraint on the **cust_subset** table is set to the filtering mode, the INSERT statement that user **linda** issues fails to insert the new row in this table. Instead the new row is inserted into the violations table, and a diagnostic row that describes the integrity violation is added to the diagnostics table.

Assume that user **joe** has started a violations and diagnostics table for the **cust_subset** table. The violations table is named **cust_subset_vio**, and the diagnostics table is named **cust_subset_dia**. The new row added to the **cust_subset_vio** violations table when user **linda** issues the INSERT statement on the **cust_subset** target table has the following column values.

ssn	fname	lname	city	informix_tupleid	informix_optype	informix_recowner
973824499	jane	NULL	los altos	1	I	linda

This new row in the **cust_subset_vio** violations table has the following characteristics:

- The first four columns of the violations table exactly match the columns of the target table. These four columns have the same names and the same data types as the corresponding columns of the target table, and they have the column values that were supplied by the INSERT statement that user **linda** entered.
- The value 1 in the **informix_tupleid** column is a unique serial identifier that is assigned to the nonconforming row.
- The value `I` in the **informix_optype** column is a code that identifies the type of operation that has caused this nonconforming row to be created. Specifically, I stands for an INSERT operation.
- The value `linda` in the **informix_recowner** column identifies the user who issued the statement that caused this nonconforming row to be created.

The INSERT statement that user **linda** issued on the **cust_subset** target table also causes a diagnostic row to be added to the **cust_subset_dia** diagnostics table. The new diagnostic row added to the diagnostics table has the following column values.

informix_tupleid	objtype	objowner	objname
1	C	joe	n104_7

This new diagnostic row in the **cust_subset_dia** diagnostics table has the following characteristics:

- This row of the diagnostics table is linked to the corresponding row of the violations table by means of the **informix_tupleid** column that appears in both tables. The value 1 appears in this column in both tables.

- The value `C` in the **objtype** column identifies the type of integrity violation that the corresponding row in the violations table caused. Specifically, the value `C` stands for a constraint violation.
- The value `joe` in the **objowner** column identifies the owner of the constraint for which an integrity violation was detected.
- The value `n104_7` in the **objname** column gives the name of the constraint for which an integrity violation was detected.

By joining the violations and diagnostics tables, user **joe** (who owns the **cust_subset** target table and its associated special tables) or the DBA can find out that the row in the violations table whose **informix_tupleid** value is 1 was created after an INSERT statement and that this row is violating a constraint. The table owner or DBA can query the **sysconstraints** system catalog table to determine that this constraint is a NOT NULL constraint. Now that the reason for the failure of the INSERT statement is known, user **joe** or the DBA can take corrective action.

Multiple diagnostic rows for one violations row:
In the preceding example, only one row in the diagnostics table corresponds to the new row in the violations table. However, more than one diagnostic row can be added to the diagnostics table when a single new row is added to the violations table. For example, if the **ssn** value (973824499) that user **linda** entered in the INSERT statement had been the same as an existing value in the **ssn** column of the **cust_subset** target table, only one new row would appear in the violations table, but the following two diagnostic rows would be present in the **cust_subset_dia** diagnostics table.

informix_tupleid	objtype	objowner	objname
1	C	joe	n104_7
1	I	joe	unq_ssn

Both rows in the diagnostics table correspond to the same row of the violations table because both of these rows have the value `1` in the **informix_tupleid** column. The first diagnostic row, however, identifies the constraint violation caused by the INSERT statement that user **linda** issued, while the second diagnostic row identifies the unique-index violation that the same INSERT statement caused. In this second diagnostic row, the value `I` in the **objtype** column stands for a unique-index violation, and the value `unq_ssn` in the **objname** column gives the name of the index for which the integrity violation was detected.

For more information about how to set database object modes, see the SET Database Object Mode statement in the *IBM Informix Guide to SQL: Syntax*.

Violations and diagnostics tables

When you start a violations table for a target table, any rows that violate constraints and unique indexes during INSERT, UPDATE, and DELETE operations on the target table do not cause the entire operation to fail, but are filtered out to the violations table. The diagnostics table contains information about the integrity violations caused by each row in the violations table. By examining these tables, you can identify the cause of failure and take corrective action by either fixing the violation or rolling back the operation.

After you create a violations table for a target table, you cannot alter the columns or the fragmentation of the base table or the violations table. If you alter the constraints on a target table after you have started the violations table, nonconforming rows will be filtered to the violations table.

For information about how to start and stop the violations tables, see the START VIOLATIONS TABLE and STOP VIOLATIONS TABLE statements in the *IBM Informix Guide to SQL: Syntax*.

Relationship of violations tables and database object modes: If you set the constraints or unique indexes defined on a table to the filtering mode, but you do not create the violations and diagnostics tables for this target table, any rows that violate a constraint or unique-index requirement during an insert, update, or delete operation are not filtered to a violations table. Instead, you receive an error message that indicates that you must start a violations table for the target table.

Similarly, if you set a disabled constraint or disabled unique index to the enabled or filtering mode and you want the ability to identify existing rows that do not satisfy the constraint or unique-index requirement, you must create the violations tables before you issue the SET Database Object Mode statement.

Examples of START VIOLATIONS TABLE statements:
The examples that follow show different ways to execute the START VIOLATIONS TABLE statement.

Start violations and diagnostics tables without specifying their names

To start a violations and diagnostics table for the target table named **customer** in the demonstration database, enter the following statement:

```
START VIOLATIONS TABLE FOR customer;
```

Because your START VIOLATIONS TABLE statement does not include a USING clause, the violations table is named **customer_vio** by default, and the diagnostics table is named **customer_dia** by default. The **customer_vio** table includes the following columns:

```
customer_num
fname
lname
company
address1
address2
city
state
zipcode
phone
informix_tupleid
informix_optype
informix_recowner
```

The **customer_vio** table has the same table definition as the **customer** table except that the **customer_vio** table has three additional columns that contain information about the operation that caused the bad row.

The **customer_dia** table includes the following columns:

```
informix_tupleid
objtype
objowner
objname
```

This list of columns shows an important difference between the diagnostics table and violations table for a target table. Whereas the violations table has a matching column for every column in the target table, the columns of the diagnostics table are independent of the schema of the target table. The diagnostics table created by any START VIOLATIONS TABLE statement always has the four columns in the list above, with the same column names and data types.

Start violations and diagnostics tables and specify their names

The following statement starts a violations and diagnostics table for the target table named **items**. The USING clause declares explicit names for the violations and diagnostics tables. The violations table is to be named **exceptions**, and the diagnostics table is to be named **reasons**.

```
START VIOLATIONS TABLE FOR items
   USING exceptions, reasons;
```

Specify the maximum number of rows in the diagnostics table

The following statement starts violations and diagnostics tables for the target table named **orders**. The MAX ROWS clause specifies the maximum number of rows that can be inserted into the **orders_dia**diagnostics table when a single statement, such as an INSERT, MERGE, or SET Database Object Mode, is executed on the target table.

```
START VIOLATIONS TABLE FOR orders MAX ROWS 50000;
```

If you do not specify a value for MAX ROWS in the START VIOLATIONS TABLE statement, there is no default limit on the number of rows in the diagnostics table, apart from the available disk space.

The MAX ROWS clause limits the number of rows only for operations in which the table functions as a diagnostics table.

Example of privileges on the violations table:
The following example illustrates how the initial set of privileges on a violations table is derived from the current set of privileges on the target table.

For example, assume that we created a table named **cust_subset** and that this table consists of the following columns: **ssn** (customer's social security number), **fname** (customer's first name), **lname** (customer's last name), and **city** (city in which the customer lives).

The following set of privileges exists on the **cust_subset** table:
- User **alvin** is the owner of the table.
- User **barbara** has the Insert and Index privileges on the table. She also has the Select privilege on the **ssn** and **lname** columns.
- User **carrie** has the Update privilege on the **city** column. She also has the Select privilege on the **ssn** column.
- User **danny** has the Alter privilege on the table.

Now user **alvin** starts a violations table named **cust_subset_viols** and a diagnostics table named **cust_subset_diags** for the **cust_subset** table, as follows:

```
START VIOLATIONS TABLE FOR cust_subset
   USING cust_subset_viols, cust_subset_diags;
```

The database server grants the following set of initial privileges on the **cust_subset_viols** violations table:

- User **alvin** is the owner of the violations table, so he has all table-level privileges on the table.
- User **barbara** has the Insert, Delete, and Index privileges on the violations table. She also has the Select privilege on the following columns of the violations table: the **ssn** column, the **lname** column, the **informix_tupleid** column, the **informix_optype** column, and the **informix_recowner** column.
- User **carrie** has the Insert and Delete privileges on the violations table. She has the Update privilege on the following columns of the violations table: the **city** column, the **informix_tupleid** column, the **informix_optype** column, and the **informix_recowner** column. She has the Select privilege on the following columns of the violations table: the **ssn** column, the **informix_tupleid** column, the **informix_optype** column, and the **informix_recowner** column.
- User **danny** has no privileges on the violations table.

Example of privileges on the diagnostics table:
The following example illustrates how the initial set of privileges on a diagnostics table is derived from the current set of privileges on the target table.

For example, assume that a table called **cust_subset** consists of the following columns: **ssn** (customer's social security number), **fname** (customer's first name), **lname** (customer's last name), and **city** (city in which the customer lives).

The following set of privileges exists on the **cust_subset** table:

- User **alvin** is the owner of the table.
- User **barbara** has the Insert and Index privileges on the table. She also has the Select privilege on the **ssn** and **lname** columns.
- User **carrie** has the Update privilege on the **city** column. She also has the Select privilege on the **ssn** column.
- User **danny** has the Alter privilege on the table.

Now user **alvin** starts a violations table named **cust_subset_viols** and a diagnostics table named **cust_subset_diags** for the **cust_subset** table, as follows:

```
START VIOLATIONS TABLE FOR cust_subset
   USING cust_subset_viols, cust_subset_diags;
```

The database server grants the following set of initial privileges on the **cust_subset_diags** diagnostics table:

- User **alvin** is the owner of the diagnostics table, so he has all table-level privileges on the table.
- User **barbara** has the Insert, Delete, Select, and Index privileges on the diagnostics table.
- User **carrie** has the Insert, Delete, Select, and Update privileges on the diagnostics table.
- User **danny** has no privileges on the diagnostics table.

Interrupted modifications

Even if all the software is error-free and all the hardware is utterly reliable, the world outside the computer can interfere. Lightning might strike the building, interrupting the electrical supply and stopping the computer in the middle of your UPDATE statement. A more likely scenario occurs when a disk fills up or a user supplies incorrect data, causing your multirow insert to stop early with an error. In any case, whenever you modify data, you must assume that some unforeseen event can interrupt the modification.

When an external cause interrupts a modification, you cannot be sure how much of the operation was completed. Even in a single-row operation, you cannot know whether the data reached the disk or the indexes were properly updated.

If multirow modifications are a problem, multistatement modifications are worse. They are usually embedded in programs so you do not see the individual SQL statements being executed. For example, to enter a new order in the demonstration database, perform the following steps:

1. Insert a row in the **orders** table. (This insert generates an order number.)
2. For each item ordered, insert a row in the **items** table.

Two ways to program an order-entry application exist. One way is to make it completely interactive so that the program inserts the first row immediately and then inserts each item as the user enters data. But this approach exposes the operation to the possibility of many more unforeseen events: the customer's telephone disconnecting, the user pressing the wrong key, the user's terminal or computer losing power, and so on.

The following list describes the correct way to build an order-entry application:

- Accept all the data interactively.
- Validate the data, and expand it (look up codes in **stock** and **manufact**, for example).
- Display the information on the screen for inspection.
- Wait for the operator to make a final commitment.
- Perform the insertions quickly.

Even with these steps, an unforeseen circumstance can halt the program after it inserts the order but before it finishes inserting the items. If that happens, the database is in an unpredictable condition: its data integrity is compromised.

Transactions

The solution to all these potential problems is called the *transaction*. A transaction is a sequence of modifications that must be accomplished either completely or not at all. The database server guarantees that operations performed within the bounds of a transaction are either completely and perfectly committed to disk, or the database is restored to the same state as before the transaction started.

The transaction is not merely protection against unforeseen failures; it also offers a program a way to escape when the program detects a logical error.

Transaction logging

The database server can keep a record of each change that it makes to the database during a transaction. If something happens to cancel the transaction, the database server automatically uses the records to reverse the changes. Many things can make a transaction fail. For example, the program that issues the SQL statements can fail or be terminated. As soon as the database server discovers that the transaction failed, which might be only after the computer and the database server are restarted, it uses the records from the transaction to return the database to the same state as before.

The process of keeping records of transactions is called *transaction logging* or simply *logging*. The records of the transactions, called *log records*, are stored in a portion of disk space separate from the database. This space is called the *logical log* because the log records represent logical units of the transactions.

IBM Informix provides support to:

- Create nonlogging (raw) or logging (standard) tables in a logging database.
- Alter a table from nonlogging to logging and vice-versa using the ALTER TABLE statement.

IBM Informix supports nonlogging tables for fast loads of very large tables. It is recommended that you do not use nonlogging tables within a transaction. To avoid concurrency problems, use the ALTER TABLE statement to make the table standard (that is, logging) before you use the table in a transaction.

For more information about nonlogging tables for IBM Informix, see the *IBM Informix Administrator's Guide*. For the performance advantages of nonlogging tables, see the *IBM Informix Performance Guide*. For information about the ALTER TABLE statement, see the *IBM Informix Guide to SQL: Syntax*.

Most IBM Informix databases do not generate transaction records automatically. The DBA decides whether to make a database use transaction logging. Without transaction logging, you cannot roll back transactions.

Logging and cascading deletes

Logging must be turned on in your database for cascading deletes to work because, when you specify a cascading delete, the delete is first performed on the primary key of the parent table. If the system fails after the rows of the primary key of the parent table are performed but before the rows of the foreign key of the child table are deleted, referential integrity is violated. If logging is turned off, even temporarily, deletes do not cascade. After logging is turned back on, however, deletes can cascade again.

IBM Informix allows you to turn on logging with the WITH LOG clause in the CREATE DATABASE statement.

Specify transactions

You can use two methods to specify the boundaries of transactions with SQL statements. In the most common method, you specify the start of a multistatement transaction by executing the BEGIN WORK statement. In databases that are created with the MODE ANSI option, no need exists to mark the beginning of a transaction. One is always in effect; you indicate only the end of each transaction.

In both methods, to specify the end of a successful transaction, execute the COMMIT WORK statement. This statement tells the database server that you reached the end of a series of statements that must succeed together. The database server does whatever is necessary to make sure that all modifications are properly completed and committed to disk.

A program can also cancel a transaction deliberately by executing the ROLLBACK WORK statement. This statement asks the database server to cancel the current transaction and undo any changes.

An order-entry application can use a transaction in the following ways when it creates a new order:

- Accept all data interactively
- Validate and expand it
- Wait for the operator to make a final commitment
- Execute BEGIN WORK
- Insert rows in the **orders** and **items** tables, checking the error code that the database server returns
- If no errors occurred, execute COMMIT WORK; otherwise execute ROLLBACK WORK

If any external failure prevents the transaction from being completed, the partial transaction rolls back when the system restarts. In all cases, the database is in a predictable state. Either the new order is completely entered, or it is not entered at all.

Backups and logs with IBM Informix database servers

By using transactions, you can ensure that the database is always in a consistent state and that your modifications are properly recorded on disk. But the disk itself is not perfectly safe. It is vulnerable to mechanical failures and to flood, fire, and earthquake. The only safeguard is to keep multiple copies of the data. These redundant copies are called *backup copies*.

The *transaction log* (also called the *logical log*) complements the backup copy of a database. Its contents are a history of all modifications that occurred since the last time the database was backed up. If you ever need to restore the database from the backup copy, you can use the transaction log to roll the database forward to its most recent state.

The database server contains elaborate features to support backups and logging. Your database server archive and backup guide describes these features.

The database server has stringent requirements for performance and reliability (for example, it supports making backup copies while databases are in use).

The database server manages its own disk space, which is devoted to logging.

The database server performs logging concurrently for all databases using a limited set of log files. The log files can be copied to another medium (backed up) while transactions are active.

Database users never have to be concerned with these facilities because the DBA usually manages them from a central location.

IBM Informix supports the **onload** and **onunload** utilities. Use the **onunload** utility to make a personal backup copy of a single database or table. This program copies a table or a database to tape. Its output consists of binary images of the disk pages as they were stored in the database server. As a result, the copy can be made quickly, and the corresponding **onload** program can restore the file quickly. However, the data format is not meaningful to any other programs. For information about how to use the **onload** and **onunload** utilities, see the *IBM Informix Migration Guide*.

If your DBA uses ON-Bar to create backups and back up logical logs, you might also be able to create your own backup copies using ON-Bar. For more information, see your *IBM Informix Backup and Restore Guide*.

Concurrency and locks

If your database is contained in a single-user workstation, without a network connecting it to other computers, concurrency is unimportant. In all other cases, you must allow for the possibility that, while your program is modifying data, another program is also reading or modifying the same data. *Concurrency* involves two or more independent uses of the same data at the same time.

A high level of concurrency is crucial to good performance in a multiuser database system. Unless controls exist on the use of data, however, concurrency can lead to a variety of negative effects. Programs could read obsolete data; modifications could be lost even though it seems they were entered successfully.

To prevent errors of this kind, the database server imposes a system of *locks*. A lock is a claim, or reservation, that a program can place on a piece of data. The database server guarantees that, as long as the data is locked, no other program can modify it. When another program requests the data, the database server either makes the program wait or turns it back with an error.

To control the effect that locks have on your data access, use a combination of SQL statements: SET LOCK MODE and either SET ISOLATION or SET TRANSACTION. You can understand the details of these statements after reading a discussion on the use of *cursors* from within programs. Cursors are covered in Chapter 8, “SQL programming,” on page 8-1, and Chapter 9, “Modify data through SQL programs,” on page 9-1. For more information about locking and concurrency, see Chapter 10, “Programming for a multiuser environment,” on page 10-1.

IBM Informix data replication

Data replication, in the broadest sense of the term, means that database objects have more than one representation at more than one distinct site. For example, one way to replicate data, so that reports can be run against the data without disturbing client applications that are using the original database, is to copy the database to a database server on a different computer.

The following list describes the advantages of data replication:

- Clients who access replicated data locally, as opposed to remote data that is not replicated, experience improved performance because they do not have to use network services.
- Clients at all sites experience improved availability with replicated data, because if local replicated data is unavailable, a copy of the data is still available, albeit remotely.

These advantages do not come without a cost. Data replication obviously requires more storage for replicated data than for unreplicated data, and updating replicated data can take more processing time than updating a single object.

Data replication can actually be implemented in the logic of client applications, by explicitly specifying where data should be found or updated. However, this method of achieving data replication is costly, error-prone, and difficult to maintain. Instead, the concept of data replication is often coupled with *replication transparency*. Replication transparency is functionality built into a database server (instead of client applications) to handle the details of locating and maintaining data replicas automatically.

Within the broad framework of data replication, an IBM Informix database server implements nearly transparent data replication of entire database servers. All the data that one database server manages is replicated and dynamically updated on another database server, usually at a remote site. Data replication of an IBM Informix database server is sometimes called *hot-site backup*, because it provides a means of maintaining a backup copy of the entire database server that can be used quickly in the event of a catastrophic failure.

Because the database server provides replication transparency, you generally do not need to be concerned with or aware of data replication; the DBA takes care of it. However, if your organization decides to use data replication, you should be aware that special connectivity considerations exist for client applications in a data replication environment. These considerations are described in the *IBM Informix Administrator's Guide*.

The IBM Informix Enterprise Replication feature provides a different method of data replication. For information on this feature, see the *IBM Informix Enterprise Replication Guide*.

Summary

Database access is regulated by the privileges that the database owner grants to you. The privileges that let you query data are often granted automatically, but the ability to modify data is regulated by specific Insert, Delete, and Update privileges that are granted on a table-by-table basis.

If data integrity constraints are imposed on the database, your ability to modify data is restricted by those constraints. Your database- and table-level privileges and any data constraints control how and when you can modify data. In addition, the object modes and violation detection features of the database affect how you can modify data and help to preserve the integrity of your data.

You can delete one or more rows from a table with the DELETE statement. Its WHERE clause selects the rows; use a SELECT statement with the same clause to preview the deletes.

The TRUNCATE statement deletes all the rows of a table.

Rows are added to a table with the INSERT statement. You can insert a single row that contains specified column values, or you can insert a block of rows that a SELECT statement generates.

Use the UPDATE statement to modify the contents of existing rows. You specify the new contents with expressions that can include subqueries, so that you can use data that is based on other tables or the updated table itself. The statement has two forms. In the first form, you specify new values column by column. In the second form, a SELECT statement or a record variable generates a set of new values.

Use the REFERENCES clause of the CREATE TABLE and ALTER TABLE statements to create relationships between tables. The ON DELETE CASCADE option of the REFERENCES clause allows you to delete rows from parent and associated child tables with one DELETE statement.

Use transactions to prevent unforeseen interruptions in a modification from leaving the database in an indeterminate state. When modifications are performed within a transaction, they are rolled back after an error occurs. The transaction log also extends the periodically made backup copy of the database. If the database must be restored, it can be brought back to its most recent state.

Data replication, which is transparent to users, offers another type of protection from catastrophic failures.

Chapter 7. Access and modify data in an external database

This section summarizes accessing tables and routines that are not in the current database.

Access other database servers

You can access any table or routine in an *external* database by qualifying the name of the database object (table, view, synonym, or routine).

When the external database is on the same database server as the current database, you must qualify the object name with the database name and a colon. For example, to refer to a table in a database other than the local database, the following SELECT statement accesses information from an external database:

```
SELECT name, number FROM salesdb:contacts
```

In this example, the query returns data from the table, **contacts**, that is in the database, **salesdb**.

A *remote* database server is any database server that is not the current database server. When the external database is on a remote database server, you must qualify the name of the database object with the database server name and the database name, as the following example illustrates:

```
SELECT name, number FROM salesdb@distantserver:contacts
```

In this example, the query returns data from the table, **contacts**, that is in the database, **salesdb** on the remote database server, **distantserver**.

For the syntax and rules on how to specify database object names in an external database, see the *IBM Informix Guide to SQL: Syntax*.

Access ANSI databases

In ANSI databases, the owner of the object is part of the object name: **ownername.objectname**. When both the current and external databases are ANSI databases, unless you are the owner of the object, you must include the owner name. The following SELECT statement shows a fully-qualified table name:

```
SELECT name, number FROM salesdb@aserver:ownername.contacts
```

Tip: You can always over-qualify an object name. That is, you can specify the full object name, database@servername:ownername.objectname, even in situations that do not require the full object name.

For more information about ANSI-compliant databases, refer to the *IBM Informix Database Design and Implementation Guide*.

Create joins between external database servers

You can use the same notation in a join. When you specify the database name explicitly, the long table names can become cumbersome unless you use aliases to shorten them, as the following example shows:

```
SELECT O.order_num, C.fname, C.lname
   FROM masterdb@central:customer C, sales@boston:orders O
   WHERE C.customer_num = O.Customer_num
```

Access external routines

To refer to a routine on a database server other than the current database server, qualify the routine name with the database server name and database name (and the owner name if the remote database is ANSI compliant), as the following SELECT statement illustrates:

```
SELECT name, salesdb@boston:how_long()
   FROM salesdb@boston:contacts
```

Restrictions for remote database access

This section summarizes the restrictions for remote database access.

SQL statements and logging modes

You can run the following SQL statements across databases and across database servers:

- CREATE DATABASE
- CREATE SYNONYM
- CREATE VIEW
- DATABASE
- DELETE
- DROP DATABASE
- EXECUTE FUNCTION
- EXECUTE PROCEDURE
- INFO
- INSERT
- LOAD
- LOCK TABLE
- SELECT
- UNLOAD
- UNLOCK TABLE
- UPDATE

To run each statement successfully across databases or database servers, the local and external databases must have the same logging mode.

Distributed operations that use SQL statements or UDRs to access other databases of the local IBM Informix instance, however, can also return the opaque built-in data types BLOB, BOOLEAN, CLOB, and LVARCHAR. They can also access DISTINCT types based on built-in types, as well as UDTs that can be cast to built-in types, provided that the DISTINCT or UDT values are explicitly cast to built-in types, and that all the DISTINCT types, UDTs, and casts are defined in all of the participating databases.

Distributed operations that access databases of other Informix instances can access or return values of the following data types:

- Built-in data types that are not opaque
- BOOLEAN

- LVARCHAR
- DISTINCT of built-in types that are not opaque
- DISTINCT of BOOLEAN
- DISTINCT of LVARCHAR
- DISTINCT of the DISTINCT data types in this list.

These data types can be returned by SPL, C, and Java-language UDRs as parameters or as return values, if the UDRs are defined in all of the participating databases. Any implicit or explicit casts defined over these data types must be duplicated across all the participating Informix instances. The DISTINCT data types must have exactly the same data type hierarchy defined in all databases that participate in the distributed query.

Access external database objects

To access external database objects:
- You must hold appropriate access permissions on these objects.
- Both databases must be set to the same locale.

Important: Distributed transactions cannot access objects in a database of another Informix server instance unless both server instances support either a TCP/IP or an IPCSTR connection, as defined in their DBSERVERNAME or DBSERVERALIASES configuration parameters and in the sqlhosts information. This connection-type requirement applies to any communication between Informix database server instances, even if both database servers reside on the same computer.

Chapter 8. SQL programming

The previous examples treat SQL as if it were an interactive computer language; that is, as if you could type a SELECT statement directly into the database server and see rows of data rolling back to you.

Of course, that is not the case. Many layers of software stand between you and the database server. The database server retains data in a binary form that must be formatted before it can be displayed. It does not return a mass of data at once; it returns one row at a time, as a program requests it.

You can access information in your database through interactive access with DB-Access, through application programs written with an SQL API such as Informix ESQL/C, or through an application language such as SPL.

Almost any program can contain SQL statements, execute them, and retrieve data from a database server. This chapter explains how these activities are performed and indicates how you can write programs that perform them.

This chapter introduces concepts that are common to SQL programming in any language. Before you can write a successful program in a particular programming language, you must first become fluent in that language. Then, because the details of the process are different in every language, you must become familiar with the publication for the IBM Informix SQL API specific to that language.

SQL in programs

You can write a program in any of several languages and mix SQL statements among the other statements of the program, just as if they were ordinary statements of that programming language. These SQL statements are embedded in the program, and the program contains *embedded SQL*, which is often abbreviated as ESQL.

SQL in SQL APIs

ESQL products are IBM Informix SQL APIs (application programming interfaces). IBM produces an SQL API for the C programming language.

The following figure shows how an SQL API product works. You write a source program in which you treat SQL statements as executable code. Your source program is processed by an embedded SQL *preprocessor*, a program that locates the embedded SQL statements and converts them into a series of procedure calls and special data structures.

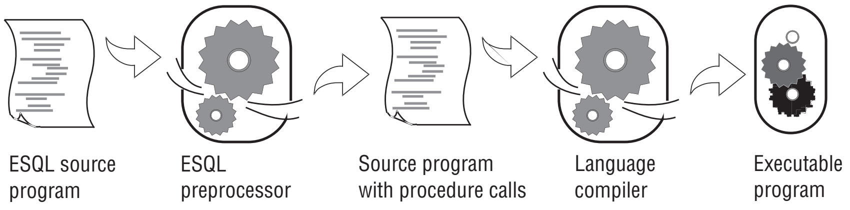


Figure 8-1. Overview of processing a program with embedded SQL statements

The converted source program then passes through the programming language compiler. The compiler output becomes an executable program after it is linked with a static or *dynamic* library of SQL API procedures. When the program runs, the SQL API library procedures are called; they set up communication with the database server to carry out the SQL operations.

If you link your executable program to a threading library package, you can develop Informix ESQL/C *multithreaded applications*. A multithreaded application can have many threads of control. It separates a process into multiple execution threads, each of which runs independently. The major advantage of a multithreaded Informix ESQL/C application is that each thread can have many active connections to a database server simultaneously. While a nonthreaded Informix ESQL/C application can establish many connections to one or more databases, it can have only one connection active at a time. A multithreaded Informix ESQL/C application can have one active connection per thread and many threads per application.

For more information on multithreaded applications, see the *IBM Informix ESQL/C Programmer's Manual*.

SQL in application languages

Whereas an IBM Informix SQL API product allows you to embed SQL in the host language, some languages include SQL as a natural part of their statement set. IBM Informix Stored Procedure Language (SPL) uses SQL as a natural part of its statement set. You use an SQL API product to write application programs. You use SPL to write routines that are stored with a database and called from an application program.

Static embedding

You can introduce SQL statements into a program through *static embedding* or *dynamic statements*. The simpler and more common way is by static embedding, which means that the SQL statements are written as part of the code. The statements are *static* because they are a fixed part of the source text. For more information on static embedding, see "Retrieve single rows" on page 8-8 and "Retrieve multiple rows" on page 8-11.

Dynamic statements

Some applications require the ability to compose SQL statements *dynamically*, in response to user input. For example, a program might have to select different columns or apply different criteria to rows, depending on what the user wants.

With dynamic SQL, the program composes an SQL statement as a string of characters in memory and passes it to the database server to be executed. Dynamic statements are not part of the code; they are constructed in memory during execution. For more information, see "Dynamic SQL" on page 8-17.

Program variables and host variables

Application programs can use program variables within SQL statements. In SPL, you put the program variable in the SQL statement as syntax allows. For example, a DELETE statement can use a program variable in its WHERE clause.

The following code example shows a program variable in SPL.

```
CREATE PROCEDURE delete_item (drop_number INT)
⋮
DELETE FROM items WHERE order_num = drop_number
⋮
```

In applications that use embedded SQL statements, the SQL statements can refer to the contents of program variables. A program variable that is named in an embedded SQL statement is called a *host variable* because the SQL statement is thought of as a guest in the program.

The following example shows a DELETE statement as it might appear when it is embedded in an IBM Informix ESQL/C source program:

```
EXEC SQL delete FROM items
   WHERE order_num = :onum;
```

In this program, you see an ordinary DELETE statement, as Chapter 6, "Modify data," on page 6-1 describes. When the Informix ESQL/C program is executed, a row of the **items** table is deleted; multiple rows can also be deleted.

The statement contains one new feature. It compares the **order_num** column to an item written as **:onum**, which is the name of a host variable.

An SQL API product provides a way to delimit the names of host variables when they appear in the context of an SQL statement. In Informix ESQL/C, a host variable can be introduced with either a dollar sign ($) or a colon (:). The colon is the ANSI-compatible format. The example statement asks the database server to delete rows in which the order number equals the current contents of the host variable named **:onum**. This numeric variable was declared and assigned a value earlier in the program.

In IBM Informix ESQL/C, an SQL statement can be introduced with either a leading dollar sign ($) or the words EXEC SQL.

The differences of syntax as illustrated in the preceding examples are trivial; the essential point is that the SQL API and SPL languages let you perform the following tasks:

- Embed SQL statements in a source program as if they were executable statements of the host language.
- Use program variables in SQL expressions the way literal values are used.

If you have programming experience, you can immediately see the possibilities. In the example, the order number to be deleted is passed in the variable **onum**. That value comes from any source that a program can use. It can be read from a file, the program can prompt a user to enter it, or it can be read from the database. The DELETE statement itself can be part of a subroutine (in which case **onum** can be a parameter of the subroutine); the subroutine can be called once or repetitively.

In short, when you embed SQL statements in a program, you can apply to them all the power of the host language. You can hide the SQL statements under many interfaces, and you can embellish the SQL functions in many ways.

Call the database server

Executing an SQL statement is essentially calling the database server as a subroutine. Information must pass from the program to the database server, and information must be returned from the database server to the program.

Some of this communication is done through host variables. You can think of the host variables named in an SQL statement as the parameters of the procedure call to the database server. In the preceding example, a host variable acts as a parameter of the WHERE clause. Host variables receive data that the database server returns, as “Retrieve multiple rows” on page 8-11 describes.

SQL Communications Area

The database server always returns a result code, and possibly other information about the effect of an operation, in a data structure known as the SQL Communications Area (SQLCA). If the database server executes an SQL statement in a user-defined routine, the SQLCA of the calling application contains the values that the SQL statement triggers in the routine.

The principal fields of the SQLCA are listed in Table 8-1 through Table 8-3 on page 8-6. The syntax that you use to describe a data structure such as the SQLCA, as well as the syntax that you use to refer to a field in it, differs among programming languages. For details, see your SQL API publication.

In particular, the subscript by which you name one element of the SQLERRD and SQLWARN arrays differs. Array elements are numbered starting with zero in IBM Informix ESQL/C, but starting with one in other languages. In this discussion, the fields are named with specific words such as `third`, and you must translate these words into the syntax of your programming language.

You can also use the SQLSTATE variable of the GET DIAGNOSTICS statement to detect, handle, and diagnose errors. See “SQLSTATE value” on page 8-7.

SQLCODE field

The SQLCODE field is the primary return code of the database server. After every SQL statement, SQLCODE is set to an integer value as the following table shows. When that value is zero, the statement is performed without error. In particular, when a statement is supposed to return data into a host variable, a code of zero means that the data has been returned and can be used. Any nonzero code means the opposite. No useful data was returned to host variables.

Table 8-1. Values of SQLCODE

Return value	**Interpretation**
value < 0	Specifies an error code.
value = 0	Indicates success.
0 < *value* < 100	After a DESCRIBE statement, an integer value that represents the type of SQL statement that is described.
100	After a successful query that returns no rows, indicates the NOT FOUND condition. NOT FOUND can also occur in an ANSI-compliant database after an INSERT INTO/SELECT, UPDATE, DELETE, or SELECT... INTO TEMP statement fails to access any rows.

End of data

The database server sets SQLCODE to `100` when the statement is performed correctly but no rows are found. This condition can occur in two situations.

The first situation involves a query that uses a cursor. (“Retrieve multiple rows” on page 8-11 describes queries that use cursors.) In these queries, the FETCH statement retrieves each value from the active set into memory. After the last row is retrieved, a subsequent FETCH statement cannot return any data. When this condition occurs, the database server sets SQLCODE to `100`, which indicates `end of data, no rows found`.

The second situation involves a query that does not use a cursor. In this case, the database server sets SQLCODE to `100` when no rows satisfy the query condition. In databases that are not ANSI compliant, only a SELECT statement that returns no rows causes SQLCODE to be set to `100`.

In ANSI-compliant databases, SELECT, DELETE, UPDATE, and INSERT statements all set SQLCODE to `100` if no rows are returned.

Negative Codes

When something unexpected goes wrong during a statement, the database server returns a negative number in SQLCODE to explain the problem. The meanings of these codes are documented in the online error message file.

SQLERRD array

Some error codes that can be reported in SQLCODE reflect general problems. The database server can set a more detailed code in the second field of SQLERRD that reveals the error that the database server I/O routines or the operating system encountered.

The integers in the SQLERRD array are set to different values following different statements. The first and fourth elements of the array are used only in IBM Informix ESQL/C. The following table shows how the fields are used.

Table 8-2. Fields of SQLERRD

Field	**Interpretation**
First	After a successful PREPARE statement for a SELECT, UPDATE, INSERT, or DELETE statement, or after a Select cursor is opened, this field contains the estimated number of rows affected.
Second	When SQLCODE contains an error code, this field contains either zero or an additional error code, called the ISAM error code, that explains the cause of the main error. After a successful insert operation of a single row, this field contains the value of any SERIAL, BIGSERIAL, or SERIAL8 value generated for that row. (This field is not updated, however, when a serial column is directly inserted as a triggered action by a trigger on a table, or by an INSTEAD OF trigger on a view.)
Third	After a successful multirow insert, update, or delete operation, this field contains the number of rows that were processed. After a multirow insert, update, or delete operation that ends with an error, this field contains the number of rows that were successfully processed before the error was detected.
Fourth	After a successful PREPARE statement for a SELECT, UPDATE, INSERT, or DELETE statement, or after a select cursor has been opened, this field contains the estimated weighted sum of disk accesses and total rows processed.
Fifth	After a syntax error in a PREPARE, EXECUTE IMMEDIATE, DECLARE, or static SQL statement, this field contains the offset in the statement text where the error was detected.
Sixth	After a successful fetch of a selected row, or a successful insert, update, or delete operation, this field contains the rowid (physical address) of the last row that was processed. Whether this rowid value corresponds to a row that the database server returns to the user depends on how the database server processes a query, particularly for SELECT statements.

Table 8-2. Fields of SQLERRD (continued)

Field	Interpretation
Seventh	Reserved.

These additional details can be useful. For example, you can use the value in the third field to report how many rows were deleted or updated. When your program prepares an SQL statement that the user enters and an error is found, the value in the fifth field enables you to display the exact point of error to the user. (DB-Access uses this feature to position the cursor when you ask to modify a statement after an error.)

SQLWARN array

The eight character fields in the SQLWARN array are set to either a blank or to `W` to indicate a variety of special conditions. Their meanings depend on the statement just executed.

A set of warning flags appears when a database opens, that is, following a CONNECT, DATABASE, or CREATE DATABASE statement. These flags tell you some characteristics of the database as a whole.

A second set of flags appears following any other statement. These flags reflect unusual events that occur during the statement, which are usually not serious enough to be reflected by SQLCODE.

Both sets of SQLWARN values are summarized in the following table.

Table 8-3. Fields of SQLWARN

Field	When opening or connecting to a database	All other SQL operations
First	Set to `W` when any other warning field is set to `W`. If blank, others need not be checked.	Set to `W` when any other warning field is set to `W`.
Second	Set to `W` when the database now open uses a transaction log.	Set to `W` if a column value is truncated when it is fetched into a host variable using a FETCH or a SELECT...INTO statement. On a REVOKE ALL statement, set to `W` when not all seven table-level privileges are revoked.
Third	Set to `W` when the database now open is ANSI compliant.	Set to `W` when a FETCH or SELECT statement returns an aggregate function (SUM, AVG, MIN, MAX) value that is NULL.
Fourth	Set to `W` when the database server is IBM Informix.	On a SELECT ... INTO, FETCH ... INTO, or EXECUTE ... INTO statement, set to `W` when the number of projection list items is not the same as the number of host variables given in the INTO clause to receive them. On a GRANT ALL statement, set to `W` when not all seven table-level access privileges are granted.

Table 8-3. Fields of SQLWARN (continued)

Field	When opening or connecting to a database	All other SQL operations
Fifth	Set to `W` when the database server stores the FLOAT data type in DECIMAL form (done when the host system lacks support for FLOAT types).	Set to `W` after a DESCRIBE statement if the prepared object contains a DELETE statement or an UPDATE statement without a WHERE clause.
Sixth	Reserved.	Set to `W` following execution of a statement that does not use ANSI-standard SQL syntax (provided the **DBANSIWARN** environment variable is set).
Seventh	Set to `W` when the application is connected to a database server that is the secondary server in a data-replication pair. That is, the server is available only for read operations.	Set to `W` when a data fragment (a dbspace) has been skipped during query processing (when the DATASKIP feature is on).
Eighth	Set to `W` when client DB_LOCALE does not match the database locale. For more information, see the *IBM Informix GLS User's Guide*.	Set to `W` when SET EXPLAIN ON AVOID_EXECUTE statement prevents query execution.

SQLERRM character string

SQLERRM can store a character string of up to 72 bytes. The SQLERRM character string contains identifiers, such as a table names, that are placed in the error message. For some networked applications, it contains an error message that the networking software generates.

If an INSERT operation fails because a constraint is violated, the name of the constraint that failed is written to SQLERRM.

Tip: If an error string is longer than 72 bytes, the overflow is silently discarded. In some contexts, this can result in the loss of information about runtime errors.

SQLSTATE value

Certain IBM Informix products, such as IBM Informix ESQL/C, support the SQLSTATE value in compliance with X/Open and ANSI SQL standards. The GET DIAGNOSTICS statement reads the SQLSTATE value to diagnose errors after you run an SQL statement. The database server returns a result code in a five-character string that is stored in a variable called SQLSTATE. The SQLSTATE error code, or value, tells you the following information about the most recently executed SQL statement:

- If the statement was successful
- If the statement was successful but generated warnings
- If the statement was successful but generated no data
- If the statement failed

For more information on the GET DIAGNOSTICS statement, the SQLSTATE variable, and the meaning of the SQLSTATE return codes, see the GET DIAGNOSTICS statement in the *IBM Informix Guide to SQL: Syntax*.

Tip: If your IBM Informix product supports GET DIAGNOSTICS and SQLSTATE, it is recommended that you use them as the primary structure to detect, handle, and diagnose errors. Using SQLSTATE allows you to detect multiple errors, and it is ANSI compliant.

Retrieve single rows

The set of rows that a SELECT statement returns is its *active set*. A *singleton* SELECT statement returns a single row. You can use embedded SELECT statements to retrieve single rows from the database into host variables. When a SELECT statement returns more than one row of data, however, a program must use a *cursor* to retrieve rows one at a time. Multiple-row select operations are discussed in "Retrieve multiple rows" on page 8-11.

To retrieve a single row of data, simply embed a SELECT statement in your program. The following example shows how you can write the embedded SELECT statement using IBM Informix ESQL/C:

```
EXEC SQL SELECT avg (total_price)
   INTO :avg_price
   FROM items
   WHERE order_num in
      (SELECT order_num from orders
      WHERE order_date < date('6/1/98') );
```

The INTO clause is the only detail that distinguishes this statement from any example in Chapter 2, "Compose SELECT statements," on page 2-1 or Chapter 5, "Compose advanced SELECT statements," on page 5-1. This clause specifies the host variables that are to receive the data that is produced.

When the program executes an embedded SELECT statement, the database server performs the query. The example statement selects an aggregate value so that it produces exactly one row of data. The row has only a single column, and its value is deposited in the host variable named **avg_price**. Subsequent lines of the program can use that variable.

You can use statements of this kind to retrieve single rows of data into host variables. The single row can have as many columns as desired. If a query produces more than one row of data, the database server cannot return any data. It returns an error code instead.

You should list as many host variables in the INTO clause as there are items in the select list. If, by accident, these lists are of different lengths, the database server returns as many values as it can and sets the warning flag in the fourth field of SQLWARN.

Data type conversion

The following Informix ESQL/C example retrieves the average of a DECIMAL column, which is itself a DECIMAL value. However, the host variable into which the average of the DECIMAL column is placed is not required to have that data type.

```
EXEC SQL SELECT avg (total_price) into :avg_price
   FROM items;
```

The declaration of the receiving variable **avg_price** in the previous example of Informix ESQL/C code is not shown. The declaration could be any one of the following definitions:

```
int avg_price;
double avg_price;
char avg_price[16];
dec_t avg_price; /* typedef of decimal number structure */
```

The data type of each host variable that is used in a statement is noted and passed to the database server with the statement. The database server does its best to convert column data into the form that the receiving variables use. Almost any conversion is allowed, although some conversions cause a precision loss. The results of the preceding example differ, depending on the data type of the receiving host variable, as the following table shows.

Data type	Result
FLOAT	The database server converts the decimal result to FLOAT, possibly truncating some fractional digits. If the magnitude of a decimal exceeds the maximum magnitude of the FLOAT format, an error is returned.
INTEGER	The database server converts the result to INTEGER, truncating fractional digits if necessary. If the integer part of the converted number does not fit the receiving variable, an error occurs.
CHARACTER	The database server converts the decimal value to a CHARACTER string. If the string is too long for the receiving variable, it is truncated. The second field of SQLWARN is set to W and the value in the SQLSTATE variable is 01004.

What if the program retrieves a NULL value?

NULL values can be stored in the database, but the data types that programming languages support do not recognize a NULL state. A program must have some way to recognize a NULL item to avoid processing it as data.

Indicator variables meet this need in SQL APIs. An indicator variable is an additional variable that is associated with a host variable that might receive a NULL item. When the database server puts data in the main variable, it also puts a special value in the indicator variable to show whether the data is NULL. In the following IBM Informix ESQL/C example, a single row is selected, and a single value is retrieved into the host variable **op_date**:

```
EXEC SQL SELECT paid_date
      INTO :op_date:op_d_ind
      FROM orders
      WHERE order_num = $the_order;
if (op_d_ind < 0) /* data was null */
   rstrdate ('01/01/1900', :op_date);
```

Because the value might be NULL, an indicator variable named **op_d_ind** is associated with the host variable. (It must be declared as a short integer elsewhere in the program.)

Following execution of the SELECT statement, the program tests the indicator variable for a negative value. A negative number (usually -1) means that the value retrieved into the main variable is NULL. If the variable is NULL, this program uses an Informix ESQL/C library function to assign a default value to the host variable. (The function **rstrdate** is part of the IBM Informix ESQL/C product.)

The syntax that you use to associate an indicator variable with a host variable differs with the language you are using, but the principle is the same in all languages.

Dealing with errors

Although the database server automatically handles conversion between data types, several things still can go wrong with a SELECT statement. In SQL programming, as in any kind of programming, you must anticipate errors and provide for them at every point.

End of data

One common event is that no rows satisfy a query. This event is signalled by an SQLSTATE code of `02000` and by a code of `100` in SQLCODE after a SELECT statement. This code indicates an error or a normal event, depending entirely on your application. If you are sure a row or rows should satisfy the query (for example, if you are reading a row using a key value that you just read from a row of another table), then the end-of-data code represents a serious failure in the logic of the program. On the other hand, if you select a row based on a key that a user supplies or some other source supplies that is less reliable than a program, a lack of data can be a normal event.

End of data with databases that are not ANSI compliant

If your database is not ANSI compliant, the end-of-data return code, `100`, is set in SQLCODE following SELECT statements only. In addition, the SQLSTATE value is set to `02000`. (Other statements, such as INSERT, UPDATE, and DELETE, set the third element of SQLERRD to show how many rows they affected; Chapter 9, "Modify data through SQL programs," on page 9-1 covers this topic.)

Serious errors

Errors that set SQLCODE to a negative value or SQLSTATE to a value that begins with anything other than `00`, `01`, or `02` are usually serious. Programs that you have developed and that are in production should rarely report these errors. Nevertheless, it is difficult to anticipate every problematic situation, so your program must be able to deal with these errors.

For example, a query can return error -206, which means that a table specified in the query is not in the database. This condition occurs if someone dropped the table after the program was written, or if the program opened the wrong database through some error of logic or mistake in input.

Interpret end of data with aggregate functions

A SELECT statement that uses an aggregate function such as **SUM**, **MIN**, or **AVG** always succeeds in returning at least one row of data, even when no rows satisfy the WHERE clause. An aggregate value based on an empty set of rows is null, but it exists nonetheless.

However, an aggregate value is also null if it is based on one or more rows that all contain null values. If you must be able to detect the difference between an aggregate value that is based on no rows and one that is based on some rows that are all null, you must include a COUNT function in the statement and an indicator variable on the aggregate value. You can then work out the following cases.

Count Value	Indicator	Case
0	-1	Zero rows selected
>0	-1	Some rows selected; all were null
>0	0	Some non-null rows selected

Default values

You can handle these inevitable errors in many ways. In some applications, more lines of code are used to handle errors than to execute functionality. In the examples in this section, however, one of the simplest solutions, the default value, should work, as the following example shows:

```
avg_price = 0; /* set default for errors */
EXEC SQL SELECT avg (total_price)
      INTO :avg_price:null_flag
      FROM items;
if (null_flag < 0) /* probably no rows */
   avg_price = 0; /* set default for 0 rows */
```

The previous example deals with the following considerations:

- If the query selects some non-null rows, the correct value is returned and used. This result is the expected and most frequent one.
- If the query selects no rows, or in the much less likely event, selects only rows that have null values in the **total_price** column (a column that should never be null), the indicator variable is set, and the default value is assigned.
- If any serious error occurs, the host variable is left unchanged; it contains the default value initially set. At this point in the program, the programmer sees no need to trap such errors and report them.

Retrieve multiple rows

When any chance exists that a query could return more than one row, the program must execute the query differently. Multirow queries are handled in two stages. First, the program starts the query. (No data is returned immediately.) Then the program requests the rows of data one at a time.

These operations are performed using a special data object called a *cursor*. A cursor is a data structure that represents the current state of a query. The following list shows the general sequence of program operations:

1. The program *declares* the cursor and its associated SELECT statement, which merely allocates storage to hold the cursor.
2. The program *opens* the cursor, which starts the execution of the associated SELECT statement and detects any errors in it.
3. The program *fetches* a row of data into host variables and processes it.
4. The program *closes* the cursor after the last row is fetched.
5. When the cursor is no longer needed, the program *frees* the cursor to deallocate the resources it uses.

These operations are performed with SQL statements named DECLARE, OPEN, FETCH, CLOSE, and FREE.

Declare a cursor

You use the DECLARE statement to declare a cursor. This statement gives the cursor a name, specifies its use, and associates it with a statement. The following example is written in IBM Informix ESQL/C:

```
EXEC SQL DECLARE the_item CURSOR FOR
   SELECT order_num, item_num, stock_num
      INTO :o_num, :i_num, :s_num
      FROM items
   FOR READ ONLY;
```

The declaration gives the cursor a name (**the_item** in this case) and associates it with a SELECT statement. (Chapter 9, “Modify data through SQL programs,” on page 9-1 discusses how a cursor can also be associated with an INSERT statement.)

The SELECT statement in this example contains an INTO clause. The INTO clause specifies which variables receive data. You can also use the FETCH statement to specify which variables receive data, as “Locate the INTO clause” on page 8-13 discusses.

The DECLARE statement is not an active statement; it merely establishes the features of the cursor and allocates storage for it. You can use the cursor declared in the preceding example to read through the **items** table once. Cursors can be declared to read backward and forward (see “Cursor input modes” on page 8-13). This cursor, because it lacks a FOR UPDATE clause and because it is designated FOR READ ONLY, is used only to read data, not to modify it. Chapter 9, “Modify data through SQL programs,” on page 9-1 covers the use of cursors to modify data.

Open a cursor

The program opens the cursor when it is ready to use it. The OPEN statement activates the cursor. It passes the associated SELECT statement to the database server, which begins the search for matching rows. The database server processes the query to the point of locating or constructing the first row of output. It does not actually return that row of data, but it does set a return code in SQLSTATE and in SQLCODE for SQL APIs. The following example shows the OPEN statement in Informix ESQL/C:

```
EXEC SQL OPEN the_item;
```

Because the database server is seeing the query for the first time, it might detect a number of errors. After the program opens the cursor, it should test SQLSTATE or SQLCODE. If the SQLSTATE value is greater than `02000` or the SQLCODE contains a negative number, the cursor is not usable. An error might be present in the SELECT statement, or some other problem might prevent the database server from executing the statement.

If SQLSTATE is equal to `00000`, or SQLCODE contains a zero, the SELECT statement is syntactically valid, and the cursor is ready to use. At this point, however, the program does not know if the cursor can produce any rows.

Fetch rows

The program uses the FETCH statement to retrieve each row of output. This statement names a cursor and can also name the host variables that receive the data. The following example shows the completed IBM Informix ESQL/C code:

```
EXEC SQL DECLARE the_item CURSOR FOR
   SELECT order_num, item_num, stock_num
      INTO :o_num, :i_num, :s_num
      FROM items;
EXEC SQL OPEN the_item;
while(SQLCODE == 0)
{
   EXEC SQL FETCH the_item;
   if(SQLCODE == 0)
      printf("%d, %d, %d", o_num, i_num, s_num);
}
```

Detect end of data

In the previous example, the WHILE condition prevents execution of the loop in case the OPEN statement returns an error. The same condition terminates the loop when SQLCODE is set to `100` to signal the end of data. However, the loop contains a test of SQLCODE. This test is necessary because, if the SELECT statement is valid yet finds no matching rows, the OPEN statement returns a zero, but the first fetch returns `100` (end of data) and no data. The following example shows another way to write the same loop:

```
EXEC SQL DECLARE the_item CURSOR FOR
   SELECT order_num, item_num, stock_num
   INTO :o_num, :i_num, :s_num
   FROM items;
EXEC SQL OPEN the_item;
if(SQLCODE == 0)
   EXEC SQL FETCH the_item;      /* fetch 1st row*/
while(SQLCODE == 0)
{
   printf("%d, %d, %d", o_num, i_num, s_num);
   EXEC SQL FETCH the_item;
}
```

In this version, the case of no returned rows is handled early, so no second test of SQLCODE exists within the loop. These versions have no measurable difference in performance because the time cost of a test of SQLCODE is a tiny fraction of the cost of a fetch.

Locate the INTO clause

The INTO clause names the host variables that are to receive the data that the database server returns. The INTO clause must appear in either the SELECT or the FETCH statement. However it cannot appear in both statements. The following example specifies host variables in the FETCH statement:

```
EXEC SQL DECLARE the_item CURSOR FOR
   SELECT order_num, item_num, stock_num
      FROM items;
EXEC SQL OPEN the_item;
while(SQLCODE == 0)
{
   EXEC SQL FETCH the_item INTO :o_num, :i_num, :s_num;
   if(SQLCODE == 0)
      printf("%d, %d, %d", o_num, i_num, s_num);
}
```

This form lets you fetch different rows into different locations. For example, you could use this form to fetch successive rows into successive elements of an array.

Cursor input modes

For purposes of input, a cursor operates in one of two modes, *sequential* or *scrolling*. A sequential cursor can fetch only the next row in sequence, so a sequential cursor can read through a table only once each time the cursor is opened. A scroll cursor can fetch the next row or any of the output rows, so a scroll cursor can read the same rows multiple times. The following example shows a sequential cursor declared in IBM Informix ESQL/C.

```
EXEC SQL DECLARE pcurs cursor for
   SELECT customer_num, lname, city
      FROM customer;
```

After the cursor is opened, it can be used only with a sequential fetch that retrieves the next row of data, as the following example shows:

```
EXEC SQL FETCH p_curs into:cnum, :clname, :ccity;
```

Each sequential fetch returns a new row.

A scroll cursor is declared with the keywords SCROLL CURSOR, as the following example from IBM Informix ESQL/C shows:

```
EXEC SQL DECLARE s_curs SCROLL CURSOR FOR
      SELECT order_num, order_date FROM orders
         WHERE customer_num > 104
```

Use the scroll cursor with a variety of fetch options. For example, the ABSOLUTE option specifies the absolute row position of the row to fetch.

```
EXEC SQL FETCH ABSOLUTE :numrow s_curs
     INTO :nordr, :nodat
```

This statement fetches the row whose position is given in the host variable **numrow**. You can also fetch the current row again, or you can fetch the first row and then scan through all the rows again. However, these features can cause the application to run more slowly, as the next section describes. For additional options that apply to scroll cursors, see the FETCH statement in the *IBM Informix Guide to SQL: Syntax*.

Active set of a cursor

Once a cursor is opened, it stands for some selection of rows. The set of all rows that the query produces is called the *active set* of the cursor. It is easy to think of the active set as a well-defined collection of rows and to think of the cursor as pointing to one row of the collection. This situation is true as long as no other programs are modifying the same data concurrently.

Create the active set

When a cursor is opened, the database server does whatever is necessary to locate the first row of selected data. Depending on how the query is phrased, this action can be easy, or it can require a great deal of work and time. Consider the following declaration of a cursor:

```
EXEC SQL DECLARE easy CURSOR FOR
   SELECT fname, lname FROM customer
      WHERE state = 'NJ'
```

Because this cursor queries only a single table in a simple way, the database server quickly determines whether any rows satisfy the query and identifies the first one. The first row is the only row the cursor finds at this time. The rest of the rows in the active set remain unknown. As a contrast, consider the following declaration of a cursor:

```
EXEC SQL DECLARE hard SCROLL CURSOR FOR
   SELECT C.customer_num, O.order_num, sum (items.total_price)
      FROM customer C, orders O, items I
      WHERE C.customer_num = O.customer_num
         AND O.order_num = I.order_num
         AND O.paid_date is null
      GROUP BY C.customer_num, O.order_num
```

The active set of this cursor is generated by joining three tables and grouping the output rows. The optimizer might be able to use indexes to produce the rows in the correct order, but generally the use of ORDER BY or GROUP BY clauses requires the database server to generate all the rows, copy them to a temporary table, and sort the table, before it can determine which row to present first.

In cases where the active set is entirely generated and saved in a temporary table, the database server can take quite some time to open the cursor. Afterwards, the database server could tell the program exactly how many rows the active set contains. However, this information is not made available. One reason is that you can never be sure which method the optimizer uses. If the optimizer can avoid sorts and temporary tables, it does so; but small changes in the query, in the sizes of the tables, or in the available indexes can change the methods of the optimizer.

Active set for a sequential cursor

The database server attempts to use as few resources as possible to maintain the active set of a cursor. If it can do so, the database server never retains more than the single row that is fetched next. It can do this for most sequential cursors. On each fetch, it returns the contents of the current row and locates the next one.

Active set for a SCROLL cursor

All the rows in the active set for a SCROLL cursor must be retained until the cursor closes because the database server cannot be sure which row the program will ask for next.

Most frequently, the database server implements the active set of a scroll cursor as a temporary table. The database server might not fill this table immediately, however (unless it created a temporary table to process the query). Usually it creates the temporary table when the cursor is opened. Then, the first time a row is fetched, the database server copies it into the temporary table and returns it to the program. When a row is fetched for a second time, it can be taken from the temporary table. This scheme uses the fewest resources, in the event that the program abandons the query before it fetches all the rows. Rows that are never fetched are not created or saved.

Active set and concurrency

When only one program is using a database, the members of the active set cannot change. This situation describes most personal computers, and it is the easiest situation to think about. But some programs must be designed for use in a multiprogramming system, where two, three, or dozens of different programs can work on the same tables simultaneously.

When other programs can update the tables while your cursor is open, the idea of the active set becomes less useful. Your program can see only one row of data at a time, but all other rows in the table can be changing.

In the case of a simple query, when the database server holds only one row of the active set, any other row can change. The instant after your program fetches a row, another program can delete the same row, or update it so that if it is examined again, it is no longer part of the active set.

When the active set, or part of it, is saved in a temporary table, *stale data* can present a problem. That is, the rows in the actual tables from which the active-set rows are derived can change. If they do, some of the active-set rows no longer reflect the current table contents.

These ideas seem unsettling at first, but as long as your program only reads the data, stale data does not exist, or rather, all data is equally stale. The active set is a snapshot of the data as it is at one moment. A row is different the next day; it does not matter if it is also different in the next millisecond. To put it another way, no practical difference exists between changes that occur while the program is running and changes that are saved and applied the instant that the program terminates.

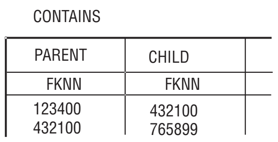
The only time that stale data can cause a problem is when the program intends to use the input data to modify the same database; for example, when a banking application must read an account balance, change it, and write it back. Chapter 9, "Modify data through SQL programs," on page 9-1 discusses programs that modify data.

Parts-explosion problem

When you use a cursor supplemented by program logic, you can solve problems that plain SQL cannot solve. One of these problems is the parts-explosion problem, sometimes called bill-of-materials processing. At the heart of this problem is a recursive relationship among objects; one object contains other objects, which contain yet others.

The problem is usually stated in terms of a manufacturing inventory. A company makes a variety of parts, for example. Some parts are discrete, but some are assemblages of other parts.

These relationships are documented in a single table, which might be called **contains**. The column **contains.parent** holds the part numbers of parts that are assemblages. The column **contains.child** has the part number of a part that is a component of the parent. If part number 123400 is an assembly of nine parts, nine rows exist with 123400 in the first column and other part numbers in the second. The following figure shows one of the rows that describe part number 123400.



CONTAINS

PARENT	CHILD
FKNN	FKNN
123400	432100
432100	765899

Figure 8-2. Parts-explosion problem

Here is the parts-explosion problem: given a part number, produce a list of all parts that are components of that part. The following example is a sketch of one solution, as implemented in IBM Informix ESQL/C:

```
int part_list[200];

boom(top_part)
int top_part;
{
   long this_part, child_part;
   int next_to_do = 0, next_free = 1;
   part_list[next_to_do] = top_part;

   EXEC SQL DECLARE part_scan CURSOR FOR
      SELECT child INTO child_part FROM contains
         WHERE parent = this_part;
   while(next_to_do < next_free)
   {
      this_part = part_list[next_to_do];
      EXEC SQL OPEN part_scan;
      while(SQLCODE == 0)
      {
         EXEC SQL FETCH part_scan;
         if(SQLCODE == 0)
         {
            part_list[next_free] = child_part;
            next_free += 1;
         }
      }
      EXEC SQL CLOSE part_scan;
      next_to_do += 1;
   }
   return (next_free - 1);
}
```

Technically speaking, each row of the **contains** table is the head node of a directed acyclic graph, or *tree*. The function performs a breadth-first search of the tree whose root is the part number passed as its parameter. The function uses a cursor named **part_scan** to return all the rows with a particular value in the **parent** column. The innermost `while` loop opens the **part_scan** cursor, fetches each row in the selection set, and closes the cursor when the part number of each component has been retrieved.

This function addresses the heart of the parts-explosion problem, but the function is not a complete solution. For example, it does not allow for components that appear at more than one level in the tree. Furthermore, a practical **contains** table would also have a column **count**, giving the count of **child** parts used in each **parent**. A program that returns a total count of each component part is much more complicated.

The iterative approach described previously is not the only way to approach the parts-explosion problem. If the number of generations has a fixed limit, you can solve the problem with a single SELECT statement using nested, outer self-joins.

If up to four generations of parts can be contained within one top-level part, the following SELECT statement returns all of them:

```
SELECT a.parent, a.child, b.child, c.child, d.child
   FROM contains a
      OUTER (contains b,
         OUTER (contains c, outer contains d) )
   WHERE a.parent = top_part_number
      AND a.child = b.parent
      AND b.child = c.parent
      AND c.child = d.parent
```

This SELECT statement returns one row for each line of descent rooted in the part given as **top_part_number**. Null values are returned for levels that do not exist. (Use indicator variables to detect them.) To extend this solution to more levels, select additional nested outer joins of the **contains** table. You can also revise this solution to return counts of the number of parts at each level.

Dynamic SQL

Although static SQL is useful, it requires that you know the exact content of every SQL statement at the time you write the program. For example, you must state exactly which columns are tested in any WHERE clause and exactly which columns are named in any select list.

No problem exists when you write a program to perform a well-defined task. But the database tasks of some programs cannot be perfectly defined in advance. In particular, a program that must respond to an interactive user might need to compose SQL statements in response to what the user enters.

Dynamic SQL allows a program to form an SQL statement during execution, so that user input determines the contents of the statement. This action is performed in the following steps:

1. The program assembles the text of an SQL statement as a character string, which is stored in a program variable.
2. It executes a PREPARE statement, which asks the database server to examine the statement text and prepare it for execution.
3. It uses the EXECUTE statement to execute the prepared statement.

In this way, a program can construct and then use any SQL statement, based on user input of any kind. For example, it can read a file of SQL statements and prepare and execute each one.

DB-Access, a utility that you can use to explore SQL interactively, is an IBM Informix ESQL/C program that constructs, prepares, and executes SQL statements dynamically. For example, DB-Access lets you use simple, interactive menus to specify the columns of a table. When you are finished, DB-Access builds the necessary CREATE TABLE or ALTER TABLE statement dynamically and prepares and executes it.

Prepare a statement

In form, a dynamic SQL statement is like any other SQL statement that is written into a program, except that it cannot contain the names of any host variables.

A prepared SQL statement has two restrictions. First, if it is a SELECT statement, it cannot include the INTO *variable* clause. The INTO *variable* clause specifies host variables into which column data is placed, and host variables are not allowed in the text of a prepared object. Second, wherever the name of a host variable normally appears in an expression, a question mark (?) is written as a placeholder in the PREPARE statement. Only the PREPARE statement can specify question mark (?) placeholders.

You can prepare a statement in this form for execution with the PREPARE statement. The following example is written in IBM Informix ESQL/C:

```
EXEC SQL prepare query_2 from
       'SELECT * from orders
          WHERE customer_num = ? and order_date > ?';
```

The two question marks in this example indicate that when the statement is executed, the values of host variables are used at those two points.

You can prepare almost any SQL statement dynamically. The only statements that you cannot prepare are the ones directly concerned with dynamic SQL and cursor management, such as the PREPARE and OPEN statements. After you prepare an UPDATE or DELETE statement, it is a good idea to test the fifth field of SQLWARN to see if you used a WHERE clause (see “SQLWARN array” on page 8-6).

The result of preparing a statement is a data structure that represents the statement. This data structure is not the same as the string of characters that produced it. In the PREPARE statement, you give a name to the data structure; it is **query_2** in the preceding example. This name is used to execute the prepared SQL statement.

The PREPARE statement does not limit the character string to one statement. It can contain multiple SQL statements, separated by semicolons. The following example shows a fairly complex transaction in IBM Informix ESQL/C:

```
strcpy(big_query, "UPDATE account SET balance = balance + ?
WHERE customer_id = ?; \ UPDATE teller SET balance =
balance + ? WHERE teller_id = ?;");
EXEC SQL PREPARE big1 FROM :big_query;
```

When this list of statements is executed, host variables must provide values for six place-holding question marks. Although it is more complicated to set up a multistatement list, performance is often better because fewer exchanges take place between the program and the database server.

Execute prepared SQL

After you prepare a statement, you can execute it multiple times. statements other than SELECT statements, and SELECT statements that return only a single row, are executed with the EXECUTE statement.

The following IBM Informix ESQL/C code prepares and executes a multistatement update of a bank account:

```
EXEC SQL BEGIN DECLARE SECTION;
char bigquery[270] = "begin work;";
EXEC SQL END DECLARE SECTION;
stcat ("update account set balance = balance + ? where ", bigquery);
stcat ("acct_number = ?;', bigquery);
stcat ("update teller set balance = balance + ? where ", bigquery);
stcat ("teller_number = ?;', bigquery);
stcat ("update branch set balance = balance + ? where ", bigquery);
stcat ("branch_number = ?;', bigquery);
stcat ("insert into history values(timestamp, values);", bigquery);

EXEC SQL prepare bigq from :bigquery;

EXEC SQL execute bigq using :delta, :acct_number, :delta,
    :teller_number, :delta, :branch_number;

EXEC SQL commit work;
```

The USING clause of the EXECUTE statement supplies a list of host variables whose values are to take the place of the question marks in the prepared statement. If a SELECT (or EXECUTE FUNCTION) returns only one row, you can use the INTO clause of EXECUTE to specify the host variables that receive the values.

Dynamic host variables

SQL APIs, which support dynamically allocated data objects, take dynamic statements one step further. They let you dynamically allocate the host variables that receive column data.

Dynamic allocation of variables makes it possible to take an arbitrary SELECT statement from program input, determine how many values it produces and their data types, and allocate the host variables of the appropriate types to hold them.

The key to this ability is the DESCRIBE statement. It takes the name of a prepared SQL statement and returns information about the statement and its contents. It sets SQLCODE to specify the type of statement; that is, the verb with which it begins. If the prepared statement is a SELECT statement, the DESCRIBE statement also returns information about the selected output data. If the prepared statement is an

INSERT statement, the DESCRIBE statement returns information about the input parameters. The data structure to which a DESCRIBE statement returns information is a predefined data structure that is allocated for this purpose and is known as a system-descriptor area. If you are using IBM Informix ESQL/C, you can use a system-descriptor area or, as an alternative, an **sqlda** structure.

The data structure that a DESCRIBE statement returns or references for a SELECT statement includes an array of structures. Each structure describes the data that is returned for one item in the select list. The program can examine the array and discover that a row of data includes a decimal value, a character value of a certain length, and an integer.

With this information, the program can allocate memory to hold the retrieved values and put the necessary pointers in the data structure for the database server to use.

Free prepared statements

A prepared SQL statement occupies space in memory. With some database servers, it can consume space that the database server owns as well as space that belongs to the program. This space is released when the program terminates, but in general, you should free this space when you finish with it.

You can use the FREE statement to release this space. The FREE statement takes either the name of a statement or the name of a cursor that was declared for a statement name, and releases the space allocated to the prepared statement. If more than one cursor is defined on the statement, freeing the statement does not free the cursor.

Quick execution

For simple statements that do not require a cursor or host variables, you can combine the actions of the PREPARE, EXECUTE, and FREE statements into a single operation. The following example shows how the EXECUTE IMMEDIATE statement takes a character string, prepares it, executes it, and frees the storage in one operation:

```
EXEC SQL execute immediate 'drop index my_temp_index';
```

This capability makes it easy to write simple SQL operations. However, because no USING clause is allowed, the EXECUTE IMMEDIATE statement cannot be used for SELECT statements.

Embed data-definition statements

Data-definition statements, the SQL statements that create databases and modify the definitions of tables, are not usually put into programs. The reason is that they are rarely performed. A database is created once, but it is queried and updated many times.

The creation of a database and its tables is generally done interactively, using DB-Access. These tools can also be run from a file of statements, so that the creation of a database can be done with one operating-system command. The data-definition statements are documented in the *IBM Informix Guide to SQL: Syntax* and the *IBM Informix Database Design and Implementation Guide*.

Grant and revoke privileges in applications

One task related to data definition is performed repeatedly: granting and revoking privileges. Because privileges must be granted and revoked frequently, possibly by users who are not skilled in SQL, one strategy is to package the GRANT and REVOKE statements in programs to give them a simpler, more convenient user interface.

The GRANT and REVOKE statements are especially good candidates for dynamic SQL. Each statement takes the following parameters:

- A list of one or more privileges
- A table name
- The name of a user

You probably need to supply at least some of these values based on program input (from the user, command-line parameters, or a file) but none can be supplied in the form of a host variable. The syntax of these statements does not allow host variables at any point.

An alternative is to assemble the parts of a statement into a character string and to prepare and execute the assembled statement. Program input can be incorporated into the prepared statement as characters.

The following IBM Informix ESQL/C function assembles a GRANT statement from parameters, and then prepares and executes it:

```
char priv_to_grant[100];
char table_name[20];
char user_id[20];

table_grant(priv_to_grant, table_name, user_id)
char *priv_to_grant;
char *table_name;
char *user_id;
{
   EXEC SQL BEGIN DECLARE SECTION;
   char grant_stmt[200];
   EXEC SQL END DECLARE SECTION;

   sprintf(grant_stmt, " GRANT %s ON %s TO %s",
      priv_to_grant, table_name, user_id);
   PREPARE the_grant FROM :grant_stmt;
   if(SQLCODE == 0)
      EXEC SQL EXECUTE the_grant;
   else
      printf("Sorry, got error # %d attempting %s",
         SQLCODE, grant_stmt);

   EXEC SQL FREE the_grant;
}
```

The opening statement of the function that the following example shows specifies its name and its three parameters. The three parameters specify the privileges to grant, the name of the table on which to grant privileges, and the ID of the user to receive them.

```
table_grant(priv_to_grant, table_name, user_id)
char *priv_to_grant;
char *table_name;
char *user_id;
```

The function uses the statements in the following example to define a local variable, **grant_stmt**, which is used to assemble and hold the GRANT statement:

```
EXEC SQL BEGIN DECLARE SECTION;
   char grant_stmt[200];
EXEC SQL END DECLARE SECTION;
```

As the following example illustrates, the GRANT statement is created by concatenating the constant parts of the statement and the function parameters:

```
sprintf(grant_stmt, " GRANT %s ON %s TO %s",priv_to_grant,
   table_name, user_id);
```

This statement concatenates the following six character strings:

- 'GRANT'
- The parameter that specifies the privileges to be granted
- 'ON'
- The parameter that specifies the table name
- 'TO'
- The parameter that specifies the user

The result is a complete GRANT statement composed partly of program input. The PREPARE statement passes the assembled statement text to the database server for parsing.

If the database server returns an error code in SQLCODE following the PREPARE statement, the function displays an error message. If the database server approves the form of the statement, it sets a zero return code. This action does not guarantee that the statement is executed properly; it means only that the statement has correct syntax. It might refer to a nonexistent table or contain many other kinds of errors that can be detected only during execution. The following portion of the example checks that **the_grant** was prepared successfully before executing it:

```
if(SQLCODE == 0)
   EXEC SQL EXECUTE the_grant;
else
   printf("Sorry, got error # %d attempting %s", SQLCODE, grant_stmt);
```

If the preparation is successful, `SQLCODE = = 0`, the next step executes the prepared statement.

Assign roles

Alternatively, the DBA can define a role with the CREATE ROLE statement, and use the GRANT and REVOKE statements to cancel or assign roles to users, and to grant and revoke privileges of roles. For example:

```
GRANT engineer TO nmartin;
```

The SET ROLE statement is needed to activate a non-default role. For more information on roles and privileges, see "Access-management strategies" on page 1-5 and "Privileges on a database and on its objects" on page 6-20. For more information on the GRANT and REVOKE statements, see the *IBM Informix Database Design and Implementation Guide*. For more information about the syntax of these statements, see *IBM Informix Guide to SQL: Syntax*.

Summary

SQL statements can be written into programs as if they were normal statements of the programming language. Program variables can be used in WHERE clauses, and data from the database can be fetched into them. A preprocessor translates the SQL code into procedure calls and data structures.

Statements that do not return data, or queries that return only one row of data, are written like ordinary imperative statements of the language. Queries that can return more than one row are associated with a cursor that represents the current row of data. Through the cursor, the program can fetch each row of data as it is needed.

Static SQL statements are written into the text of the program. However, the program can form new SQL statements dynamically, as it runs, and execute them also. In the most advanced cases, the program can obtain information about the number and types of columns that a query returns and dynamically allocate the memory space to hold them.

Chapter 9. Modify data through SQL programs

The previous chapter describes how to insert or embed SQL statements, especially the SELECT statement, into programs written in other languages. Embedded SQL enables a program to retrieve rows of data from a database.

This chapter discusses the issues that arise when a program needs to delete, insert, or update rows to modify the database. As in Chapter 8, “SQL programming,” on page 8-1, this chapter prepares you for reading your IBM Informix embedded language publication.

The general use of the INSERT, UPDATE, and DELETE statements is discussed in Chapter 6, “Modify data,” on page 6-1. This chapter examines their use from within a program. You can easily embed the statements in a program, but it can be difficult to handle errors and to deal with concurrent modifications from multiple programs.

The DELETE statement

To delete rows from a table, a program executes a DELETE statement. The DELETE statement can specify rows in the usual way, with a WHERE clause, or it can refer to a single row, the last one fetched through a specified cursor.

Whenever you delete rows, you must consider whether rows in other tables depend on the deleted rows. This problem of coordinated deletions is covered in Chapter 6, “Modify data,” on page 6-1. The problem is the same when deletions are made from within a program.

Direct deletions

You can embed a DELETE statement in a program. The following example uses IBM Informix ESQL/C:

```
EXEC SQL delete from items
   WHERE order_num = :onum;
```

You can also prepare and execute a statement of the same form dynamically. In either case, the statement works directly on the database to affect one or more rows.

The WHERE clause in the example uses the value of a host variable named **onum**. Following the operation, results are posted in SQLSTATE and in the **sqlca** structure, as usual. The third element of the SQLERRD array contains the count of rows deleted even if an error occurs. The value in SQLCODE shows the overall success of the operation. If the value is not negative, no errors occurred and the third element of SQLERRD is the count of all rows that satisfied the WHERE clause and were deleted.

Errors during direct deletions

When an error occurs, the statement ends prematurely. The values in SQLSTATE and in SQLCODE and the second element of SQLERRD explain its cause, and the count of rows reveals how many rows were deleted. For many errors, that count is zero because the errors prevented the database server from beginning the operation. For example, if the named table does not exist, or if a column tested in the WHERE clause is renamed, no deletions are attempted.

However, certain errors can be discovered after the operation begins and some rows are processed. The most common of these errors is a lock conflict. The database server must obtain an exclusive lock on a row before it can delete that row. Other programs might be using the rows from the table, preventing the database server from locking a row. Because the issue of locking affects all types of modifications, Chapter 10, "Programming for a multiuser environment," on page 10-1, discusses it.

Other, rarer types of errors can strike after deletions begin. For example, hardware errors that occur while the database is being updated.

Transaction logging

The best way to prepare for any kind of error during a modification is to use transaction logging. In the event of an error, you can tell the database server to put the database back the way it was. The following example is based on the example in the section "Direct deletions" on page 9-1, which is extended to use transactions:

```
EXEC SQL begin work;                /* start the transaction*/
EXEC SQL delete from items
     where order_num = :onum;
del_result = sqlca.sqlcode;         /* save two error */
del_isamno = sqlca.sqlerrd[1];      /* code numbers */
del_rowcnt = sqlca.sqlerrd[2];      /* and count of rows */
if (del_result < 0)                 /* problem found: */
   EXEC SQL rollback work;          /* put everything back */
else                                /* everything worked OK:*/
   EXEC SQL commit work;            /* finish transaction */
```

A key point in this example is that the program saves the important return values in the **sqlca** structure before it ends the transaction. Both the ROLLBACK WORK and COMMIT WORK statements, like other SQL statements, set return codes in the **sqlca** structure. However, if you want to report the codes that the error generated, you must save them before executing ROLLBACK WORK. The ROLLBACK WORK statement removes all of the pending transaction, including its error codes.

The advantage of using transactions is that the database is left in a known, predictable state no matter what goes wrong. No question remains about how much of the modification is completed; either all of it or none of it is completed.

In a database with logging, if a user does not start an explicit transaction, the database server initiates an internal transaction prior to execution of the statement and terminates the transaction after execution completes or fails. If the statement execution succeeds, the internal transaction is committed. If the statement fails, the internal transaction is rolled back.

Coordinated deletions

The usefulness of transaction logging is particularly clear when you must modify more than one table. For example, consider the problem of deleting an order from the demonstration database. In the simplest form of the problem, you must delete rows from two tables, **orders** and **items**, as the following example of IBM Informix ESQL/C shows:

```
EXEC SQL BEGIN WORK;
EXEC SQL DELETE FROM items
   WHERE order_num = :o_num;
```

```
if (SQLCODE >= 0)
{
   EXEC SQL DELETE FROM orders
      WHERE order_num == :o_num;
{
   if (SQLCODE >= 0)
      EXEC SQL COMMIT WORK;
{
   else
{
      printf("Error %d on DELETE", SQLCODE);
      EXEC SQL ROLLBACK WORK;
}
```

The logic of this program is much the same whether or not transactions are used. If they are not used, the person who sees the error message has a much more difficult set of decisions to make. Depending on when the error occurred, one of the following situations applies:

- No deletions were performed; all rows with this order number remain in the database.
- Some, but not all, item rows were deleted; an order record with only some items remains.
- All item rows were deleted, but the order row remains.
- All rows were deleted.

In the second and third cases, the database is corrupted to some extent; it contains partial information that can cause some queries to produce wrong answers. You must take careful action to restore consistency to the information. When transactions are used, all these uncertainties are prevented.

Delete with a cursor

You can also write a DELETE statement with a cursor to delete the row that was last fetched. Deleting rows in this manner lets you program deletions based on conditions that cannot be tested in a WHERE clause, as the following example shows. The following example applies only to databases that are not ANSI compliant because of the way that the beginning and ending of the transaction are set up.

Warning: The design of the Informix ESQL/C function in this example is unsafe. It depends on the current isolation level for correct operation. Isolation levels are discussed later in the chapter. For more information on isolation levels, see Chapter 10, “Programming for a multiuser environment,” on page 10-1. Even when the function works as intended, its effects depend on the physical order of rows in the table, which is not generally a good idea.

```
int delDupOrder()
{
   int ord_num;
   int dup_cnt, ret_code;

   EXEC SQL declare scan_ord cursor for
      select order_num, order_date
         into :ord_num, :ord_date
         from orders for update;
   EXEC SQL open scan_ord;
   if (sqlca.sqlcode != 0)
      return (sqlca.sqlcode);
   EXEC SQL begin work;
   for(;;)
   {
      EXEC SQL fetch next scan_ord;
      if (sqlca.sqlcode != 0) break;
      dup_cnt = 0; /* default in case of error */
      EXEC SQL select count(*) into dup_cnt from orders
         where order_num = :ord_num;
      if (dup_cnt > 1)
      {
         EXEC SQL delete from orders
            where current of scan_ord;
         if (sqlca.sqlcode != 0)
            break;
      }
   }
   ret_code = sqlca.sqlcode;
   if (ret_code == 100)            /* merely end of data */
      EXEC SQL commit work;
   else      /* error on fetch or on delete */
      EXEC SQL rollback work;
   return (ret_code);
}
```

The purpose of the function is to delete rows that contain duplicate order numbers. In fact, in the demonstration database, the **orders.order_num** column has a unique index, so duplicate rows cannot occur in it. However, a similar function can be written for another database; this one uses familiar column names.

The function declares **scan_ord**, a cursor to scan all rows in the **orders** table. It is declared with the FOR UPDATE clause, which states that the cursor can modify data. If the cursor opens properly, the function begins a transaction and then loops over rows of the table. For each row, it uses an embedded SELECT statement to determine how many rows of the table have the order number of the current row. (This step fails without the correct isolation level, as Chapter 10, "Programming for a multiuser environment," on page 10-1 describes.)

In the demonstration database, with its unique index on this table, the count returned to **dup_cnt** is always one. However, if it is greater, the function deletes the current row of the table, reducing the count of duplicates by one.

Cleanup functions of this sort are sometimes needed, but they generally need more sophisticated design. This function deletes all duplicate rows except the last one that the database server returns. That order has nothing to do with the content of the rows or their meanings. You can improve the function in the previous example by adding, perhaps, an ORDER BY clause to the cursor declaration. However, you cannot use ORDER BY and FOR UPDATE together. "An insert example" on page 9-7 presents a better approach.

The INSERT statement

You can embed the INSERT statement in programs. Its form and use in a program are the same as described in Chapter 6, "Modify data," on page 6-1 with the additional feature that you can use host variables in expressions, both in the VALUES and WHERE clauses. Moreover, in a program you have the additional ability to insert rows with a cursor.

An insert cursor

The DECLARE CURSOR statement has many variations. Most are used to create cursors for different kinds of scans over data, but one variation creates a special kind of cursor, called an *insert cursor*. You use an insert cursor with the PUT and FLUSH statements to efficiently insert rows into a table in bulk.

Declare an insert cursor

To create an insert cursor, declare a cursor to be for an INSERT statement instead of a SELECT statement. You cannot use such a cursor to fetch rows of data; you can use it only to insert them. The following 4GL code fragment shows the declaration of an insert cursor:

```
DEFINE the_company LIKE customer.company,
   the_fname LIKE customer.fname,
   the_lname LIKE customer.lname
DECLARE new_custs CURSOR FOR
   INSERT INTO customer (company, fname, lname)
      VALUES (the_company, the_fname, the_lname)
```

When you open an insert cursor, a buffer is created in memory to hold a block of rows. The buffer receives rows of data as the program produces them; then they are passed to the database server in a block when the buffer is full. The buffer reduces the amount of communication between the program and the database server, and it lets the database server insert the rows with less difficulty. As a result, the insertions go faster.

The buffer is always made large enough to hold at least two rows of inserted values. It is large enough to hold more than two rows when the rows are shorter than the minimum buffer size.

Insert with a cursor

The code in the previous example ("Declare an insert cursor") prepares an insert cursor for use. The continuation, as the following example shows, demonstrates how the cursor can be used. For simplicity, this example assumes that a function named **next_cust** returns either information about a new customer or null data to signal the end of input.

```
EXEC SQL BEGIN WORK;
EXEC SQL OPEN new_custs;
while(SQLCODE == 0)
{
   next_cust();
   if(the_company == NULL)
      break;
   EXEC SQL PUT new_custs;
}
if(SQLCODE == 0)                    /* if no problem with PUT */
{
   EXEC SQL FLUSH new_custs;        /* write any rows left */
   if(SQLCODE == 0)                 /* if no problem with FLUSH */
      EXEC SQL COMMIT WORK;         /* commit changes */
}
else
   EXEC SQL ROLLBACK WORK;          /* else undo changes */
```

The code in this example calls **next_cust** repeatedly. When it returns non-null data, the PUT statement sends the returned data to the row buffer. When the buffer fills, the rows it contains are automatically sent to the database server. The loop normally ends when **next_cust** has no more data to return. Then the FLUSH statement writes any rows that remain in the buffer, after which the transaction terminates.

Re-examine the information about the INSERT statement. See "The INSERT statement" on page 9-4. The statement by itself, not part of a cursor definition, inserts a single row into the **customer** table. In fact, the whole apparatus of the insert cursor can be dropped from the example code, and the INSERT statement can be written into the code where the PUT statement now stands. The difference is that an insert cursor causes a program to run somewhat faster.

Status codes after PUT and FLUSH

When a program executes a PUT statement, the program should test whether the row is placed in the buffer successfully. If the new row fits in the buffer, the only action of PUT is to copy the row to the buffer. No errors can occur in this case. However, if the row does not fit, the entire buffer load is passed to the database server for insertion, and an error can occur.

The values returned into the SQL Communications Area (SQLCA) give the program the information it needs to sort out each case. SQLCODE and SQLSTATE are set to zero after every PUT statement if no error occurs and to a negative error code if an error occurs.

The database server sets the third element of SQLERRD to the number of rows actually inserted into the table, as follows

- Zero, if the new row is merely moved to the buffer
- The number of rows that are in the buffer, if the buffer load is inserted without error
- The number of rows inserted before an error occurs, if one did occur

Read the code once again to see how SQLCODE is used (see the previous example). First, if the OPEN statement yields an error, the loop is not executed because the WHILE condition fails, the FLUSH operation is not performed, and the transaction rolls back. Second, if the PUT statement returns an error, the loop ends because of the WHILE condition, the FLUSH operation is not performed, and the transaction rolls back. This condition can occur only if the loop generates enough rows to fill the buffer at least once; otherwise, the PUT statement cannot generate an error.

The program might end the loop with rows still in the buffer, possibly without inserting any rows. At this point, the SQL status is zero, and the FLUSH operation occurs. If the FLUSH operation produces an error code, the transaction rolls back. Only when all inserts are successfully performed is the transaction committed.

Rows of constants

The insert cursor mechanism supports one special case where high performance is easy to obtain. In this case, all the values listed in the INSERT statement are constants: no expressions and no host variables are listed, just literal numbers and strings of characters. No matter how many times such an INSERT operation occurs, the rows it produces are identical. When the rows are identical, copying, buffering, and transmitting each identical row is pointless.

Instead, for this kind of INSERT operation, the PUT statement does nothing except to increment a counter. When a FLUSH operation is finally performed, a single copy of the row and the count of inserts are passed to the database server. The database server creates and inserts that many rows in one operation.

You do not usually insert a quantity of identical rows. You can insert identical rows when you first establish a database to populate a large table with null data.

An insert example

"Delete with a cursor" on page 9-3 contains an example of the DELETE statement whose purpose is to look for and delete duplicate rows of a table. A better way to perform this task is to select the desired rows instead of deleting the undesired ones. The code in the following IBM Informix ESQL/C example shows one way to do this task:

```
EXEC SQL BEGIN DECLARE SECTION;
   long last_ord = 1;
   struct {
      long int o_num;
      date     o_date;
      long     c_num;
      char     o_shipinst[40];
      char     o_backlog;
      char     o_po[10];
      date     o_shipdate;
      decimal  o_shipwt;
      decimal  o_shipchg;
      date     o_paiddate;
      } ord_row;
EXEC SQL END DECLARE SECTION;

EXEC SQL BEGIN WORK;
EXEC SQL INSERT INTO new_orders
   SELECT * FROM orders main
      WHERE 1 = (SELECT COUNT(*) FROM orders minor
         WHERE main.order_num = minor.order_num);
EXEC SQL COMMIT WORK;

EXEC SQL DECLARE dup_row CURSOR FOR
   SELECT * FROM orders main INTO :ord_row
      WHERE 1 < (SELECT COUNT(*) FROM orders minor
         WHERE main.order_num = minor.order_num)
      ORDER BY order_date;
EXEC SQL DECLARE ins_row CURSOR FOR
   INSERT INTO new_orders VALUES (:ord_row);

EXEC SQL BEGIN WORK;
EXEC SQL OPEN ins_row;
EXEC SQL OPEN dup_row;
while(SQLCODE == 0)
{
   EXEC SQL FETCH dup_row;
   if(SQLCODE == 0)
   {
      if(ord_row.o_num != last_ord)
         EXEC SQL PUT ins_row;
      last_ord = ord_row.o_num
      continue;
   }
   break;
}
if(SQLCODE != 0 && SQLCODE != 100)
   EXEC SQL ROLLBACK WORK;
else
   EXEC SQL COMMIT WORK;
EXEC SQL CLOSE ins_row;
EXEC SQL CLOSE dup_row;
```

This example begins with an ordinary INSERT statement, which finds all the nonduplicated rows of the table and inserts them into another table, presumably created before the program started. That action leaves only the duplicate rows. (In the demonstration database, the **orders** table has a unique index and cannot have duplicate rows. Assume that this example deals with some other database.)

The code in the previous example then declares two cursors. The first, called **dup_row**, returns the duplicate rows in the table. Because **dup_row** is for input only, it can use the ORDER BY clause to impose some order on the duplicates other than the physical record order used in the example on page "Delete with a cursor" on page 9-3. In this example, the duplicate rows are ordered by their dates (the oldest one remains), but you can use any other order based on the data.

The second cursor, **ins_row**, is an insert cursor. This cursor takes advantage of the ability to use a C structure, **ord_row**, to supply values for all columns in the row.

The remainder of the code examines the rows that are returned through **dup_row**. It inserts the first one from each group of duplicates into the new table and disregards the rest.

For the sake of brevity, the preceding example uses the simplest kind of error handling. If an error occurs before all rows have been processed, the sample code rolls back the active transaction.

How many rows were affected?

When your program uses a cursor to select rows, it can test SQLCODE for `100` (or SQLSTATE for `02000`), the end-of-data return code. This code is set to indicate that no rows, or no more rows, satisfy the query conditions. For databases that are not ANSI compliant, the end-of-data return code is set in SQLCODE or SQLSTATE only following SELECT statements; it is not used following DELETE, INSERT, or UPDATE statements. For ANSI-compliant databases, SQLCODE is also set to `100` for updates, deletes, and inserts that affect zero rows.

A query that finds no data is not a success. However, an UPDATE or DELETE statement that happens to update or delete no rows is still considered a success. It updated or deleted the set of rows that its WHERE clause said it should; however, the set was empty.

In the same way, the INSERT statement does not set the end-of-data return code even when the source of the inserted rows is a SELECT statement, and the SELECT statement selected no rows. The INSERT statement is a success because it inserted as many rows as it was asked to (that is, zero).

To find out how many rows are inserted, updated, or deleted, a program can test the third element of SQLERRD. The count of rows is there, regardless of the value (zero or negative) in SQLCODE.

The UPDATE statement

You can embed the UPDATE statement in a program in any of the forms that Chapter 6, "Modify data," on page 6-1 describes with the additional feature that you can name host variables in expressions, both in the SET and WHERE clauses. Moreover, a program can update the row that a cursor addresses.

An update cursor

An *update cursor* permits you to delete or update the current row; that is, the most recently fetched row. The following example in IBM Informix ESQL/C shows the declaration of an update cursor:

```
EXEC SQL
   DECLARE names CURSOR FOR
      SELECT fname, lname, company
      FROM customer
   FOR UPDATE;
```

The program that uses this cursor can fetch rows in the usual way.

```
EXEC SQL
   FETCH names INTO :FNAME, :LNAME, :COMPANY;
```

If the program then decides that the row needs to be changed, it can do so.

```
if (strcmp(COMPANY, "SONY") ==0)
   {
   EXEC SQL
      UPDATE customer
         SET fname = 'Midori', lname = 'Tokugawa'
         WHERE CURRENT OF names;
   }
```

The words `CURRENT OF names` take the place of the usual test expressions in the WHERE clause. In other respects, the UPDATE statement is the same as usual, even including the specification of the table name, which is implicit in the cursor name but still required.

The purpose of the keyword UPDATE

The purpose of the keyword UPDATE in a cursor is to let the database server know that the program can update (or delete) any row that it fetches. The database server places a more demanding lock on rows that are fetched through an update cursor and a less demanding lock when it fetches a row for a cursor that is not declared with that keyword. This action results in better performance for ordinary cursors and a higher level of concurrent use in a multiprocessing system. (Chapter 10, “Programming for a multiuser environment,” on page 10-1 discusses levels of locks and concurrent use.)

Update specific columns

The following example has updated specific columns of the preceding example of an update cursor:

```
EXEC SQL
   DECLARE names CURSOR FOR
      SELECT fname, lname, company, phone
         INTO  :FNAME,:LNAME,:COMPANY,:PHONE FROM customer
   FOR UPDATE OF fname, lname
END-EXEC.
```

Only the **fname** and **lname** columns can be updated through this cursor. A statement such as the following one is rejected as an error:

```
EXEC SQL
   UPDATE customer
      SET company = 'Siemens'
      WHERE CURRENT OF names
END-EXEC.
```

If the program attempts such an update, an error code is returned and no update occurs. An attempt to delete with WHERE CURRENT OF is also rejected, because deletion affects all columns.

UPDATE keyword not always needed

The ANSI standard for SQL does not provide for the FOR UPDATE clause in a cursor definition. When a program uses an ANSI-compliant database, it can update or delete with any cursor.

Cleanup a table

A final, hypothetical example of how to use an update cursor presents a problem that should never arise with an established database but could arise in the initial design phases of an application.

In the example, a large table named **target** is created and populated. A character column, **dactyl**, inadvertently acquires some null values. These rows should be deleted. Furthermore, a new column, **serials**, is added to the table with the ALTER TABLE statement. This column is to have unique integer values installed. The following example shows the IBM Informix ESQL/C code you use to accomplish these tasks:

```
EXEC SQL BEGIN DECLARE SECTION;
char dcol[80];
short dcolint;
int sequence;
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE target_row CURSOR FOR
   SELECT datcol
      INTO :dcol:dcolint
      FROM target
   FOR UPDATE OF serials;
EXEC SQL BEGIN WORK;
EXEC SQL OPEN target_row;
if (sqlca.sqlcode == 0) EXEC SQL FETCH NEXT target_row;
for(sequence = 1; sqlca.sqlcode == 0; ++sequence)
{
   if (dcolint < 0) /* null datcol */
      EXEC SQL DELETE WHERE CURRENT OF target_row;
   else
      EXEC SQL UPDATE target SET serials = :sequence
         WHERE CURRENT OF target_row;
}
if (sqlca.sqlcode >= 0)
   EXEC SQL COMMIT WORK;
else EXEC SQL ROLLBACK WORK;
```

Summary

A program can execute the INSERT, DELETE, and UPDATE statements, as Chapter 6, “Modify data,” on page 6-1 describes. A program can also scan through a table with a cursor, updating or deleting selected rows. It can also use a cursor to insert rows, with the benefit that the rows are buffered and sent to the database server in blocks.

In all these activities, you must make sure that the program detects errors and returns the database to a known state when an error occurs. The most important tool for doing this is transaction logging. Without transaction logging, it is more difficult to write programs that can recover from errors.

Chapter 10. Programming for a multiuser environment

This section describes several programming issues you need to be aware of when you work in a multiuser environment.

If your database is contained in a single-user workstation and does not access data from another computer, your programs can modify data freely. In all other cases, you must allow for the possibility that, while your program is modifying data, another program is reading or modifying the same data. This situation is described as *concurrency*: two or more independent uses of the same data at the same time. This section addresses concurrency, locking, and isolation levels.

This section also describes the statement cache feature, which can reduce per-session memory allocation and speed up query processing. The statement cache stores statements that can then be shared among different user sessions that use identical SQL statements.

Concurrency and performance

Concurrency is crucial to good performance in a multiprogramming system. When access to the data is *serialized* so that only one program at a time can use it, processing slows dramatically.

Locks and integrity

Unless controls are placed on the use of data, concurrency can lead to a variety of negative effects. Programs can read obsolete data, or modifications can be lost even though they were apparently completed.

To prevent errors of this kind, the database server imposes a system of *locks*. A lock is a claim, or reservation, that a program can place on a piece of data. The database server guarantees that, as long as the data is locked, no other program can modify it. When another program requests the data, the database server either makes the program wait or turns it back with an error.

Locks and performance

Because a lock serializes access to one piece of data, it reduces concurrency; any other programs that want access to that data must wait. The database server can place a lock on a single row, a disk page, a whole table, or an entire database. (A disk page might hold multiple rows and a row might require multiple disk pages.) The more locks it places and the larger the objects it locks, the more concurrency is reduced. The fewer the locks and the smaller the locked objects, the greater concurrency and performance can be.

The following sections discuss how you can achieve the following goals with your program:

- Place all the locks necessary to ensure data integrity.
- Lock the fewest, smallest pieces of data possible consistent with the preceding goal.

Concurrency issues

To understand the hazards of concurrency, you must think in terms of multiple programs, each executing at its own speed. Suppose that your program is fetching rows through the following cursor:

```
EXEC SQL DECLARE sto_curse CURSOR FOR
   SELECT * FROM stock
      WHERE manu_code = 'ANZ';
```

The transfer of each row from the database server to the program takes time. During and between transfers, other programs can perform other database operations. At about the same time that your program fetches the rows produced by that query, another user's program might execute the following update:

```
EXEC SQL UPDATE stock
   SET unit_price = 1.15 * unit_price
      WHERE manu_code = 'ANZ';
```

In other words, both programs are reading through the same table, one fetching certain rows and the other changing the same rows. The following scenarios are possible:

1. The other program finishes its update before your program fetches its first row.

   Your program shows you only updated rows.
2. Your program fetches every row before the other program has a chance to update it.

   Your program shows you only original rows.
3. After your program fetches some original rows, the other program catches up and goes on to update some rows that your program has yet to read; then it executes the COMMIT WORK statement.

   Your program might return a mixture of original rows and updated rows.
4. Same as number 3, except that after updating the table, the other program issues a ROLLBACK WORK statement.

   Your program can show you a mixture of original rows and updated rows that no longer exist in the database.

The first two possibilities are harmless. In possibility number 1, the update is complete before your query begins. It makes no difference whether the update finished a microsecond ago or a week ago.

In possibility number 2, your query is, in effect, complete before the update begins. The other program might have been working just one row behind yours, or it might not start until tomorrow night; it does not matter.

The last two possibilities, however, can be important to the design of some applications. In possibility number 3, the query returns a mix of updated and original data. That result can be detrimental in some applications. In others, such as one that is taking an average of all prices, it might not matter at all.

Possibility number 4 can be disastrous if a program returns some rows of data that, because their transaction was cancelled, can no longer be found in the table.

Another concern arises when your program uses a cursor to update or delete the last-fetched row. Erroneous results occur with the following sequence of events:

- Your program fetches the row.
- Another program updates or deletes the row.

- Your program updates or deletes WHERE CURRENT OF *cursor_name*.

To control concurrent events such as these, use the locking and *isolation level* features of the database server.

How locks work

IBM Informix database servers support a complex, flexible set of locking features that the topics in this section describe.

Kinds of locks

The following table shows the types of locks that IBM Informix database servers support for different situations.

Lock type	Use
Shared	A shared lock reserves its object for reading only. It prevents the object from changing while the lock remains. More than one program can place a shared lock on the same object. More than one object can read the record while it is locked in shared mode.
Exclusive	An exclusive lock reserves its object for the use of a single program. This lock is used when the program intends to change the object. You cannot place an exclusive lock where any other kind of lock exists. After you place an exclusive lock, you cannot place another lock on the same object.
Promotable (or Update)	A promotable (or update) lock establishes the intent to update. You can only place it where no other promotable or exclusive lock exists. You can place promotable locks on records that already have shared locks. When the program is about to change the locked object, you can promote the promotable lock to an exclusive lock, but only if no other locks, including shared locks, are on the record at the time the lock would change from promotable to exclusive. If a shared lock was on the record when the promotable lock was set, you must drop the shared lock before the promotable lock can be promoted to an exclusive lock.

Lock scope

You can apply locks to entire databases, entire tables, disk pages, single rows, or index-key values. The size of the object that is being locked is referred to as the *scope* of the lock (also called the *lock granularity*). In general, the larger the scope of a lock, the more concurrency is reduced, but the simpler programming becomes.

Database locks

You can lock an entire database. The act of opening a database places a shared lock on the name of the database. A database is opened with the CONNECT, DATABASE, or CREATE DATABASE statements. As long as a program has a database open, the shared lock on the name prevents any other program from dropping the database or putting an exclusive lock on it.

The following statement shows how you might lock an entire database exclusively:

```
DATABASE database_one EXCLUSIVE
```

This statement succeeds if no other program has opened that database. After the lock is placed, no other program can open the database, even for reading, because its attempt to place a shared lock on the database name fails.

A database lock is released only when the database closes. That action can be performed explicitly with the DISCONNECT or CLOSE DATABASE statements or implicitly by executing another DATABASE statement.

Because locking a database reduces concurrency in that database to zero, it makes programming simple; concurrent effects cannot happen. However, you should lock a database only when no other programs need access. Database locking is often used before applying massive changes to data during off-peak hours.

Table locks

You can lock entire tables. In some cases, the database server performs this action automatically. You can also use the LOCK TABLE statement to lock an entire table explicitly.

The LOCK TABLE statement or the database server can place the following types of table locks:

Shared lock
No users can write to the table. In shared mode, the database server places one shared lock on the table, which informs other users that no updates can be performed. In addition, the database server adds locks for every row updated, deleted, or inserted.

Exclusive lock
No other users can read from or write to the table. In exclusive mode, the database server places only one exclusive lock on the table, no matter how many rows it updates. An exclusive table lock prevents any concurrent use of the table and, therefore, can have a serious effect on performance if many other programs are contending for the use of the table. However, when you need to update most of the rows in a table, place an exclusive lock on the table.

Lock a table with the LOCK TABLE statement: A transaction tells the database server to use table-level locking for a table with the LOCK TABLE statement. The following example shows how to place an exclusive lock on a table:

```
LOCK TABLE tab1 IN EXCLUSIVE MODE
```

The following example shows how to place a shared lock on a table:

```
LOCK TABLE tab2 IN SHARE MODE
```

Tip: You can set the isolation level for your database server to achieve the same degree of protection as the shared table lock while providing greater concurrency.

When the database server automatically locks a table: The database server always locks an entire table while it performs operations for any of the following statements:

- ALTER FRAGMENT
- ALTER INDEX
- ALTER TABLE
- CREATE INDEX
- DROP INDEX
- RENAME COLUMN
- RENAME TABLE

Completion of the statement (or end of the transaction) releases the lock. An entire table can also be locked automatically during certain queries.

Avoid table locking with the ONLINE keyword:
You can avoid table locking when you CREATE or DROP an index using the ONLINE keyword. While the index is being created or dropped online, no DDL operations on the table are supported, but operations that were concurrent when the CREATE INDEX or DROP INDEX statement was issued can be completed. The specified index is not created or dropped until no other processes are concurrently accessing the table. Then locks are held briefly to write the system catalog data associated with the index. This increases the availability of the system, since the table is still readable by ongoing and new sessions. The following statement shows how to use the ONLINE keyword to avoid automatic table locking with a CREATE INDEX statement:

```
CREATE INDEX idx_1 ON customer (lname) ONLINE;
```

Row and key locks

You can lock one row of a table. A program can lock one row or a selection of rows while other programs continue to work on other rows of the same table.

Row and key locking are not the default behaviors. You must specify row-level locking when you create the table. The following example creates a table with row-level locking:

```
CREATE TABLE tab1
(
col1...
) LOCK MODE ROW;
```

If you specify a LOCK MODE clause when you create a table, you can later change the lock mode with the ALTER TABLE statement. The following statement changes the lock mode on the reservations table to page-level locking:

```
ALTER TABLE tab1 LOCK MODE PAGE
```

In certain cases, the database server has to lock a row that does not exist. To do this, the database server places a lock on an index-key value. Key locks are used identically to row locks. When the table uses row locking, key locks are implemented as locks on imaginary rows. When the table uses page locking, a key lock is placed on the index page that contains the key or that would contain the key if it existed.

When you insert, update, or delete a key (performed automatically when you insert, update, or delete a row), the database server creates a lock on the key in the index.

Row and key locks generally provide the best performance overall when you update a relatively small number of rows because they increase concurrency. However, the database server incurs some overhead in obtaining a lock.

When one or more rows in a table are locked by an exclusive lock, the effect on other users partly depends on their transaction isolation level. Other users whose isolation levels is not Dirty Read might encounter transactions that fail because the exclusive lock was not released within a specified time limit.

For Committed Read or Dirty Read isolation level operations that attempt to access tables on which a concurrent session has set exclusive row-level locks, the risk of locking conflicts can be reduced by enabling transactions to read the most recently committed version of the data in the locked rows, rather than waiting for the transaction that set the lock to be committed or rolled back. Enabling access to the last committed version of exclusively locked rows can be accomplished in several ways:

- For an individual session, issue this SQL statement
  ```
  SET ISOLATION TO COMMITTED READ LAST COMMITTED;
  ```
- For all sessions using the Committed Read or Read Committed isolation level, the DBA can set the USELASTCOMMITTED configuration parameter to `'ALL'` or to `'COMMITTED READ'`.
- For an individual session using the Committed Read or Read Committed isolation level, any user can issue the SET ENVIRONMENT USELASTCOMMITTED statement with `'ALL'` or `'COMMITTED READ'` as the value of this session environment option.
- For all sessions using Dirty Read or Read Uncommitted isolation levels, the DBA can set the USELASTCOMMITTED configuration parameter to `'ALL'` or to `'DIRTY READ'`.
- For an individual session using the Dirty Read or Read Uncommitted isolation levels, any user can issue the SET ENVIRONMENT USELASTCOMMITTED statement with `'ALL'` or `'DIRTY READ'` as the value of this session environment option.

This LAST COMMITTED feature is useful only when row-level locking is in effect, rather than when another session holds an exclusive lock on the entire table. This feature is disabled for any table on which the LOCK TABLE statement applies a table-level lock. See the description of the SET ENVIRONMENT statement in the *IBM Informix Guide to SQL: Syntax* and the description of the USELASTCOMMITTED configuration parameter in*IBM Informix Administrator's Reference* for more information about this feature for concurrent access to tables in which some rows are locked by exclusive locks, and for restrictions on the kinds of tables that can support this feature.

Page locks

The database server stores data in units called *disk pages*. A disk page contains one or more rows. In some cases, it is better to lock a disk page than to lock individual rows on it. For example, with operations that require changing a large number of rows, you might choose page-level locking because row-level locking (one lock per row) might not be cost effective.

If you do not specify a LOCK MODE clause when you create a table, the default behavior for the database server is page-level locking. With page locking, the database server locks the entire page that contains the row. If you update several rows that are stored on the same page, the database server uses only one lock for the page.

Set the row or page lock mode for all CREATE TABLE statements: IBM Informix allows you to set the lock mode to page-level locking or row-level locking for all newly created tables for a single user (per session) or for multiple users (per server). You no longer need to specify the lock mode every time that you create a new table with the CREATE TABLE statement.

If you want every new table created within your session to be created with a particular lock mode, you have to set the **IFX_DEF_TABLE_LOCKMODE** environment variable. For example, for every new table created within your session to be created with lock mode row, set **IFX_DEF_TABLE_LOCKMODE** to ROW. To override this behavior, use the CREATE TABLE or ALTER TABLE statements and redefine the LOCK MODE clause.

Single-user lock mode: Set the single-user lock mode if all of the new tables that you create in your session require the same lock mode. Set the single-user lock mode with the **IFX_DEF_TABLE_LOCKMODE** environment variable. For example, for every new table created within your session to be created with row-level locking, set **IFX_DEF_TABLE_LOCKMODE** to ROW. To override this behavior, use the CREATE TABLE or ALTER TABLE statements and redefine the LOCK MODE clause. For more information on setting environment variables, see the *IBM Informix Guide to SQL: Reference*.

Multiple-user lock mode: Database administrators can use the multiple-user lock mode to create greater concurrency by designating the lock mode for all users on the same server. All tables that any user creates on that server will then have the same lock mode. To enable multiple-user lock mode, set the **IFX_DEF_TABLE_LOCKMODE** environment variable before starting the database server or set the DEF_TABLES_LOCKMODE configuration parameter.

Rules of precedence:
Locking mode for CREATE TABLE or ALTER TABLE has the following rules of precedence, listed in order of highest precedence to lowest:
1. CREATE TABLE or ALTER TABLE SQL statements that use the LOCK MODE clause
2. Single-user environment variable setting
3. Multi-user environment variable setting in the server environment
4. Configuration parameters in the configuration file
5. Default behavior (page-level locking)

Coarse index locks

When you change the lock mode of an index from normal to coarse lock mode, index-level locks are acquired on the index instead of item-level or page-level locks, which are the normal locks. This mode reduces the number of lock calls on an index.

Use the coarse lock mode when you know the index is not going to change; that is, when read-only operations are performed on the index.

Use the normal lock mode to have the database server place item-level or page-level locks on the index as necessary. Use this mode when the index gets updated frequently.

When the database server executes the command to change the lock mode to coarse, it acquires an exclusive lock on the table for the duration of the command. Any transactions that are currently using a lock of finer granularity must complete before the database server switches to the coarse lock mode.

Smart-large-object locks

Locks on a CLOB or BLOB column are separate from the lock on the row. Smart large objects are locked only when they are accessed. When you lock a table that contains a CLOB or BLOB column, no smart large objects are locked. If accessed for writing, the smart large object is locked in update mode, and the lock is promoted to exclusive when the actual write occurs. If accessed for reading, the smart large object is locked in shared mode. The database server recognizes the transaction isolation mode, so if Repeatable Read isolation level is set, the database server does not release smart-large-object read locks before end of transaction.

When the database server retrieves a row and updates a smart large object that the row points to, only the smart large object is exclusively locked during the time it is being updated.

Byte-range locks:
You can lock a range of bytes for a smart large object. Byte-range locks allow a transaction to selectively lock only those bytes that are accessed so that writers and readers simultaneously can access different byte ranges in the same smart large object.

For information about how to use byte-range locks, see your *IBM Informix Performance Guide*.

Byte-range locks support deadlock detection. For information about deadlock detection, see "Handle a deadlock" on page 10-17.

Duration of a lock

The program controls the duration of a database lock. A database lock is released when the database closes.

Depending on whether the database uses transactions, table lock durations vary. If the database does not use transactions (that is, if no transaction log exists and you do not use a COMMIT WORK statement), a table lock remains until it is removed by the execution of the UNLOCK TABLE statement.

The duration of table, row, and index locks depends on what SQL statements you use and on whether transactions are in use.

When you use transactions, the end of a transaction releases all table, row, page, and index locks. When a transaction ends, all locks are released.

Locks while modifying

When the database server fetches a row through an update cursor, it places a promotable lock on the fetched row. If this action succeeds, the database server knows that no other program can alter that row. Because a promotable lock is not exclusive, other programs can continue to read the row. A promotable lock can improve performance because the program that fetched the row can take some time before it issues the UPDATE or DELETE statement, or it can simply fetch the next row. When it is time to modify a row, the database server obtains an exclusive lock on the row. If it already has a promotable lock, it changes that lock to exclusive status.

The duration of an exclusive row lock depends on whether transactions are in use. If they are not in use, the lock is released as soon as the modified row is written to disk. When transactions are in use, all such locks are held until the end of the transaction. This action prevents other programs from using rows that might be rolled back to their original state.

When transactions are in use, a key lock is used whenever a row is deleted. Using a key lock prevents the following error from occurring:
- Program A deletes a row.
- Program B inserts a row that has the same key.
- Program A rolls back its transaction, forcing the database server to restore its deleted row.

  What is to be done with the row inserted by Program B?

By locking the index, the database server prevents a second program from inserting a row until the first program commits its transaction.

The locks placed while the database server reads various rows are controlled by the current isolation level, as discussed in the next section.

Lock with the SELECT statement

The type and duration of locks that the database server places depend on the isolation set in the application and whether the SELECT statement is within an update cursor.

This section describes the different isolation levels and update cursors.

Set the isolation level

The *isolation level* is the degree to which your program is isolated from the concurrent actions of other programs. The database server offers a choice of isolation levels that reflect a different set of rules for how a program uses locks when it reads data.

To set the isolation level, use either the SET ISOLATION or SET TRANSACTION statement. The SET TRANSACTION statement also lets you set access modes. For more information about access modes, see "Control data modification with access modes" on page 10-15.

SET TRANSACTION versus SET ISOLATION

The SET TRANSACTION statement complies with ANSI SQL-92. This statement is similar to the IBM Informix SET ISOLATION statement; however, the SET ISOLATION statement is not ANSI compliant and does not provide access modes.

The following table shows the relationships between the isolation levels that you set with the SET TRANSACTION and SET ISOLATION statements.

SET TRANSACTION correlates with	SET ISOLATION
Read Uncommitted	Dirty Read
Read Committed	Committed Read
Not Supported	Cursor Stability
(ANSI) Repeatable Read	(IBM Informix) Repeatable Read
Serializable	(IBM Informix) Repeatable Read

The major difference between the SET TRANSACTION and SET ISOLATION statements is the behavior of the isolation levels within transactions. The SET TRANSACTION statement can be issued only once for a transaction. Any cursors opened during that transaction are guaranteed to have that isolation level (or access mode if you are defining an access mode). With the SET ISOLATION statement, after a transaction is started, you can change the isolation level more than once within the transaction. The following examples illustrate the difference between the use of SET ISOLATION and the use of SET TRANSACTION.

SET ISOLATION:

```
EXEC SQL BEGIN WORK;
EXEC SQL SET ISOLATION TO DIRTY READ;
EXEC SQL SELECT ... ;
EXEC SQL SET ISOLATION TO REPEATABLE READ;
EXEC SQL INSERT ... ;
EXEC SQL COMMIT WORK;
   -- Executes without error
```

SET TRANSACTION:

```
EXEC SQL BEGIN WORK;
EXEC SQL SET TRANSACTION ISOLATION LEVEL TO SERIALIZABLE;
EXEC SQL SELECT ... ;
EXEC SQL SET TRANSACTION ISOLATION LEVEL TO READ COMMITTED;
Error -876: Cannot issue SET TRANSACTION once a transaction has started.
```

ANSI Read Uncommitted and IBM Informix Dirty Read isolation

The simplest isolation level, ANSI Read Uncommitted and IBM Informix Dirty Read, amounts to virtually no isolation. When a program fetches a row, it places no locks, and it respects none; it simply copies rows from the database without regard to what other programs are doing.

A program always receives complete rows of data. Even under ANSI Read Uncommitted or IBM Informix Dirty Read isolation, a program never sees a row in which some columns are updated and some are not. However, a program that uses ANSI Read Uncommitted or IBM Informix Dirty Read isolation sometimes reads updated rows before the updating program ends its transaction. If the updating program later rolls back its transaction, the reading program processes data that never really existed (possibility number 4 on page 10-2 in the list of concurrency issues).

ANSI Read Uncommitted or IBM Informix Dirty Read is the most efficient isolation level. The reading program never waits and never makes another program wait. It is the preferred level in any of the following cases:

- All tables are static; that is, concurrent programs only read and never modify data.
- The table is held in an exclusive lock.
- Only one program is using the table.

ANSI Read Committed and IBM Informix Committed Read isolation

When a program requests the ANSI Read Committed or IBM Informix Committed Read isolation level, the database server guarantees that it never returns a row that is not committed to the database. This action prevents reading data that is not committed and that is subsequently rolled back.

ANSI Read Committed or IBM Informix Committed Read is implemented simply. Before it fetches a row, the database server tests to determine whether an updating process placed a lock on the row; if not, it returns the row. Because rows that have been updated (but that are not yet committed) have locks on them, this test ensures that the program does not read uncommitted data.

ANSI Read Committed or IBM Informix Committed Read does not actually place a lock on the fetched row, so this isolation level is almost as efficient as ANSI Read Uncommitted or IBM Informix Dirty Read. This isolation level is appropriate to use when each row of data is processed as an independent unit, without reference to other rows in the same or other tables.

Locking conflicts can occur in ANSI Read Committed or IBM Informix Committed Read sessions, however, if the attempt to place the test lock is not successful because a concurrent session holds a shared lock on the row. To avoid waiting for concurrent transactions to release shared locks (by committing or rolling back), Informix supports the Last Committed option to the Committed Read isolation level. When this Last Committed option is in effect, a shared lock by another session causes the query to return the most recently committed version of the row.

The Last Committed feature can also be activated by setting the USELASTCOMMITTED configuration parameter to `'COMMITTED READ'` or to `'ALL'`, or by setting USELASTCOMMITTED session environment option in the SET ENVIRONMENT statement in the **sysdbopen( )** procedure when the user connects to the database. For more information about the Last Committed option to the ANSI Read Committed or IBM Informix Committed Read isolation levels, see the description of the SET ISOLATION statement in the *IBM Informix Guide to SQL: Syntax*. For information about the USELASTCOMMITTED configuration parameter, see the *IBM Informix Administrator's Reference*.

IBM Informix Cursor Stability isolation

The next level, Cursor Stability, is available only with the IBM Informix SQL statement SET ISOLATION.

When Cursor Stability is in effect, IBM Informix places a lock on the latest row fetched. It places a shared lock for an ordinary cursor or a promotable lock for an update cursor. Only one row is locked at a time; that is, each time a row is fetched, the lock on the previous row is released (unless that row is updated, in which case the lock holds until the end of the transaction). Because Cursor Stability locks only one row at a time, it restricts concurrency less than a table lock or database lock.

Cursor Stability ensures that a row does not change while the program examines it. Such row stability is important when the program updates some other table based on the data it reads from the row. Because of Cursor Stability, the program is assured that the update is based on current information. It prevents the use of *stale data*.

The following example illustrates effective use of Cursor Stability isolation. In terms of the demonstration database, Program A wants to insert a new stock item for manufacturer Hero (HRO). Concurrently, Program B wants to delete manufacturer HRO and all stock associated with it. The following sequence of events can occur:

1. Program A, operating under Cursor Stability, fetches the HRO row from the **manufact** table to learn the manufacturer code. This action places a shared lock on the row.
2. Program B issues a DELETE statement for that row. Because of the lock, the database server makes the program wait.

3. Program A inserts a new row in the **stock** table using the manufacturer code it obtained from the **manufact** table.
4. Program A closes its cursor on the **manufact** table or reads a different row of it, releasing its lock.
5. Program B, released from its wait, completes the deletion of the row and goes on to delete the rows of **stock** that use manufacturer code HRO, including the row that Program A just inserted.

If Program A used a lesser level of isolation, the following sequence could occur:

1. Program A reads the HRO row of the **manufact** table to learn the manufacturer code. No lock is placed.
2. Program B issues a DELETE statement for that row. It succeeds.
3. Program B deletes all rows of **stock** that use manufacturer code HRO.
4. Program B ends.
5. Program A, not aware that its copy of the HRO row is now invalid, inserts a new row of **stock** using the manufacturer code HRO.
6. Program A ends.

At the end, a row occurs in **stock** that has no matching manufacturer code in **manufact**. Furthermore, Program B apparently has a bug; it did not delete the rows that it was supposed to delete. Use of the Cursor Stability isolation level prevents these effects.

The preceding scenario could be rearranged to fail even with Cursor Stability. All that is required is for Program B to operate on tables in the reverse sequence to Program A. If Program B deletes from **stock** before it removes the row of **manufact**, no degree of isolation can prevent an error. Whenever this kind of error is possible, all programs that are involved must use the same sequence of access.

ANSI Serializable, ANSI Repeatable Read, and IBM Informix Repeatable Read isolation

Where ANSI Serializable or ANSI Repeatable Read are required, a single isolation level is provided, called IBM Informix Repeatable Read. This is logically equivalent to ANSI Serializable. Because ANSI Serializable is more restrictive than ANSI Repeatable Read, IBM Informix Repeatable Read can be used when ANSI Repeatable Read is desired (although IBM Informix Repeatable Read is more restrictive than is necessary in such contexts).

The Repeatable Read isolation level asks the database server to put a lock on every row the program examines and fetches. The locks that are placed are shareable for an ordinary cursor and promotable for an update cursor. The locks are placed individually as each row is examined. They are not released until the cursor closes or a transaction ends.

Repeatable Read allows a program that uses a scroll cursor to read selected rows more than once and to be sure that they are not modified or deleted between readings. (Chapter 8, “SQL programming,” on page 8-1 describes scroll cursors.) No lower isolation level guarantees that rows still exist and are unchanged the second time they are read.

Repeatable Read isolation places the largest number of locks and holds them the longest. Therefore, it is the level that reduces concurrency the most. If your program uses this level of isolation, think carefully about how many locks it places, how long they are held, and what the effect can be on other programs.

In addition to the effect on concurrency, the large number of locks can be a problem. The database server records the number of locks by each program in a lock table. If the maximum number of locks is exceeded, the lock table fills up, and the database server cannot place a lock. An error code is returned. The person who administers an Informix database server system can monitor the lock table and tell you when it is heavily used.

The isolation level in an ANSI-compliant database is set to Serializable by default. The Serializable isolation level is required to ensure that operations behave according to the ANSI standard for SQL.

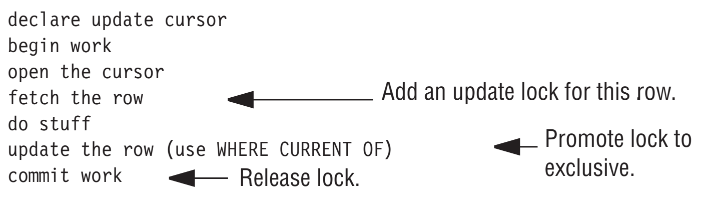
Update cursors

An update cursor is a special kind of cursor that applications can use when the row might potentially be updated. To use an update cursor, execute SELECT FOR UPDATE in your application. Update cursors use *promotable locks*; that is, the database server places an update lock (meaning other users can still view the row) when the application fetches the row, but the lock is changed to an exclusive lock when the application updates the row using an update cursor and UPDATE...WHERE CURRENT OF.

The advantage of using an update cursor is that you can view the row with the confidence that other users cannot change it or view it with an update cursor while you are viewing it and before you update it.

Tip: In an ANSI-compliant database, update cursors are unnecessary because any select cursor behaves the same as an update cursor.

The pseudocode in the following figure shows when the database server places and releases locks with a cursor.



```
declare update cursor
begin work
open the cursor
fetch the row
do stuff
update the row (use WHERE CURRENT OF)
commit work
```

Figure 10-1. Locks Placed for Update

Retain update locks

If a user has the isolation level set lower than Repeatable Read, the database server releases update locks placed on rows as soon as the next row is fetched from a cursor. With this feature, you can use the RETAIN UPDATE LOCKS clause to retain an update lock until the end of a transaction when you set any of the following isolation levels:

- Dirty Read
- Committed Read
- Cursor Stability

This feature lets you avoid the overhead of Repeatable Read isolation level or workarounds such as dummy updates on a row. When the RETAIN UPDATE LOCKS feature is turned on and an update lock is implicitly placed on a row during a fetch of a SELECT...FOR UPDATE statement, the update lock is not released until the end of the transaction. With the RETAIN UPDATE LOCKS feature, only update locks are held until end of transaction, whereas the Repeatable Read isolation level holds both update locks and shared locks until end of transaction.

The following example shows how to use the RETAIN UPDATE LOCKS clause when you set the isolation level to Committed Read.

```
SET ISOLATION TO COMMITTED READ RETAIN UPDATE LOCKS
```

To turn off the RETAIN UPDATE LOCKS feature, set the isolation level without the RETAIN UPDATE LOCKS clause. When you turn off the feature, update locks are not released directly. However, from this point on, a subsequent fetch releases the update lock of the immediately preceding fetch but not of earlier fetch operations. A close cursor releases the update lock on the current row.

For more information about how to use the RETAIN UPDATE LOCKS feature when you specify an isolation level, see the *IBM Informix Guide to SQL: Syntax*.

Exclusive locks that occur with some SQL statements

When you execute an INSERT, UPDATE, or DELETE statement, the database server uses *exclusive locks*. An exclusive lock means that no other users can update or delete the item until the database server removes the lock. In addition, no other users can view the row unless they are using the Dirty Read isolation level.

When the database server removes the exclusive lock depends on whether the database supports transaction logging.

For more information about these exclusive locks, see Locks placed with INSERT, UPDATE, and DELETE statements.

The behavior of the lock types

IBM Informix database servers store locks in an internal lock table. When the database server reads a row, it checks if the row or its associated page, table, or database is listed in the lock table. If it is in the lock table, the database server must also check the lock type. The lock table can contain the following types of locks.

Lock name	Description	Statement usually placing the lock
S	Shared lock	SELECT
X	Exclusive lock	INSERT, UPDATE, DELETE
U	Update lock	SELECT in an update cursor
B	Byte lock	Any statement that updates VARCHAR columns

In addition, the lock table might store *intent locks*. An intent lock can be an intent shared (IS), intent exclusive (IX), or intent shared exclusive (SIX). An intent lock is the lock the database server (lock manager) places on a higher granularity object when a lower granularity object needs to be locked. For example, when a user locks a row or page in Shared lock mode, the database server places an IS (intent shared) lock on the table to provide an instant check that no other user holds an X lock on the table. In this case, intent locks are placed on the table only and not on the row or page. Intent locks can be placed at the level of a row, page, or table only.

The user does not have direct control over intent locks; the lock manager internally manages all intent locks.

The following table shows what locks a user (or the database server) can place if another user (or the database server) holds a certain type of lock. For example, if one user holds an exclusive lock on an item, another user requesting any kind of lock (exclusive, update or shared) receives an error. In addition, the database server is unable to place any intent locks on an item if a user holds an exclusive lock on the item.

	Hold X lock	**Hold U lock**	**Hold S lock**	**Hold IS lock**	**Hold SIX lock**	**Hold IX lock**
Request X lock	No	No	No	No	No	No
Request U lock	No	No	Yes	Yes	No	No
Request S lock	No	Yes	Yes	Yes	No	No
Request IS lock	No	Yes	Yes	Yes	Yes	Yes
Request SIX lock	No	No	No	Yes	No	No
Request IX lock	No	No	No	Yes	No	Yes

For information about how locking affects performance, see your *IBM Informix Performance Guide*.

Control data modification with access modes

IBM Informix database servers support access modes. Access modes affect read and write concurrency for rows within transactions and are set with the SET TRANSACTION statement. You can use access modes to control data modification among shared files.

Transactions are read-write by default. If you specify that a transaction is read-only, that transaction cannot perform the following tasks:
- Insert, delete, or update table rows
- Create, alter, or drop any database object such as a schema, table, temporary table, index, or stored routine
- Grant or revoke privileges
- Update statistics
- Rename columns or tables

Read-only access mode prohibits updates.

You can execute stored routines in a read-only transaction as long as the routine does not try to perform any restricted operations.

For information about how to use the SET TRANSACTION statement to specify an access mode, see the *IBM Informix Guide to SQL: Syntax*.

Set the lock mode

The lock mode determines what happens when your program encounters locked data. One of the following situations occurs when a program attempts to fetch or modify a locked row:

- The database server immediately returns an error code in SQLCODE or SQLSTATE to the program.
- The database server suspends the program until the program that placed the lock removes the lock.
- The database server suspends the program for a time and then, if the lock is not removed, the database server sends an error-return code to the program.

You choose among these results with the SET LOCK MODE statement.

Waiting for locks

When a user encounters a lock, the default behavior of a database server is to return an error to the application. If you prefer to wait indefinitely for a lock (this choice is best for many applications), you can execute the following SQL statement:

```
SET LOCK MODE TO WAIT
```

When this lock mode is set, your program usually ignores the existence of other concurrent programs. When your program needs to access a row that another program has locked, it waits until the lock is removed, then proceeds. In most cases, the delays are imperceptible.

You can also wait for a specific number of seconds, as in the following example:

```
SET LOCK MODE TO WAIT 20
```

Not waiting for locks

The disadvantage of waiting for locks is that the wait might become long (although properly designed applications should hold their locks briefly). When the possibility of a long delay is not acceptable, a program can execute the following statement:

```
SET LOCK MODE TO NOT WAIT
```

When the program requests a locked row, it immediately receives an error code (for example, error -107 `Record is locked`), and the current SQL statement terminates. The program must roll back its current transaction and try again.

The initial setting is not waiting when a program starts up. If you are using SQL interactively and see an error related to locking, set the lock mode to wait. If you are writing a program, consider making that one of the first embedded SQL statements that the program executes.

Limited time wait

You can ask the database server to set an upper limit on a wait with the following statement:

```
SET LOCK MODE TO WAIT 17
```

This statement places an upper limit of 17 seconds on the length of any wait. If a lock is not removed in that time, the error code is returned.

Handle a deadlock

A *deadlock* is a situation in which a pair of programs blocks the progress of each other. Each program has a lock on some object that the other program wants to access. A deadlock arises only when all programs concerned set their lock modes to wait for locks.

An IBM Informix database server detects deadlocks immediately when they only involve data at a single network server. It prevents the deadlock from occurring by returning an error code (error -143 `ISAM error: deadlock detected`) to the second program to request a lock. The error code is the one the program receives if it sets its lock mode to not wait for locks. If your program receives an error code related to locks even after it sets lock mode to wait, you know the cause is an impending deadlock.

Handling external deadlock

A deadlock can also occur between programs on different database servers. In this case, the database server cannot instantly detect the deadlock. (Perfect deadlock detection requires excessive communications traffic among all database servers in a network.) Instead, each database server sets an upper limit on the amount of time that a program can wait to obtain a lock on data at a different database server. If the time expires, the database server assumes that a deadlock was the cause and returns a lock-related error code.

In other words, when external databases are involved, every program runs with a maximum lock-waiting time. The DBA can set or modify the maximum for the database server.

Simple concurrency

If you are not sure which choice to make concerning locking and concurrency, you can use the following guideline: If your application accesses non-static tables, and there is no risk of deadlock, have your program execute the following statements when it starts up (immediately after the first CONNECT or DATABASE statement):

```
SET LOCK MODE TO WAIT
SET ISOLATION TO REPEATABLE READ
```

Ignore the return codes from both statements. Proceed as if no other programs exist. If no performance problems arise, you do not need to read this section again.

Hold cursors

When transaction logging is used, IBM Informix guarantees that anything done within a transaction can be rolled back at the end of it. To handle transactions reliably, the database server normally applies the following rules:

- When a transaction ends, all cursors are closed.
- When a transaction ends, all locks are released.

The rules that are used to handle transactions reliably are normal with most database systems that support transactions, and they do not cause any trouble for most applications. However, circumstances exist in which using standard transactions with cursors is not possible. For example, the following code works fine without transactions. However, when transactions are added, closing the cursor conflicts with using two cursors simultaneously.

```
EXEC SQL DECLARE master CURSOR FOR
EXEC SQL DECLARE detail CURSOR FOR  FOR UPDATE
EXEC SQL OPEN master;
while(SQLCODE == 0)
{
   EXEC SQL FETCH master INTO
   if(SQLCODE == 0)
   {
      EXEC SQL BEGIN WORK;
      EXEC SQL OPEN detail USING
      EXEC SQL FETCH detail
      EXEC SQL UPDATE  WHERE CURRENT OF detail
      EXEC SQL COMMIT WORK;
   }
}
EXEC SQL CLOSE master;
```

In this design, one cursor is used to scan a table. Selected records are used as the basis for updating a different table. The problem is that when each update is treated as a separate transaction (as the pseudocode in the previous example shows), the COMMIT WORK statement following the UPDATE closes all cursors, including the master cursor.

The simplest alternative is to move the COMMIT WORK and BEGIN WORK statements to be the last and first statements, respectively, so that the entire scan over the master table is one large transaction. Treating the scan of the master table as one large transaction is sometimes possible, but it can become impractical if many rows need to be updated. The number of locks can be too large, and they are held for the duration of the program.

A solution that IBM Informix database servers support is to add the keywords WITH HOLD to the declaration of the master cursor. Such a cursor is referred to as a *hold cursor* and is not closed at the end of a transaction. The database server still closes all other cursors, and it still releases all locks, but the hold cursor remains open until it is explicitly closed.

Before you attempt to use a hold cursor, you must be sure that you understand the locking mechanism described here, and you must also understand the programs that are running concurrently. Whenever COMMIT WORK is executed, all locks are released, including any locks placed on rows fetched through the hold cursor.

The removal of locks has little importance if the cursor is used as intended, for a single forward scan over a table. However, you can specify WITH HOLD for any cursor, including update cursors and scroll cursors. Before you do this, you must understand the implications of the fact that all locks (including locks on entire tables) are released at the end of a transaction.

The SQL statement cache

The SQL statement cache is a feature that lets you store in a buffer identical SQL statements that are executed repeatedly so the statements can be reused among different user sessions without the need for per-session memory allocation. Statement caching can dramatically improve performance for applications that contain a large number of prepared statements. However, performance improvements are less dramatic when statement caching is used to cache statements that are prepared once and executed many times.

Use SQL to turn on or turn off statement caching for an individual database session when statement caching is enabled for the database server. The following statement shows how to use SQL to turn on caching for the current database session:

```
SET STATEMENT CACHE ON
```

The following statement shows how to use SQL to turn off caching for the current database session:

```
SET STATEMENT CACHE OFF
```

If you attempt to turn on or turn off statement caching when caching is disabled, the database server returns an error.

For information about syntax for the SET STATEMENT CACHE statement, see the *IBM Informix Guide to SQL: Syntax*. For information about the STMT_CACHE and STMT_CACHE_SIZE configuration parameters, see the *IBM Informix Administrator's Reference* and your *IBM Informix Performance Guide*. For information about the **STMT_CACHE** environment variable, see the *IBM Informix Guide to SQL: Reference*.

Summary

Whenever multiple programs have access to a database concurrently (and when at least one of them can modify data), all programs must allow for the possibility that another program can change the data even as they read it. The database server provides a mechanism of locks and isolation levels that usually allow programs to run as if they were alone with the data.

The SET STATEMENT CACHE statement allows you to store in a buffer identical SQL statements that are used repeatedly. When statement caching is turned on, the database server stores the identical statements so they can be reused among different user sessions without the need for per-session memory allocation.

Chapter 11. Create and use SPL routines

This section describes how to create and use SPL routines. An SPL routine is a user-defined routine written in IBM Informix Stored Procedure Language (SPL). IBM Informix SPL is an extension to SQL that provides flow control, such as looping and branching. Anyone who has the Resource privilege on a database can create an SPL routine.

Routines written in SQL are parsed, optimized as far as possible, and then stored in the system catalog tables in executable format. An SPL routine might be a good choice for SQL-intensive tasks. SPL routines can execute routines written in C or other external languages, and external routines can execute SPL routines.

You can use SPL routines to perform any task that you can perform in SQL and to expand what you can accomplish with SQL alone. Because SPL is a language native to the database, and because SPL routines are parsed and optimized when they are created rather than at runtime, SPL routines can improve performance for some tasks. SPL routines can also reduce traffic between a client application and the database server and reduce program complexity.

The syntax for each SPL statement is described in the *IBM Informix Guide to SQL: Syntax*. Examples accompany the syntax for each statement.

Introduction to SPL routines

An SPL *routine* is a generic term that includes SPL *procedures* and SPL *functions*. An SPL procedure is a routine written in SPL and SQL that does not return a value. An SPL function is a routine written in SPL and SQL that returns a single value, a value with a complex data type, or multiple values. Generally, a routine written in SPL that returns a value is an SPL function.

You use SQL and SPL statements to write an SPL routine. SPL statements can be used only inside the CREATE PROCEDURE, CREATE PROCEDURE FROM, CREATE FUNCTION, and CREATE FUNCTION FROM statements. All these statements are available with SQL APIs such as IBM Informix ESQL/C. The CREATE PROCEDURE and CREATE FUNCTION statements are available with DB-Access.

To list all SPL routines in a database, run this command, which creates and displays the schema for a database:

```
dbschema -d database_name -f all
```

What you can do with SPL routines

You can accomplish a wide range of objectives with SPL routines, including improving database performance, simplifying writing applications, and limiting or monitoring access to data.

Because an SPL routine is stored in an executable format, you can use it to execute frequently repeated tasks to improve performance. When you execute an SPL routine rather than straight SQL code, you can bypass repeated parsing, validity checking, and query optimization.

You can use an SPL routine in a data-manipulation SQL statement to supply values to that statement. For example, you can use a routine to perform the following actions:

- Supply values to be inserted into a table
- Supply a value that makes up part of a condition clause in a SELECT, DELETE, or UPDATE statement

These actions are two possible uses of a routine in a data-manipulation statement, but others exist. In fact, any expression in a data-manipulation SQL statement can consist of a routine call.

You can also issue SQL statements in an SPL routine to hide those SQL statements from a database user. Rather than having all users learn how to use SQL, one experienced SQL user can write an SPL routine to encapsulate an SQL activity and let others know that the routine is stored in the database so that they can execute it.

You can write an SPL routine to be run with the DBA privilege by a user who does not have the DBA privilege. This feature allows you to limit and control access to data in the database. Alternatively, an SPL routine can monitor the users who access certain tables or data. For more information about how to use SPL routines to control access to data, see the *IBM Informix Database Design and Implementation Guide*.

You also can write SPL routines that use Dynamic SQL. For an overview with detailed examples of how to create and use prepared objects and Dynamic SQL in SPL routines, see this IBM **developerWorks**® article: Dynamic SQL support in Informix Dynamic Server Stored Procedure Language.

SPL routines format

An SPL routine consists of a beginning statement, a statement block, and an ending statement. Within the statement block, you can use SQL or SPL statements.

The CREATE PROCEDURE or CREATE FUNCTION statement

You must first decide if the routine that you are creating returns values or not. If the routine does not return a value, use the CREATE PROCEDURE statement to create an SPL procedure. If the routine returns a value, use the CREATE FUNCTION statement to create an SPL function.

To create an SPL routine, use one CREATE PROCEDURE or CREATE FUNCTION statement to write the body of the routine and register it.

Begin and end the routine

To create an SPL routine that does not return values, start with the CREATE PROCEDURE statement and end with the END PROCEDURE keyword. The following figure shows how to begin and end an SPL procedure.

```
CREATE PROCEDURE new_price( per_cent REAL )
. . .
END PROCEDURE;
```

Figure 11-1. Begin and end an SPL procedure.

For more information about naming conventions, see the Identifier segment in the *IBM Informix Guide to SQL: Syntax*.

To create an SPL function that returns one or more values, start with the CREATE FUNCTION statement and end with the END FUNCTION keyword. The following figure shows how to begin and end an SPL function.

```
CREATE FUNCTION discount_price( per_cent REAL)
   RETURNING MONEY;
. . .
END FUNCTION;
```

Figure 11-2. Begin and end an SPL function.

In SPL routines, the END PROCEDURE or END FUNCTION keywords are required.

Important: For compatibility with earlier IBM Informix products, you can use CREATE PROCEDURE with a RETURNING clause to create a user-defined routine that returns a value. Your code will be easier to read and to maintain, however, it you use CREATE PROCEDURE for SPL routines that do not return values (SPL procedures) and CREATE FUNCTION for SPL routines that return one or more values (SPL functions).

Specify a routine name

You specify a name for the SPL routine immediately following the CREATE PROCEDURE or CREATE FUNCTION statement and before the parameter list, as the figure shows.

```
CREATE PROCEDURE add_price (arg INT )
```

Figure 11-3. Specify a name for the SPL routine.

IBM Informix allows you to create more than one SPL routine with the same name but with different parameters. This feature is known as *routine overloading*. For example, you might create each of the following SPL routines in your database:

```
CREATE PROCEDURE multiply (a INT, b FLOAT)
CREATE PROCEDURE multiply (a INT, b SMALLINT)
CREATE PROCEDURE multiply (a REAL, b REAL)
```

If you call a routine with the name **multiply()**, the database server evaluates the name of the routine and its arguments to determine which routine to execute.

Routine resolution is the process in which the database server searches for a routine signature that it can use, given the name of the routine and a list of arguments. Every routine has a *signature* that uniquely identifies the routine based on the following information:

- The type of routine (procedure or function)
- The routine name
- The number of parameters
- The data types of the parameters
- The order of the parameters

The routine signature is used in a CREATE, DROP, or EXECUTE statement if you enter the full parameter list of the routine. For example, each statement in the following figure uses a routine signature.

```
CREATE FUNCTION multiply(a INT, b INT);

DROP PROCEDURE end_of_list(n SET, row_id INT);

EXECUTE FUNCTION compare_point(m point, n point);
```

Figure 11-4. Routine signatures.

Add a specific name

Because IBM Informix supports routine overloading, an SPL routine might not be uniquely identified by its name alone. However, a routine can be uniquely identified by a *specific name*. A specific name is a unique identifier that you define in the CREATE PROCEDURE or CREATE FUNCTION statement, in addition to the routine name. A specific name is defined with the SPECIFIC keyword and is unique in the database. Two routines in the same database cannot have the same specific name, even if they have different owners.

A specific name can be up to 128 bytes long. The following figure shows how to define the specific name **calc1** in a CREATE FUNCTION statement that creates the **calculate()** function.

```
CREATE FUNCTION calculate(a INT, b INT, c INT)
   RETURNING INT
   SPECIFIC calc1;
. . .
END FUNCTION;
```

Figure 11-5. Define the specific name.

Because the owner **bsmith** has given the SPL function the specific name **calc1**, no other user can define a routine—SPL or external—with the specific name **calc1**. Now you can refer to the routine as **bsmith.calculate** or with the SPECIFIC keyword **calc1** in any statement that requires the SPECIFIC keyword.

Add a parameter list

When you create an SPL routine, you can define a parameter list so that the routine accepts one or more arguments when it is invoked. The parameter list is optional.

A parameter to an SPL routine must have a name and can be defined with a default value. The following are the categories of data types that a parameter can specify:
- Built-in data types
- Opaque data types
- Distinct data types
- Row types
- Collection types
- Smart large objects (CLOB and BLOB)

The parameter list cannot specify any of the following data types directly:
- SERIAL
- SERIAL8
- BIGSERIAL
- TEXT
- BYTE

For the serial data types, however, a routine can return numerically equivalent values that are cast to a corresponding integer type (INT, INT8, or BIGINT). Similarly, for a routine to support the simple large object data types, the parameter list can include the REFERENCES keyword to return a descriptor that points to the storage location of the TEXT or BYTE object.

The following figure shows examples of parameter lists.

```
CREATE PROCEDURE raise_price(per_cent INT);

CREATE FUNCTION  raise_price(per_cent INT DEFAULT 5);

CREATE PROCEDURE update_emp(n employee_t);
CREATE FUNCTION  update_nums( list1 LIST(ROW (a VARCHAR(10),
                                              b VARCHAR(10),
                                              c INT) NOT NULL ));
```

Figure 11-6. Examples of different parameter lists.

When you define a parameter, you accomplish two tasks at once:
- You request that the user supply a value when the routine is executed.
- You implicitly define a variable (with the same name as the parameter name) that you can use as a local variable in the body of the routine.

If you define a parameter with a default value, the user can execute the SPL routine with or without the corresponding argument. If the user executes the SPL routine without the argument, the database server assigns the parameter the default value as an argument.

When you invoke an SPL routine, you can give an argument a NULL value. SPL routines handle NULL values by default. However, you cannot give an argument a NULL value if the argument is a collection element.

Simple large objects as parameters:
Although you cannot define a parameter with a simple large object (a large object that contains TEXT or BYTE data types), you can use the REFERENCES keyword to define a parameter that points to a simple large object, as the following figure shows.

```
CREATE PROCEDURE proc1(lo_text REFERENCES TEXT)

CREATE FUNCTION proc2(lo_byte REFERENCES BYTE DEFAULT NULL)
```

Figure 11-7. Use of the REFERENCES keyword.

The REFERENCES keyword means that the SPL routine is passed a descriptor that contains a pointer to the simple large object, not the object itself.

Undefined arguments:
When you invoke an SPL routine, you can specify all, some, or none of the defined arguments. If you do not specify an argument, and if its corresponding parameter does not have a default value, the argument, which is used as a variable within the SPL routine, is given a status of *undefined*.

Undefined is a special status used for SPL variables that have no value. The SPL routine executes without error, as long as you do not attempt to use the variable that has the status undefined in the body of the routine.

The undefined status is not the same as a NULL value. (The NULL value means that the value is not known, or does not exist, or is not applicable.)

Add a return clause

If you use CREATE FUNCTION to create an SPL routine, you must specify a return clause that returns one or more values.

Tip: If you use the CREATE PROCEDURE statement to create an SPL routine, you have the option of specifying a return clause. Your code will be easier to read and to maintain, however, it you instead use the CREATE FUNCTION statement to create a routine that returns values.

To specify a return clause, use the RETURNING or RETURNS keyword with a list of data types the routine will return. The data types can be any SQL data types except SERIAL, SERIAL8, TEXT, or BYTE.

The return clause in the following figure specifies that the SPL routine will return an INT value and a REAL value.

```
FUNCTION find_group(id INT)
   RETURNING INT, REAL;
. . .
END FUNCTION;
```

Figure 11-8. Specify the return clause.

After you specify a return clause, you must also specify a RETURN statement in the body of the routine that explicitly returns the values to the calling routine. For more information on writing the RETURN statement, see “Return values from an SPL function” on page 11-31.

To specify that the function should return a simple large object (a TEXT or BYTE value), you must use the REFERENCES clause, as in the following figure, because an SPL routine returns only a pointer to the object, not the object itself.

```
CREATE FUNCTION find_obj(id INT)
   RETURNING REFERENCES BYTE;
```

Figure 11-9. Use of the REFERENCES clause.

Add display labels

You can use CREATE FUNCTION to create a routine that specifies names for the display labels for the values returned. If you do not specify names for the display labels, the labels will display as **expression**.

In addition, although using CREATE FUNCTION for routines that return values is recommended, you can use CREATE PROCEDURE to create a routine that returns values and specifies display labels for the values returned.

If you choose to specify a display label for one return value, you must specify a display label for every return value. In addition, each return value must have a unique display label.

To add display labels, you must specify a return clause, use the RETURNING keyword. The return clause in the following figure specifies that the routine will return an INT value with a `serial_num` display label, a CHAR value with a `name` display label, and an INT value with a `points` display label. You could use either CREATE FUNCTION or CREATE PROCEDURE in the following figure.

```
CREATE FUNCTION p(inval INT DEFAULT 0)
   RETURNING INT AS serial_num, CHAR (10) AS name, INT AS points;
   RETURN (inval + 1002), "Newton", 100;
END FUNCTION;
```

Figure 11-10. Specify the return clause.

The returned values and their display labels are shown in the following figure.

```
serial_num    name      points

1002          Newton    100
```

Figure 11-11. Returned values and their display labels.

Tip: Because you can specify display labels for return values directly in a SELECT statement, when a SPL routine is used in a SELECT statement, the labels will display as **expression**. For more information on specifying display labels for return values in a SELECT statement, see Chapter 2, "Compose SELECT statements," on page 2-1.

Specify whether the SPL function is variant

When you create an SPL function, the function is variant by default. A function is variant if it returns different results when it is invoked with the same arguments or if it modifies a database or variable state. For example, a function that returns the current date or time is a variant function.

Although SPL functions are variant by default, if you specify WITH NOT VARIANT when you create a function, the function cannot contain any SQL statements. You can define a functional index only on a nonvariant function.

Add a modifier

When you write SPL functions, you can use the WITH clause to add a modifier to the CREATE FUNCTION statement. In the WITH clause, you can specify the COMMUTATOR or NEGATOR functions. The other modifiers are for external routines.

Restriction: You can use the COMMUTATOR or NEGATOR modifiers with SPL functions only. You cannot use any modifiers with SPL procedures.

The COMMUTATOR modifier:
The COMMUTATOR modifier allows you to specify an SPL function that is the *commutator function* of the SPL function you are creating. A commutator function accepts the same arguments as the SPL function you are creating, but in opposite order, and returns the same value. The commutator function might be more cost effective for the SQL optimizer to execute.

For example, the functions **lessthan(a,b)**, which returns TRUE if **a** is less than **b**, and **greaterthan(b,a)**, which returns TRUE if **b** is greater than or equal to **a**, are commutator functions. The following figure uses the WITH clause to define a commutator function.

```
CREATE FUNCTION lessthan( a dtype1, b dtype2 )
   RETURNING BOOLEAN
   WITH ( COMMUTATOR = greaterthan );
. . .
END FUNCTION;
```

Figure 11-12. Define a commutator function.

The optimizer might use **greaterthan(b,a)** if it is less expensive to execute than **lessthan(a,b)**. To specify a commutator function, you must own both the commutator function and the SPL function you are writing. You must also grant the user of your SPL function the Execute privilege on both functions.

For a detailed description of granting privileges, see the description of the GRANT statement in the *IBM Informix Guide to SQL: Syntax*.

The NEGATOR modifier:
The NEGATOR modifier is available for Boolean functions. Two Boolean functions are *negator functions* if they take the same arguments, in the same order, and return complementary Boolean values.

For example, the functions **equal(a,b)**, which returns TRUE if **a** is equal to **b**, and **notequal(a,b)**, which returns FALSE if **a** is equal to **b,** are negator functions. The optimizer might choose to execute the negator function you specify if it is less expensive than the original function.

Tthe following figure shows how to use the WITH clause of a CREATE FUNCTION statement to specify a negator function.

```
CREATE FUNCTION equal( a dtype1, b dtype2 )
   RETURNING BOOLEAN
   WITH ( NEGATOR = notequal );
. . .
END FUNCTION;
```

Figure 11-13. Specify a negator function.

Tip: By default, any SPL routine can handle NULL values that are passed to it in the argument list. In other words, the HANDLESNULLS modifier is set to YES for SPL routines, and you cannot change its value.

For more information on the COMMUTATOR and NEGATOR modifiers, see the Routine Modifier segment in the *IBM Informix Guide to SQL: Syntax*.

Specify a DOCUMENT clause

The DOCUMENT and WITH LISTING IN clauses follow END PROCEDURE or END FUNCTION statements.

The DOCUMENT clause lets you add comments to your SPL routine that another routine can select from the system catalog tables, if needed. The DOCUMENT clause in the following figure contains a usage statement that shows a user how to run the SPL routine.

```
CREATE FUNCTION raise_prices(per_cent INT)
. . .
END FUNCTION
   DOCUMENT "USAGE: EXECUTE FUNCTION raise_prices (xxx)",
            "xxx = percentage from 1 - 100";
```

Figure 11-14. Usage statement that shows a user how to run the SPL routine.

Remember to place single or double quotation marks around the literal clause. If the literal clause extends past one line, place quotation marks around each line.

Specify a listing file

The WITH LISTING IN option allows you to direct any compile-time warnings that might occur to a file.

The following figure shows how to log the compile-time warnings in `/tmp/warn_file` when you work on UNIX.

```
CREATE FUNCTION raise_prices(per_cent INT)
. . .
END FUNCTION
   WITH LISTING IN '/tmp/warn_file'
```

Figure 11-15. Log the compile-time warnings on UNIX.

The following figure shows how to log the compile-time warnings in `\tmp\listfile` when you work on Windows.

```
CREATE FUNCTION raise_prices(per_cent INT)
. . .
END FUNCTION
   WITH LISTING IN 'C:\tmp\listfile'
```

Figure 11-16. Log the compile-time warnings on Windows.

Always remember to place single or double quotation marks around the file name or path name.

Add comments

You can add a comment to any line of an SPL routine, even a blank line.

To add a comment, use any of the following comment notation styles:

- Place a double hyphen (`--`) at the left of the comment.
- Enclose the comment text between a pair of braces ({   . . . }).
- Delimit the comment between C-style "slash and asterisk" comment indicators (`/*   . . . */`).

To add a multiple-line comment, take one of the following actions:

- Place a double hyphen before each line of the comment
- Enclose the entire comment within the pair of braces.
- Place `/*` at the left of the first line of the comment, and place `*/` at the end of the last line of the comment.

Braces as comment indicators are IBM Informix an extension to the ANSI/ISO standard for the SQL language. All three comment styles are also valid in SPL routines.

If you use braces or C-style comment indicators to delimit the text of a comment, the opening indicator must be in the same style as the closing indicator.

All the examples in the following figure are valid comments.

```
SELECT * FROM customer -- Selects all columns and rows

SELECT * FROM customer
   -- Selects all columns and rows
   -- from the customer table

SELECT * FROM customer
   { Selects all columns and rows
     from the customer table }

SELECT * FROM customer
   /* Selects all columns and rows
     from the customer table */
```

Figure 11-17. Valid comment examples.

Important: Braces ({ }) can be used to delimit comments and also to delimit the list of elements in a collection. To ensure that the parser correctly recognizes the end of a comment or list of elements in a collection, use the double hyphen (--) for comments in an SPL routine that handles collection data types.

Example of a complete routine

The following CREATE FUNCTION statement creates a routine that reads a customer address:

```
CREATE FUNCTION read_address       (lastname CHAR(15)) -- one argument
   RETURNING CHAR(15), CHAR(15), CHAR(20), CHAR(15),CHAR(2)
      CHAR(5); -- 6 items

   DEFINE p_lname,p_fname, p_city CHAR(15);
      --define each routine variable
   DEFINE p_add CHAR(20);
   DEFINE p_state CHAR(2);
   DEFINE p_zip CHAR(5);

   SELECT fname, address1, city, state, zipcode
      INTO p_fname, p_add, p_city, p_state, p_zip
      FROM customer
      WHERE lname = lastname;

   RETURN p_fname, lastname, p_add, p_city, p_state, p_zip;
      --6 items
END FUNCTION;

DOCUMENT 'This routine takes the last name of a customer as',
   --brief description
   'its only argument. It returns the full name and address',
   'of the customer.'

WITH LISTING IN 'pathname' -- modify this pathname according
-- to the conventions that your operating system requires

-- compile-time warnings go here
; -- end of the routine read_address
```

Create an SPL routine in a program

To use an SQL API to create an SPL routine, put the text of the CREATE PROCEDURE or CREATE FUNCTION statement in a file. Use the CREATE PROCEDURE FROM or CREATE FUNCTION FROM statement and refer to that file to compile the routine. For example, to create a routine to read a customer name, you can use a statement such as the one in the previous example and store it in a file. If the file is named `read_add_source`, the following statement compiles the **read_address** routine:

```
CREATE PROCEDURE FROM 'read_add_source';
```

The following example shows how the previous SQL statement looks in an Informix ESQL/C program:

```
/* This program creates whatever routine is in *
 * the file 'read_add_source'.
 */
#include <stdio.h>
EXEC SQL include sqlca;
EXEC SQL include sqlda;
EXEC SQL include datetime;
/* Program to create a routine from the pwd */

main()
{
EXEC SQL database play;
EXEC SQL create procedure from 'read_add_source';
}
```

Routines in distributed operation

After you create an SPL routine, you cannot change the body of the routine. Instead, you need to drop the routine and re-create it. Before you drop the routine, however, make sure that you have a copy of its text somewhere outside the database.

In general, use DROP PROCEDURE with an SPL procedure name and DROP FUNCTION with an SPL function name, as the following figure shows.

```
DROP PROCEDURE raise_prices;
DROP FUNCTION read_address;
```

Figure 11-18. DROP PROCEDURE and DROP FUNCTION.

Tip: You can also use DROP PROCEDURE with a function name to drop an SPL function. However, it is recommended that you use DROP PROCEDURE only with procedure names and DROP FUNCTION only with function names.

However, if the database has other routines of the same name (overloaded routines), you cannot drop the SPL routine by its routine name alone. To drop a routine that has been overloaded, you must specify either its signature or its specific name. The following figure shows two ways that you might drop a routine that is overloaded.

```
DROP FUNCTION calculate( a INT, b INT, c INT);
   -- this is a signature

DROP SPECIFIC FUNCTION calc1;
   -- this is a specific name
```

Figure 11-19. Drop a routine that is overloaded.

If you do not know the type of a routine (function or procedure), you can use the DROP ROUTINE statement to drop it. DROP ROUTINE works with either functions or procedures. DROP ROUTINE also has a SPECIFIC keyword, as the following figure shows.

```
DROP ROUTINE calculate;
DROP SPECIFIC ROUTINE calc1;
```

Figure 11-20. The DROP ROUTINE statement.

Before you drop an SPL routine stored on a remote database server, be aware of the following restriction. You can drop an SPL routine with a fully qualified routine name in the form `database@dbservername:owner.routinename` only if the routine name alone, without its arguments, is enough to identify the routine. SPL routines that access tables in databases of non-local database servers, or that are invoked as UDRs of a database of another database server, can only have non-opaque built-in data types as their arguments or returned values. If the tables or the UDR resides on another database of the same Informix instance, however, the arguments and returned values of routines written in SPL (or in external languages that Informix supports) can be the built-in opaque data types BLOB, BOOLEAN, CLOB, and LVARCHAR. They can also be UDTs or DISTINCT data types if the following conditions are true:

- The remote database has the same server as the current database.
- The UDT arguments are explicitly cast to a built-in data type.
- The DISTINCT types are based on built-in types and are explicitly cast to built-in types.
- The SPL routine and all the casts are defined in all participating databases.

Define and use variables

Any variable that you use in an SPL routine, other than a variable that is implicitly defined in the parameter list of the routine, must be defined in the body of the routine.

The value of a variable is held in memory; the variable is not a database object. Therefore, rolling back a transaction does not restore the values of SPL variables.

To define a variable in an SPL routine, use the DEFINE statement. DEFINE is not an executable statement. DEFINE must appear after the CREATE PROCEDURE statement and before any other statements. The examples in the following figure are all legal variable definitions.

```
DEFINE a INT;
DEFINE person person_t;
DEFINE GLOBAL gl_out INT DEFAULT 13;
```

Figure 11-21. Variable definitions.

For more information on DEFINE, see the description in the *IBM Informix Guide to SQL: Syntax*.

An SPL variable has a name and a data type. The variable name must be a valid identifier, as described in the Identifier segment in the *IBM Informix Guide to SQL: Syntax*.

Declare local variables

You can define a variable to be either *local* or *global* in scope. This section describes local variables. In an SPL routine, local variables:

- Are valid only for the duration of the SPL routine
- Are reset to their initial values or to a value the user passes to the routine, each time the routine is executed
- Cannot have default values

You can define a local variable on any of the following data types:

- Built-in data types (except SERIAL, SERIAL8, BIGSERIAL, TEXT, or BYTE)
- Any extended data type (row type, opaque, distinct, or collection type) that is defined in the database prior to execution of the SPL routine

The scope of a local variable is the statement block in which it is declared. You can use the same variable name outside the statement block with a different definition.

For more information on defining global variables, see "Declare global variables" on page 11-20.

Scope of local variables

A local variable is valid within the statement block in which it is defined and within any nested statement blocks, unless you redefine the variable within the statement block.

In the beginning of the SPL procedure in the following figure, the integer variables **x**, **y**, and **z** are defined and initialized.

```
CREATE PROCEDURE scope()
   DEFINE x,y,z INT;
   LET x = 5;
   LET y = 10;
   LET z = x + y; --z is 15
   BEGIN
      DEFINE x, q INT;
      DEFINE z CHAR(5);
      LET x = 100;
      LET q = x + y;   -- q = 110
      LET z = 'silly'; -- z receives a character value
   END
   LET y = x; -- y is now 5
   LET x = z; -- z is now 15, not 'silly'
END PROCEDURE;
```

Figure 11-22. Define and initialize variables.

The BEGIN and END statements mark a nested statement block in which the integer variables **x** and **q** are defined as well as the CHAR variable **z**. Within the nested block, the redefined variable **x** masks the original variable **x**. After the END statement, which marks the end of the nested block, the original value of **x** is accessible again.

Declare variables of built-in data types

A variable that you declare as a built-in SQL data type can hold a value retrieved from a column of that built-in type. You can declare an SPL variable as most built-in types, except BIGSERIAL, SERIAL, and SERIAL8, as the following figure illustrates.

```
DEFINE x INT;
DEFINE y INT8;
DEFINE name CHAR(15);
DEFINE this_day DATETIME YEAR TO DAY;
```

Figure 11-23. Built-in type variables.

You can declare SPL variables of appropriate integer data types (such as BIGINT, INT, or INT8) to store the values of serial columns or of sequence objects.

Declare variables for smart large objects

A variable for a BLOB or CLOB object (or a data type that contains a smart large object) does not contain the object itself but rather a pointer to the object. The following figure shows how to define a variable for BLOB and CLOB objects.

```
DEFINE a_blob BLOB;
DEFINE b_clob CLOB;
```

Figure 11-24. Variables for BLOB or CLOB objects.

Declare variables for simple large objects

A variable for a simple large object (a TEXT or BYTE object) does not contain the object itself but rather a pointer to the object. When you define a variable on the TEXT or BYTE data type, you must use the keyword REFERENCES before the data type, as the following figure shows.

```
DEFINE t REFERENCES TEXT;
DEFINE b REFERENCES BYTE;
```

Figure 11-25. Use the REFERENCES keyword before the data type.

Declare collection variables

In order to hold a collection fetched from the database, a variable must be of type SET, MULTISET, or LIST.

Important: A collection variable must be defined as a local variable. You cannot define a collection variable as a global variable.

A variable of SET, MULTISET, or LIST type is a collection variable that holds a collection of the type named in the DEFINE statement. The following figure shows how to define typed collection variables.

```
DEFINE a SET ( INT NOT NULL );

DEFINE b MULTISET ( ROW (  b1 INT,
                           b2 CHAR(50),
                        )  NOT NULL );

DEFINE c LIST ( SET (DECIMAL NOT NULL) NOT NULL);
```

Figure 11-26. Define typed collection variables.

You must always define the elements of a collection variable as NOT NULL. In this example, the variable **a** is defined to hold a SET of non-NULL integers; the variable **b** holds a MULTISET of non-NULL row types; and the variable **c** holds a LIST of non-NULL sets of non-NULL decimal values.

In a variable definition, you can nest complex types in any combination or depth to match the data types stored in your database.

You cannot assign a collection variable of one type to a collection variable of another type. For example, if you define a collection variable as a SET, you cannot assign another collection variable of MULTISET or LIST type to it.

Declare row-type variables

Row-type variables hold data from named or unnamed row types. You can define a *named row variable* or an *unnamed row variable*. Suppose you define the named row types that the following figure shows.

```
CREATE ROW TYPE zip_t
(
   z_code      CHAR(5),
   z_suffix    CHAR(4)
);

CREATE ROW TYPE address_t
(
   street      VARCHAR(20),
   city        VARCHAR(20),
   state       CHAR(2),
   zip         zip_t
);

CREATE ROW TYPE employee_t
(
   name        VARCHAR(30),
   address     address_t
   salary      INTEGER
);

CREATE TABLE employee OF TYPE employee_t;
```

Figure 11-27. Named and unnamed row variables.

If you define a variable with the name of a named row type, the variable can only hold data of that row type. In the following figure, the **person** variable can only hold data of **employee_t** type.

```
DEFINE person employee_t;
```

Figure 11-28. Defining the person variable.

To define a variable that holds data stored in an unnamed row type, use the ROW keyword followed by the fields of the row type, as the following figure shows.

```
DEFINE manager ROW (name        VARCHAR(30),
                    department  VARCHAR(30),
                    salary      INTEGER );
```

Figure 11-29. Use the ROW keyword followed by the fields of the row type.

Because unnamed row types are type-checked for structural equivalence only, a variable defined with an unnamed row type can hold data from any unnamed row type that has the same number of fields and the same type definitions. Therefore, the variable **manager** can hold data from any of the row types in the following figure.

```
ROW ( name         VARCHAR(30),
      department   VARCHAR(30),
      salary       INTEGER );

ROW ( french      VARCHAR(30),
      spanish     VARCHAR(30),
      number      INTEGER );

ROW ( title       VARCHAR(30),
      musician    VARCHAR(30),
      price       INTEGER );
```

Figure 11-30. Unnamed row types.

Important: Before you can use a row type variable, you must initialize the row variable with a LET statement or SELECTINTO statement.

Declare opaque- and distinct-type variables

Opaque-type variables hold data retrieved from opaque data types. *Distinct-type variables* hold data retrieved from distinct data types. If you define a variable with an opaque data type or a distinct data type, the variable can only hold data of that type.

If you define an opaque data type named **point** and a distinct data type named **centerpoint**, you can define SPL variables to hold data from the two types, as the following figure shows.

```
DEFINE a point;
DEFINE b centerpoint;
```

Figure 11-31. Defining SPL variables to hold opaque and distinct data types.

The variable **a** can only hold data of type **point**, and **b** can only hold data of type **centerpoint**.

Declare variables for column data with the LIKE clause

If you use the LIKE clause, the database server defines a variable to have the same data type as a column in a table or view.

If the column contains a collection, row type, or nested complex type, the variable has the complex or nested complex type defined in the column.

In the following figure, the variable **loc1** defines the data type for the **locations** column in the **image** table.

```
DEFINE loc1 LIKE image.locations;
```

Figure 11-32. Define the loc1 data type for the locations column in the image table.

Declare PROCEDURE type variables

In an SPL routine, you can define a variable of type PROCEDURE and assign the variable the name of an existing SPL routine or external routine. Defining a variable of PROCEDURE type indicates that the variable is a call to a user-defined routine, not a built-in routine of the same name.

For example, the statement in the following figure defines **length** as an SPL procedure or SPL function, not as the built-in LENGTH function.

```
DEFINE length PROCEDURE;
LET x = length( a,b,c );
```

Figure 11-33. Define length as an SPL procedure.

This definition disables the built-in **LENGTH** function within the scope of the statement block. You would use such a definition if you had already created an SPL or external routine with the name LENGTH.

Because IBM Informix supports routine overloading, you can define more than one SPL routine or external routine with the same name. If you call any routine from an SPL routine, Informix determines which routine to use, based on the arguments specified and the routine determination rules. For information about routine overloading and routine determination, see *IBM Informix User-Defined Routines and Data Types Developer's Guide*.

Tip: If you create an SPL routine with the same name as an aggregate function (**SUM**, **MAX**, **MIN**, **AVG**, **COUNT**) or with the name **extend**, you must qualify the routine name with an owner name.

Subscripts with variables

You can use subscripts with variables of CHAR, VARCHAR, NCHAR, NVARCHAR, BYTE, or TEXT data type. The subscripts indicate the starting and ending character positions that you want to use within the variable.

Subscripts must always be constants. You cannot use variables as subscripts. The following figure illustrates how to use a subscript with a CHAR(15) variable.

```
DEFINE name CHAR(15);
LET name[4,7] = 'Ream';
SELECT fname[1,3] INTO name[1,3] FROM customer
   WHERE lname = 'Ream';
```

Figure 11-34. A subscript with a CHAR(15) variable.

In this example, the customer's last name is placed between positions 4 and 7 of **name**. The first three characters of the customer's first name is retrieved into positions 1 through 3 of **name**. The part of the variable that is delimited by the two subscripts is referred to as a *substring*.

Variable and keyword ambiguity

If you declare a variable whose name is an SQL keyword, ambiguities can occur. The following rules for identifiers help you avoid ambiguities for SPL variables, SPL routine names, and built-in function names:

- Defined variables take the highest precedence.
- Routines defined with the PROCEDURE keyword in a DEFINE statement take precedence over SQL functions.
- SQL functions take precedence over SPL routines that exist but are not identified with the PROCEDURE keyword in a DEFINE statement.

In general, avoid using an ANSI-reserved word for the name of the variable. For example, you cannot define a variable with the name **count** or **max** because they are the names of aggregate functions. For a list of the reserved keywords that you should avoid using as variable names, see the Identifier segment in the *IBM Informix Guide to SQL: Syntax*.

For information about ambiguities between SPL routine names and SQL function names, see the *IBM Informix Guide to SQL: Syntax*.

Variables and column names:
If you use the same identifier for an SPL variable that you use for a column name, the database server assumes that each instance of the identifier is a variable. Qualify the column name with the table name, using dot notation, in order to use the identifier as a column name.

In the SELECT statement in the following figure, **customer.lname** is a column name and **lname** is a variable name.

```
CREATE PROCEDURE table_test()

   DEFINE lname CHAR(15);
   LET lname = 'Miller';

   SELECT customer.lname INTO lname FROM customer
      WHERE customer_num = 502;
. . .
END PROCEDURE;
```

Figure 11-35. Column names and variable names in a SELECT statement.

Variables and SQL functions:
If you use the same identifier for an SPL variable as for an SQL function, the database server assumes that an instance of the identifier is a variable and disallows the use of the SQL function. You cannot use the SQL function within the block of code in which the variable is defined. The example in the following figure shows a block within an SPL procedure in which the variable called **user** is defined. This definition disallows the use of the USER function in the BEGIN END block.

```
CREATE PROCEDURE user_test()
   DEFINE name CHAR(10);
   DEFINE name2 CHAR(10);
   LET name = user; -- the SQL function

   BEGIN
      DEFINE user CHAR(15); -- disables user function
      LET user = 'Miller';
      LET name = user; -- assigns 'Miller' to variable name
   END
   . . .
   LET name2 = user; -- SQL function again
```

Figure 11-36. A procedure that disallows the use of the USER function in the BEGIN END block.

Declare global variables

A *global variable* has its value stored in memory and is available to other SPL routines, run by the same user session, on the same database. A global variable has the following characteristics:

- It requires a default value.
- It can be used in any SPL routine, although it must be defined in each routine in which it is used.
- It carries its value from one SPL routine to another until the session ends.

Restriction: You cannot define a collection variable as a global variable.

The following figure shows two SPL functions that share a global variable.

```
CREATE FUNCTION func1()  RETURNING INT;
   DEFINE GLOBAL gvar INT DEFAULT 2;
   LET gvar = gvar + 1;
   RETURN gvar;
END FUNCTION;

CREATE FUNCTION func2()  RETURNING INT;
   DEFINE GLOBAL gvar INT DEFAULT 5;
   LET gvar = gvar + 1;
   RETURN gvar;
END FUNCTION;
```

Figure 11-37. Two SPL functions that share a global variable.

Although you must define a global variable with a default value, the variable is only set to the default the first time you use it. If you execute the two functions in the following figure in the order given, the value of **gvar** would be 4.

```
EXECUTE FUNCTION func1();
EXECUTE FUNCTION func2();
```

Figure 11-38. Global variable default values.

But if you execute the functions in the opposite order, as the following figure shows, the value of **gvar** would be 7.

```
EXECUTE FUNCTION func2();
EXECUTE FUNCTION func1();
```

Figure 11-39. Global variable default values.

For more information, see "Executing routines" on page 11-53.

Assign values to variables

Within an SPL routine, use the LET statement to assign values to the variables you have already defined.

If you do not assign a value to a variable, either by an argument passed to the routine or by a LET statement, the variable has an undefined value.

An undefined value is different from a NULL value. If you attempt to use a variable with an undefined value within the SPL routine, you receive an error.

You can assign a value to a routine variable in any of the following ways:
- Use a LET statement.
- Use a SELECT INTO statement.
- Use a CALL statement with a procedure that has a RETURNING clause.
- Use an EXECUTE PROCEDURE INTO or EXECUTE FUNCTION INTO statement.

The LET statement

With a LET statement, you can use one or more variable names with an equal (=) sign and a valid expression or function name. Each example in the following figure is a valid LET statement.

```
LET a = 5;
LET b = 6; LET c = 10;
LET a,b = 10,c+d;
LET a,b = (SELECT cola,colb
     FROM tab1 WHERE cola=10);
LET d = func1(x,y);
```

Figure 11-40. Valid LET statements.

IBM Informix allows you to assign a value to an opaque-type variable, a row-type variable, or a field of a row type. You can also return the value of an external function or another SPL function to an SPL variable.

Suppose you define the named row types **zip_t** and **address_t**, as Figure 11-27 on page 11-16 shows. Anytime you define a row-type variable, you must initialize the variable before you can use it. The following figure shows how you might define and initialize a row-type variable. You can use any row-type value to initialize the variable.

```
DEFINE a address_t;
LET a = ROW ('A Street', 'Nowhere', 'AA',
         ROW(NULL, NULL))::address_t
```

Figure 11-41. Define and initialize a row-type variable.

After you define and initialize the row-type variable, you can write the LET statements that the following figure shows.

```
LET a.zip.z_code = 32601;
LET a.zip.z_suffix = 4555;
   -- Assign values to the fields of address_t
```

Figure 11-42. Write the LET statements.

Tip: Use dot notation in the form **variable.field** or **variable.field.field** to access the fields of a row type, as “Handle row-type data” on page 11-34 describes.

Suppose you define an opaque-type **point** that contains two values that define a two-dimensional point, and the text representation of the values is **'(x,y)'**. You might also have a function **circum()** that calculates the circumference of a circle, given the point **'(x,y)'** and a radius **r**.

If you define an opaque-type **center** that defines a point as the center of a circle, and a function **circum()** that calculates the circumference of a circle, based on a point and the radius, you can write variable declarations for each. In the following figure, **c** is an opaque type variable and **d** holds the value that the external function **circum()** returns.

```
DEFINE c point;
DEFINE r REAL;
DEFINE d REAL;

LET c = '(29.9,1.0)' ;
   -- Assign a value to an opaque type variable

LET d = circum( c, r );
   -- Assign a value returned from circum()
```

Figure 11-43. Writing variable declarations.

The *IBM Informix Guide to SQL: Syntax* describes in detail the syntax of the LET statement.

Other ways to assign values to variables

You can use the SELECT statement to fetch a value from the database and assign it directly to a variable, as the following figure shows.

```
SELECT fname, lname INTO a, b FROM customer
   WHERE customer_num = 101
```

Figure 11-44. Fetch a value from the database and assign it directly to a variable.

Use the CALL or EXECUTE PROCEDURE statements to assign values returned by an SPL function or an external function to one or more SPL variables. You might use either of the statements in the following figure to return the full name and address from the SPL function **read_address** into the specified SPL variables.

```
EXECUTE FUNCTION read_address('Smith')
   INTO p_fname, p_lname, p_add, p_city, p_state,
        p_zip;

CALL read_address('Smith')
   RETURNING p_fname, p_lname, p_add, p_city,
             p_state, p_zip;
```

Figure 11-45. Return the full name and address from the SPL function.

Expressions in SPL routines

You can use any SQL expression in an SPL routine, except for an aggregate expression. The *IBM Informix Guide to SQL: Syntax* provides the complete syntax and descriptions for SQL expressions.

The following examples contain SQL expressions:

```
var1
var1 + var2 + 5
read_address('Miller')
read_address(lastname = 'Miller')
get_duedate(acct_num) + 10 UNITS DAY
       fname[1,5] || ''|| lname '(415)' || get_phonenum(cust_name)
```

Writing the statement block

Every SPL routine has at least one statement block, which is a group of SQL and SPL statements between the CREATE statement and the END statement. You can use any SPL statement or any allowed SQL statement within a statement block. For a list of SQL statements that are not allowed within an SPL statement block, see the description of the statement block segment in the *IBM Informix Guide to SQL: Syntax*.

Implicit and explicit statement blocks

In an SPL routine, the *implicit statement block* extends from the end of the CREATE statement to the beginning of the END statement. You can also define an *explicit statement block*, which starts with a BEGIN statement and ends with an END statement, as the following figure shows.

```
BEGIN
   DEFINE distance INT;
   LET distance = 2;
END
```

Figure 11-46. Explicit statement block.

The explicit statement block allows you to define variables or processing that are valid only within the statement block. For example, you can define or redefine variables, or handle exceptions differently, for just the scope of the explicit statement block.

The SPL function in the following figure has an explicit statement block that redefines a variable defined in the implicit block.

```
CREATE FUNCTION block_demo()
   RETURNING INT;
      DEFINE distance INT;
   LET distance = 37;
   BEGIN
      DEFINE distance INT;
      LET distance = 2;
   END
   RETURN distance;

END FUNCTION;
```

Figure 11-47. An explicit statement block that redefines a variable defined in the implicit block.

In this example, the implicit statement block defines the variable **distance** and gives it a value of 37. The explicit statement block defines a different variable named **distance** and gives it a value of 2. However, the RETURN statement returns the value stored in the first **distance** variable, or 37.

The FOREACH loop

A FOREACH loop defines a *cursor*, a specific identifier that points to one item in a group, whether a group of rows or the elements in a collection.

The FOREACH loop declares and opens a cursor, fetches rows from the database, works on each item in the group, and then closes the cursor. You must declare a cursor if a SELECT, EXECUTE PROCEDURE, or EXECUTE FUNCTION statement might return more than one row. After you declare the cursor, you place the SELECT, EXECUTE PROCEDURE, or EXECUTE FUNCTION statement within it.

An SPL routine that returns a group of rows is called a *cursor routine* because you must use a cursor to access the data it returns. An SPL routine that returns no value, a single value, or any other value that does not require a cursor is called a *noncursor routine*. The FOREACH loop declares and opens a cursor, fetches rows or a collection from the database, works on each item in the group, and then closes the cursor. You must declare a cursor if a SELECT, EXECUTE PROCEDURE, or EXECUTE FUNCTION statement might return more than one row or a collection. After you declare the cursor, you place the SELECT, EXECUTE PROCEDURE, or EXECUTE FUNCTION statement within it.

In a FOREACH loop, you can use an EXECUTE FUNCTION or SELECT INTO statement to execute an external function that is an iterator function.

The FOREACH loop to define cursors

A FOREACH loop begins with the FOREACH keyword and ends with END FOREACH. Between FOREACH and END FOREACH, you can declare a cursor or use EXECUTE PROCEDURE or EXECUTE FUNCTION. The two examples in the following figure show the structure of FOREACH loops.

```
FOREACH cursor FOR
   SELECT column INTO variable FROM table
. . .
END FOREACH;

FOREACH
   EXECUTE FUNCTION name() INTO variable;
END FOREACH;
```

Figure 11-48. Structure of FOREACH loops.

The following figure creates a routine that uses a FOREACH loop to operate on the **employee** table.

```
CREATE_PROCEDURE increase_by_pct( pct INTEGER )
   DEFINE s INTEGER;

   FOREACH sal_cursor FOR
      SELECT salary INTO s FROM employee
         WHERE salary > 35000
      LET s = s + s * ( pct/100 );
      UPDATE employee SET salary = s
         WHERE CURRENT OF sal_cursor;
   END FOREACH;

END PROCEDURE;
```

Figure 11-49. A FOREACH loop that operates on the employee table.

The routine in preceding figure performs these tasks within the FOREACH loop:
- Declares a cursor
- Selects one **salary** value at a time from **employee**
- Increases the salary by a percentage
- Updates **employee** with the new salary
- Fetches the next salary value

The SELECT statement is placed within a cursor because it returns all the salaries in the table greater than 35000.

The WHERE CURRENT OF clause in the UPDATE statement updates only the row on which the cursor is currently positioned, and sets an *update cursor* on the current row. An update cursor places an update lock on the row so that no other user can update the row until your update occurs.

An SPL routine will set an update cursor automatically if an UPDATE or DELETE statement within the FOREACH loop uses the WHERE CURRENT OF clause. If you use WHERE CURRENT OF, you must explicitly reference the cursor within the FOREACH statement. If you are using an update cursor, you can add a BEGIN WORK statement before the FOREACH statement and a COMMIT WORK statement after END FOREACH, as the following figure shows.

```
BEGIN WORK;
   FOREACH sal_cursor FOR
      SELECT salary INTO s FROM employee WHERE salary > 35000;
      LET s = s + s * ( pct/100 );
      UPDATE employee SET salary = s WHERE CURRENT OF sal_cursor
   END FOREACH;
COMMIT WORK;
```

Figure 11-50. Set an update cursor automatically.

For each iteration of the FOREACH loop in the preceding figure, a new lock is acquired (if you use row level locking). The COMMIT WORK statement releases all of the locks (and commits all of the updated rows as a single transaction) after the last iteration of the FOREACH loop.

To commit an updated row after each iteration of the loop, you must open the cursor WITH HOLD, and include the BEGIN WORK and COMMIT WORK statements *within* the FOREACH loop, as in the following SPL routine.

```
CREATE PROCEDURE serial_update();
    DEFINE p_col2 INT;
    DEFINE i INT;
    LET i = 1;
    FOREACH cur_su WITH HOLD FOR
        SELECT col2 INTO p_col2 FROM customer WHERE 1=1
        BEGIN WORK;
            UPDATE customer SET customer_num = p_col2 WHERE CURRENT OF cur_su;
        COMMIT WORK;
        LET i = i + 1;
    END FOREACH;
END PROCEDURE;
```

Figure 11-51. Committing an updated row after each iteration of the loop.

SPL routine **serial_update()** commits each row as a separate transaction.

Restriction for FOREACH loops

Within a FOREACH loop, the SELECT query must complete execution before any DELETE, INSERT, or UPDATE operation that changes the data set of the SELECT cursor. One way to ensure that the SELECT query completes, use an ORDER BY clause in the SELECT statement. The ORDER BY clause creates an index on the columns and prevents errors caused by UPDATE, INSERT, DELETE statements modifying the query results of the SELECT statement in the same FOREACH loop

An IF - ELIF - ELSE structure

The following SPL routine uses an IF - ELIF - ELSE structure to compare the two arguments that the routine accepts.

```
CREATE FUNCTION str_compare( str1 CHAR(20), str2 CHAR(20))
   RETURNING INTEGER;

   DEFINE result INTEGER;

   IF str1 > str2 THEN
      LET result = 1;
   ELIF str2 > str1 THEN
      LET result = -1;
   ELSE
      LET result = 0;
   END IF
   RETURN result;
END FUNCTION;
```

Figure 11-52. An IF - ELIF - ELSE structure to compare two arguments.

Suppose you define a table named **manager** with the columns that the following figure shows.

```
CREATE TABLE manager
(
   mgr_name   VARCHAR(30),
   department VARCHAR(12),
   dept_no    SMALLINT,
   direct_reports SET( VARCHAR(30) NOT NULL ),
   projects LIST( ROW ( pro_name VARCHAR(15),
   pro_members SET( VARCHAR(20) NOT NULL ) )
                    NOT NULL),
   salary     INTEGER,
);
```

Figure 11-53. Define the manager table.

The following SPL routine uses an IF - ELIF - ELSE structure to check the number of elements in the SET in the **direct_reports** column and call various external routines based on the results.

```
CREATE FUNCTION checklist( d SMALLINT )
   RETURNING VARCHAR(30), VARCHAR(12), INTEGER;

   DEFINE name VARCHAR(30);
   DEFINE dept VARCHAR(12);
   DEFINE num INTEGER;

   SELECT mgr_name, department,
          CARDINALITY(direct_reports)
      FROM manager INTO name, dept, num
      WHERE dept_no = d;
   IF num > 20 THEN
      EXECUTE FUNCTION add_mgr(dept);
   ELIF num = 0 THEN
      EXECUTE FUNCTION del_mgr(dept);
   ELSE
      RETURN name, dept, num;
   END IF;

END FUNCTION;
```

Figure 11-54. An IF - ELIF - ELSE structure to check the number of elements in the SET.

The **cardinality()** function counts the number of elements that a collection contains. For more information, see "Cardinality function" on page 4-12.

An IF - ELIF - ELSE structure in an SPL routine has up to the following four parts:

- An IF THEN condition

  If the condition following the IF statement is TRUE, the routine executes the statements in the IF block. If the condition is false, the routine evaluates the ELIF condition.

  The expression in an IF statement can be any valid condition, as the Condition segment of the *IBM Informix Guide to SQL: Syntax* describes. For the complete syntax and a detailed discussion of the IF statement, see the *IBM Informix Guide to SQL: Syntax*.
- One or more ELIF conditions (optional)

  The routine evaluates the ELIF condition only if the IF condition is false. If the ELIF condition is true, the routine executes the statements in the ELIF block. If the ELIF condition is false, the routine either evaluates the next ELIF block or executes the ELSE statement.
- An ELSE condition (optional)

  The routine executes the statements in the ELSE block if the IF condition and all of the ELIF conditions are false.
- An END IF statement

  The END IF statement ends the statement block.

Add WHILE and FOR loops

Both the WHILE and FOR statements create execution loops in SPL routines. A WHILE loop starts with a WHILE *condition*, executes a block of statements as long as the condition is true, and ends with END WHILE.

The following figure shows a valid WHILE condition. The routine executes the WHILE loop as long as the condition specified in the WHILE statement is true.

```
CREATE PROCEDURE test_rows( num INT )

   DEFINE i INTEGER;
   LET i = 1;

   WHILE i < num
      INSERT INTO table1 (numbers) VALUES (i);
      LET i = i + 1;
   END WHILE;

END PROCEDURE;
```

Figure 11-55. Routine to execute the WHILE loop as long as the condition specified in the WHILE statement is true.

The SPL routine in the previous figure accepts an integer as an argument and then inserts an integer value into the **numbers** column of **table1** each time it executes the WHILE loop. The values inserted start at 1 and increase to `num - 1`.

Be careful that you do not create an endless loop, as the following figure shows.

```
CREATE PROCEDURE endless_loop()

   DEFINE i INTEGER;
   LET i = 1;
   WHILE ( 1 = 1 )            -- don't do this!
      LET i = i + 1;
      INSERT INTO table1 VALUES (i);
   END WHILE;

END PROCEDURE;
```

Figure 11-56. Routine to accept an integer as an argument and then insert an integer value into the numbers column.

A FOR loop extends from a FOR statement to an END FOR statement and executes for a specified number of iterations, which are defined in the FOR statement. The following figure shows several ways to define the iterations in the FOR loop.

For each iteration of the FOR loop, the iteration variable (declared as *i* in the examples that follow) is reset, and the statements within the loop are executed with the new value of the variable.

```
FOR i = 1 TO 10
. . .
END FOR;

FOR i = 1 TO 10 STEP 2
. . .
END FOR;

FOR i IN (2,4,8,14,22,32)
. . .
END FOR;

FOR i IN (1 TO 20 STEP 5, 20 to 1 STEP -5, 1,2,3,4,5)
. . .
END FOR:
```

Figure 11-57. Defining iterations in the FOR loop.

In the first example, the SPL procedure executes the FOR loop as long as *i* is between 1 and 10, inclusive. In the second example, *i* steps from 1 to 3, 5, 7, and so on, but never exceeds 10. The third example checks whether *i* is within a defined set of values. In the fourth example, the SPL procedure executes the loop when *i* is 1, 6, 11, 16, 20, 15, 10, 5, 1, 2, 3, 4, or 5—in other words, 13 times.

Tip: The main difference between a WHILE loop and a FOR loop is that a FOR loop is guaranteed to finish, but a WHILE loop is not. The FOR statement specifies the exact number of times the loop executes, unless a statement causes the routine to exit the loop. With WHILE, it is possible to create an endless loop.

Exit a loop

In a FOR, FOREACH, LOOP, or WHILE loop that has no label, you can use the CONTINUE or EXIT statement to control the execution of the loop.

- CONTINUE causes the routine to skip the statements in the rest of the loop and move to the next iteration of the FOR, LOOP, or WHILE statement.
- EXIT ends the loop and causes the routine to continue executing with the first statement following the END FOR, the END LOOP, or the END WHILE keywords.

Remember that EXIT must be followed by the FOREACH keyword when it appears within a FOREACH statement that is the innermost loop of nested loop statements. EXIT can appear with no immediately following keyword when it appears within the FOR, LOOP, or WHILE statement, but an error is issued if you specify a keyword that does not match the loop statement from which the EXIT statement was issued. An error is also issued if EXIT appears outside the context of a loop statement.

For more information about loops in SPL routines, including labelled loops, see *IBM Informix Guide to SQL: Syntax*.

The following figure shows examples of CONTINUE and EXIT within a FOR loop.

```
FOR i = 1 TO 10
   IF i = 5 THEN
      CONTINUE FOR;
. . .
   ELIF i = 8 THEN
      EXIT FOR;
   END IF;

END FOR;
```

Figure 11-58. Examples of CONTINUE and EXIT within a FOR loop.

Tip: You can use CONTINUE and EXIT to improve the performance of SPL routines so that loops do not execute unnecessarily.

Return values from an SPL function

SPL functions can return one or more values. To have your SPL function return values, you need to include the following two parts:

1. Write a RETURNING clause in the CREATE PROCEDURE or CREATE FUNCTION statement that specifies the number of values to be returned and their data types.
2. In the body of the function, enter a RETURN statement that explicitly returns the values.

Tip: You can define a routine with the CREATE PROCEDURE statement that returns values, but in that case, the routine is actually a function. It is recommended that you use the CREATE FUNCTION statement when the routine returns values.

After you define a return clause (with a RETURNING statement), the SPL function can return values that match those specified in number and data type, or no values at all. If you specify a return clause, and the SPL routine returns no actual values, it is still considered a function. In that case, the routine returns a NULL value for each value defined in the return clause.

An SPL function can return variables, expressions, or the result of another function call. If the SPL function returns a variable, the function must first assign the variable a value by one of the following methods:

- A LET statement
- A default value
- A SELECT statement
- Another function that passes a value into the variable

Each value an SPL function returns can be up to 32 kilobytes long.

Important: The return value for an SPL function must be a specific data type. You cannot specify a generic row or generic collection data type as a return type.

Return a single value

The following figure shows how an SPL function can return a single value.

```
CREATE FUNCTION increase_by_pct(amt DECIMAL, pct DECIMAL)
   RETURNING DECIMAL;

   DEFINE result DECIMAL;

   LET result = amt + amt * (pct/100);

   RETURN result;

END FUNCTION;
```

Figure 11-59. SPL function that returns a single value.

The **increase_by_pct** function receives two arguments of DECIMAL value, an amount to be increased and a percentage by which to increase it. The return clause specifies that the function will return one DECIMAL value. The RETURN statement returns the DECIMAL value stored in **result**.

Return multiple values

An SPL function can return more than one value from a single row of a table. The following figure shows an SPL function that returns two column values from a single row of a table.

```
CREATE FUNCTION birth_date( num INTEGER )
   RETURNING VARCHAR(30), DATE;

   DEFINE n VARCHAR(30);
   DEFINE b DATE;

   SELECT name, bdate INTO n, b FROM emp_tab
      WHERE emp_no = num;
   RETURN n, b;

END FUNCTION;
```

Figure 11-60. SPL function that returns two column values from a single row of a table.

The function returns two values (a name and birthdate) to the calling routine from one row of the **emp_tab** table. In this case, the calling routine must be prepared to handle the VARCHAR and DATE values returned.

The following figure shows an SPL function that returns more than one value from more than one row.

```
CREATE FUNCTION birth_date_2( num INTEGER )
   RETURNING VARCHAR(30), DATE;
   DEFINE n VARCHAR(30);
   DEFINE b DATE;
   FOREACH cursor1 FOR
      SELECT name, bdate INTO n, b FROM emp_tab
         WHERE emp_no > num
      RETURN n, b WITH RESUME;
   END FOREACH;
END FUNCTION;
```

Figure 11-61. SPL function that returns more than one value from more than one row.

In preceding figure, the SELECT statement fetches two values from the set of rows whose employee number is higher than the number the user enters. The set of rows that satisfy the condition could contain one row, many rows, or zero rows. Because the SELECT statement can return many rows, it is placed within a cursor.

Tip: When a statement within an SPL routine returns no rows, the corresponding SPL variables are assigned NULL values.

The RETURN statement uses the WITH RESUME keywords. When RETURN WITH RESUME is executed, control is returned to the calling routine. But the next time the SPL function is called (by a FETCH or the next iteration of a cursor in the calling routine), all the variables in the SPL function keep their same values, and execution continues at the statement immediately following the RETURN WITH RESUME statement.

If your SPL routine returns multiple values, the calling routine must be able to handle the multiple values through a cursor or loop, as follows:
- If the calling routine is an SPL routine, it needs a FOREACH loop.
- If the calling routine is an Informix ESQL/C program, it needs a cursor declared with the DECLARE statement.
- If the calling routine is an external routine, it needs a cursor or loop appropriate to the language in which the routine is written.

Important: The values returned by a UDR from external databases of a local server must be built-in data types or UDTs explicitly cast to built-in types or DISTINCT types based on built-in types and explicitly cast to built-in types. In addition, you must define the UDR and all the casts in the participating databases.

An example of SQL operations you can perform across databases follows:

```
database db1;
create table ltab1(lcol1 integer, lcol2 boolean, lcol3 lvarchar);
insert into ltab1 values(1, 't', "test string 1");

database db2;
create table rtab1(r1col1 boolean, r1col2 blob, r1col3 integer)
put r1col2 in (sbsp);
create table rtab2(r2col1 lvarchar, r2col2 clob) put r2col2 in (sbsp);
create table rtab3(r3col1 integer, r3col2 boolean,
r3col3 lvarchar, r3col4 circle);

create view rvw1 as select  * from rtab3;
```

(The example is a cross-database Insert.)

```
database db1;
create view lvw1 as select * from db2:rtab2;
insert into db2:rtab1 values('t',
filetoblob('blobfile', 'client', 'db2:rtab1', 'r1col2'), 100);
insert into db2:rtab2 values("inserted directly to rtab2",
filetoclob('clobfile', 'client', 'db2:rtab2', 'r2col2'));
insert into db2:rtab3 (r3col1, r3col2, r3col3)
select lcol1, lcol2, lcol3 from ltab1;
insert into db2:rvw1 values(200, 'f', "inserted via rvw1");
insert into lvw1 values ("inserted via lvw1", NULL);
```

Handle row-type data

In an SPL routine, you can use named ROW types and unnamed ROW types as parameter definitions, arguments, variable definitions, and return values. For information about how to declare a ROW variable in SPL, see “Declare row-type variables” on page 11-16.

The following figure defines a row type **salary_t** and an **emp_info** table, which are the examples that this section uses.

```
CREATE ROW TYPE salary_t(base MONEY(9,2), bonus MONEY(9,2))

CREATE TABLE emp_info (emp_name VARCHAR(30), salary salary_t);
```

Figure 11-62. Define a row type salary_t and an emp_info table

The **emp_info** table has columns for the employee name and salary information.

Precedence of dot notation

With IBM Informix, a value that uses dot notation (as in **proj.name**) in an SQL statement in an SPL routine is interpreted as having one of three meanings, in the following order of precedence:

1. *variable.field*
2. *column.field*
3. *table.column*

In other words, the expression **proj.name** is first evaluated as *variable.field.* If the routine does not find a variable **proj**, it evaluates the expression as *column.field*. If the routine does not find a column **proj**, it evaluates the expression as *table.column*. (If the names cannot be resolved as identifiers of objects in the database or of variables or fields that were declared in the SPL routine, then an error is returned.)

Update a row-type expression

From within an SPL routine, you can use a ROW variable to update a row-type expression. The following figure shows an SPL procedure **emp_raise** that is used to update the **emp_info** table when an employee's base salary increases by a certain percentage.

```
CREATE PROCEDURE emp_raise( name VARCHAR(30),
                 pct DECIMAL(3,2) )

   DEFINE row_var salary_t;

   SELECT salary INTO row_var FROM emp_info
      WHERE emp_name = name;

   LET row_var.base = row_var.base * pct;

   UPDATE emp_info SET salary = row_var
      WHERE emp_name = name;
END PROCEDURE;
```

Figure 11-63. SPL procedure used to update the emp_info table.

The SELECT statement selects a row from the **salary** column of **emp_info table** into the ROW variable **row_var**.

The **emp_raise** procedure uses SPL dot notation to directly access the **base** field of the variable **row_var**. In this case, the dot notation means *variable.field*. The **emp_raise** procedure recalculates the value of **row_var.base** as (`row_var.base * pct`). The procedure then updates the **salary** column of the **emp_info** table with the new **row_var** value.

Important: A row-type variable must be initialized as a row before its fields can be set or referenced. You can initialize a row-type variable with a SELECT INTO statement or LET statement.

Handle collections

A *collection* is a group of elements of the same data type, such as a SET, MULTISET, or LIST.

A table might contain a collection stored as the contents of a column or as a field of a ROW type within a column. A collection can be either simple or nested. A *simple collection* is a SET, MULTISET, or LIST of built-in, opaque, or distinct data types. A *nested collection* is a collection that contains other collections.

Collection data types

The following sections of the chapter rely on several different examples to show how you can manipulate collections in SPL programs.

The basics of handling collections in SPL programs are illustrated with the **numbers** table, as the following figure shows.

```
CREATE TABLE numbers
(
   id INTEGER PRIMARY KEY,
   primes      SET( INTEGER NOT NULL ),
   evens       LIST( INTEGER NOT NULL ),
   twin_primes  LIST( SET( INTEGER NOT NULL )
                  NOT NULL )
```

Figure 11-64. Handle collections in SPL programs.

The **primes** and **evens** columns hold simple collections. The **twin_primes** column holds a nested collection, a LIST of SETs. (Twin prime numbers are pairs of consecutive prime numbers whose difference is 2, such as 5 and 7, or 11 and 13. The **twin_primes** column is designed to allow you to enter such pairs.

Some examples in this chapter use the **polygons** table in the following figure to illustrate how to manipulate collections. The **polygons** table contains a collection to represent two-dimensional graphical data. For example, suppose that you define an opaque data type named **point** that has two double-precision values that represent the **x** and **y** coordinates of a two-dimensional point whose coordinates might be represented as `'1.0, 3.0'`. Using the **point** data type, you can create a table that contains a set of points that define a polygon.

```
CREATE OPAQUE TYPE point ( INTERNALLENGTH = 8);

CREATE TABLE polygons
(
   id          INTEGER PRIMARY KEY,
   definition  SET( point NOT NULL )
);
```

Figure 11-65. Manipulate collections.

The **definition** column in the **polygons** table contains a simple collection, a SET of **point** values.

Prepare for collection data types

Before you can access and handle an individual element of a simple or nested collection, you must perform the following tasks:

- Declare a collection variable to hold the collection.
- Declare an element variable to hold an individual element of the collection.
- Select the collection from the database into the collection variable.

After you take these initial steps, you can insert elements into the collection or select and handle elements that are already in the collection.

Each of these steps is explained in the following sections, using the **numbers** table as an example.

Tip: You can handle collections in any SPL routine.

Declare a collection variable

Before you can retrieve a collection from the database into an SPL routine, you must declare a collection variable. The following figure shows how to declare a collection variable to retrieve the **primes** column from the **numbers** table.

```
DEFINE p_coll SET( INTEGER NOT NULL );
```

Figure 11-66. Declare a collection variable.

The DEFINE statement declares a collection variable **p_coll**, whose type matches the data type of the collection stored in the **primes** column.

Declare an element variable

After you declare a collection variable, you declare an element variable to hold individual elements of the collection. The data type of the element variable must match the data type of the collection elements.

For example, to hold an element of the SET in the **primes** column, use an element variable declaration such as the one that the following figure shows.

```
DEFINE p INTEGER;
```

Figure 11-67. An element variable declaration.

To declare a variable that holds an element of the **twin_primes** column, which holds a nested collection, use a variable declaration such as the one that the following figure shows.

```
DEFINE s SET( INTEGER NOT NULL );
```

Figure 11-68. A variable declaration.

The variable **s** holds a SET of integers. Each SET is an element of the LIST stored in **twin_primes**.

Select a collection into a collection variable

After you declare a collection variable, you can fetch a collection into it. To fetch a collection into a collection variable, enter a SELECT INTO statement that selects the collection column from the database into the collection variable you have named.

For example, to select the collection stored in one row of the **primes** column of **numbers**, add a SELECT statement, such as the one that the following figure shows, to your SPL routine.

```
SELECT primes INTO p_coll FROM numbers
   WHERE id = 220;
```

Figure 11-69. Add a SELECT statement to select the collection stored in one row.

The WHERE clause in the SELECT statement specifies that you want to select the collection stored in just one row of **numbers**. The statement places the collection into the collection variable **p_coll**, which Figure 11-66 on page 11-36 declares.

The variable **p_coll** now holds a collection from the **primes** column, which could contain the value `SET {5,7,31,19,13}`.

Insert elements into a collection variable

After you retrieve a collection into a collection variable, you can insert a value into the collection variable. The syntax of the INSERT statement varies slightly, depending on the type of the collection to which you want to add values.

Insert into a SET or MULTISET

To insert into a SET or MULTISET stored in a collection variable, use an INSERT statement and follow the TABLE keyword with the collection variable, as the following figure shows.

```
INSERT INTO TABLE(p_coll) VALUES(3);
```

Figure 11-70. Insert into a SET or MULTISET stored in a collection variable.

The TABLE keyword makes the collection variable a collection-derived table. Collection-derived tables are described in the section "Handle collections in SELECT statements" on page 5-27. The collection that the previous figure derives is a virtual table of one column, with each element of the collection representing a row of the table. Before the insert, consider **p_coll** as a virtual table that contains the rows (elements) that the following figure shows.

```
5
7
31
19
13
```

Figure 11-71. Virtual table elements.

After the insert, **p_coll** might look like the virtual table that the following figure shows.

```
5
7
31
19
13
3
```

Figure 11-72. Virtual table elements.

Because the collection is a SET, the new value is added to the collection, but the position of the new element is undefined. The same principle is true for a MULTISET.

Tip: You can only insert one value at a time into a simple collection.

Insert into a LIST

If the collection is a LIST, you can add the new element at a specific point in the LIST or at the end of the LIST. As with a SET or MULTISET, you must first define a collection variable and select a collection from the database into the collection variable.

The following figure shows the statements you need to define a collection variable and select a LIST from the **numbers** table into the collection variable.

```
DEFINE e_coll LIST(INTEGER NOT NULL);

SELECT evens INTO e_coll FROM numbers
   WHERE id = 99;
```

Figure 11-73. Defining a collection variable and selecting a LIST.

At this point, the value of **e_coll** might be `LIST {2,4,6,8,10}`. Because **e_coll** holds a LIST, each element has a numbered position in the list. To add an element at a specific point in a LIST, add an AT *position* clause to the INSERT statement, as the following figure shows.

```
INSERT AT 3 INTO TABLE(e_coll) VALUES(12);
```

Figure 11-74. Add an element at a specific point in a LIST.

Now the LIST in **e_coll** has the elements `{2,4,12,6,8,10}`, in that order.

The value you enter for the *position* in the AT clause can be a number or a variable, but it must have an INTEGER or SMALLINT data type. You cannot use a letter, floating-point number, decimal value, or expression.

Check the cardinality of a LIST collection

At times you might want to add an element at the end of a LIST. In this case, you can use the **cardinality()** function to find the number of elements in a LIST and then enter a position that is greater than the value **cardinality()** returns.

IBM Informix allows you to use the **cardinality()** function with a collection that is stored in a column but not with a collection that is stored in a collection variable. In an SPL routine, you can check the cardinality of a collection in a column with a SELECT statement and return the value to a variable.

Suppose that in the **numbers** table, the **evens** column of the row whose **id** column is 99 still contains the collection `LIST {2,4,6,8,10}`. This time, you want to add the element 12 at the end of the LIST. You can do so with the SPL procedure **end_of_list**, as the following figure shows.

```
CREATE PROCEDURE end_of_list()

   DEFINE n SMALLINT;
   DEFINE list_var LIST(INTEGER NOT NULL);

   SELECT CARDINALITY(evens) FROM numbers INTO n
      WHERE id = 100;

   LET n = n + 1;

   SELECT evens INTO list_var FROM numbers
      WHERE id = 100;

   INSERT AT n INTO TABLE(list_var) VALUES(12);

END PROCEDURE;
```

Figure 11-75. The end_of_list SPL procedure.

In **end_of_list**, the variable **n** holds the value that **cardinality()** returns, that is, the count of the items in the LIST. The LET statement increments **n**, so that the INSERT statement can insert a value at the last position of the LIST. The SELECT statement selects the collection from one row of the table into the collection variable **list_var**. The INSERT statement inserts the element 12 at the end of the list.

Syntax of the VALUES clause

The syntax of the VALUES clause is different when you insert into an SPL collection variable from when you insert into a collection column. The syntax rules for inserting literals into collection variables are as follows:

- Use parentheses after the VALUES keyword to enclose the complete list of values.
- If you are inserting into a simple collection, you do not need to use a type constructor or brackets.
- If you are inserting into a nested collection, you need to specify a literal collection.

Select elements from a collection

Suppose you want your SPL routine to select elements from the collection stored in the collection variable, one at time, so that you can handle the elements.

To move through the elements of a collection, you first need to declare a cursor using a FOREACH statement, just as you would declare a cursor to move through a set of rows. The following figure shows the FOREACH and END FOREACH statements, with no statements between them yet.

```
FOREACH cursor1 FOR
. . .
END FOREACH
```

Figure 11-76. FOREACH and END FOREACH statements.

The FOREACH statement is described in “The FOREACH loop” on page 11-24 and the *IBM Informix Guide to SQL: Syntax*.

The next topic, "The collection query," describes the statements that are omitted between the FOREACH and END FOREACH statements.

The examples in the following sections are based on the **polygons** table of Figure 11-65 on page 11-36.

The collection query

After you declare the cursor between the FOREACH and END FOREACH statements, you enter a special, restricted form of the SELECT statement known as a *collection query*.

A collection query is a SELECT statement that uses the FROM TABLE keywords followed by the name of a collection variable. The following figure shows this structure, which is known as a *collection-derived table*.

```
FOREACH cursor1 FOR

   SELECT * INTO pnt FROM TABLE(vertexes)
   . . .
END FOREACH
```

Figure 11-77. Collection-derived table.

The SELECT statement uses the collection variable **vertexes** as a collection-derived table. You can think of a collection-derived table as a table of one column, with each element of the collection being a row of the table. For example, you can visualize the SET of four points stored in **vertexes** as a table with four rows, such as the one that the following figure shows.

```
'(3.0,1.0)'
'(8.0,1.0)'
'(3.0,4.0)'
'(8.0,4.0)'
```

Figure 11-78. Table with four rows.

After the first iteration of the FOREACH statement in the previous figure, the collection query selects the first element in **vertexes** and stores it in **pnt**, so that **pnt** contains the value `'(3.0,1.0)'`.

Tip: Because the collection variable **vertexes** contains a SET, not a LIST, the elements in **vertexes** have no defined order. In a real database, the value **`'(3.0,1.0)'`** might not be the first element in the SET.

Add the collection query to the SPL routine

Now you can add the cursor defined with FOREACH and the collection query to the SPL routine, as the following example shows.

```
CREATE PROCEDURE shapes()

   DEFINE vertexes SET( point NOT NULL );
   DEFINE pnt point;

   SELECT definition INTO vertexes FROM polygons
      WHERE id = 207;

   FOREACH cursor1 FOR
      SELECT * INTO pnt FROM TABLE(vertexes)
   . . .
   END FOREACH
. . .
END PROCEDURE;
```

Figure 11-79. Cursor defined with FOREACH and the collection query.

The statements shown above form the framework of an SPL routine that handles the elements of a collection variable. To decompose a collection into its elements, use a collection-derived table. After the collection is decomposed into its elements, the routine can access elements individually as rows of the collection-derived table. Now that you have selected one element in **pnt**, you can update or delete that element, as "Update a collection element" on page 11-45 and "Delete a collection element" describe.

For the complete syntax of the collection query, see the SELECT statement in the *IBM Informix Guide to SQL: Syntax*. For the syntax of a collection-derived table, see the Collection-Derived Table segment in the *IBM Informix Guide to SQL: Syntax*.

Tip: If you are selecting from a collection that contains no elements or zero elements, you can use a collection query without declaring a cursor. However, if the collection contains more than one element and you do not use a cursor, you will receive an error message.

Attention: In the program fragment above, the database server would have issued a syntax error if the query (

```
SELECT * INTO pnt FROM TABLE(vertexes)
```

) within the FOREACH cursor definition had ended with a semicolon (**;**) character as a statement terminator. Here the END FOREACH keywords are the logical statement terminator.

Delete a collection element

After you select an individual element from a collection variable into an element variable, you can delete the element from the collection. For example, after you select a point from the collection variable **vertexes** with a collection query, you can remove the point from the collection.

The steps involved in deleting a collection element include:

1. Declare a collection variable and an element variable.
2. Select the collection from the database into the collection variable.
3. Declare a cursor so that you can select elements one at a time from the collection variable.
4. Write a loop or branch that locates the element that you want to delete.

5. Delete the element from the collection using a DELETE WHERE CURRENT OF statement that uses the collection variable as a collection-derived table.

The following figure shows a routine that deletes one of the four points in **vertexes**, so that the polygon becomes a triangle instead of a rectangle.

```
CREATE PROCEDURE shapes()

   DEFINE vertexes SET( point NOT NULL );
   DEFINE pnt point;

   SELECT definition INTO vertexes FROM polygons
      WHERE id = 207;

   FOREACH cursor1 FOR
      SELECT * INTO pnt FROM TABLE(vertexes)
      IF pnt = '(3,4)' THEN
            -- calls the equals function that
            -- compares two values of point type
         DELETE FROM TABLE(vertexes)
            WHERE CURRENT OF cursor1;
         EXIT FOREACH;
      ELSE
         CONTINUE FOREACH;
      END IF;
   END FOREACH
. . .
END PROCEDURE;
```

Figure 11-80. Routine that deletes one of the four points.

In previous figure, the FOREACH statement declares a cursor. The SELECT statement is a collection-derived query that selects one element at a time from the collection variable **vertexes** into the element variable **pnt**.

The IF THEN ELSE structure tests the value currently in **pnt** to see if it is the point `'(3,4)'`. Note that the expression `pnt = '(3,4)'` calls the instance of the **equal()** function defined on the point data type. If the current value in **pnt** is `'(3,4)'`, the DELETE statement deletes it, and the EXIT FOREACH statement exits the cursor.

Tip: Deleting an element from a collection stored in a collection variable does not delete it from the collection stored in the database. After you delete the element from a collection variable, you must update the collection stored in the database with the new collection. For an example that shows how to update a collection column, see "Update the collection in the database."

The syntax for the DELETE statement is described in the *IBM Informix Guide to SQL: Syntax*.

Update the collection in the database

After you change the contents of a collection variable in an SPL routine (by deleting, updating, or inserting an element), you must update the database with the new collection.

To update a collection in the database, add an UPDATE statement that sets the collection column in the table to the contents of the updated collection variable. For example, the UPDATE statement in the following figure shows how to update the **polygons** table to set the **definition** column to the new collection stored in the collection variable **vertexes**.

```
CREATE PROCEDURE shapes()

   DEFINE vertexes SET(point NOT NULL);
   DEFINE pnt point;

   SELECT definition INTO vertexes FROM polygons
      WHERE id = 207;

   FOREACH cursor1 FOR
      SELECT * INTO pnt FROM TABLE(vertexes)
      IF pnt = '(3,4)' THEN
            -- calls the equals function that
            -- compares two values of point type
         DELETE FROM TABLE(vertexes)
            WHERE CURRENT OF cursor1;
         EXIT FOREACH;
      ELSE
         CONTINUE FOREACH;
      END IF;
   END FOREACH

   UPDATE polygons SET definition = vertexes
      WHERE id = 207;

END PROCEDURE;
```

Figure 11-81. Update a collection in the database.

Now the **shapes()** routine is complete. After you run **shapes()**, the collection stored in the row whose ID column is `207` is updated so that it contains three values instead of four.

You can use the **shapes()** routine as a framework for writing other SPL routines that manipulate collections.

The elements of the collection now stored in the **definition** column of row `207` of the **polygons** table are listed as follows:

```
'(3,1)'
'(8,1)'
'(8,4)'
```

Delete the entire collection

If you want to delete all the elements of a collection, you can use a single SQL statement. You do not need to declare a cursor. To delete an entire collection, you must perform the following tasks:

- Define a collection variable.
- Select the collection from the database into a collection variable.
- Enter a DELETE statement that uses the collection variable as a collection-derived table.
- Update the collection from the database.

The following figure shows the statements that you might use in an SPL routine to delete an entire collection.

```
DEFINE vertexes SET( INTEGER NOT NULL );

SELECT definition INTO vertexes FROM polygons
   WHERE id = 207;

DELETE FROM TABLE(vertexes);

UPDATE polygons SET definition = vertexes
   WHERE id = 207;
```

Figure 11-82. SPL routine to delete an entire collection.

This form of the DELETE statement deletes the entire collection in the collection variable **vertexes**. You cannot use a WHERE clause in a DELETE statement that uses a collection-derived table.

After the UPDATE statement, the **polygons** table contains an empty collection where the **id** column is equal to 207.

The syntax for the DELETE statement is described in the *IBM Informix Guide to SQL: Syntax*.

Update a collection element

You can update a collection element by accessing the collection within a cursor just as you select or delete an individual element.

If you want to update the collection SET{100, 200, 300, 500} to change the value 500 to 400, retrieve the SET from the database into a collection variable and then declare a cursor to move through the elements in the SET, as the following figure shows.

```
DEFINE s SET(INTEGER NOT NULL);
DEFINE n INTEGER;

SELECT numbers INTO s FROM orders
   WHERE order_num = 10;

FOREACH cursor1 FOR
   SELECT * INTO n FROM TABLE(s)
   IF ( n == 500 ) THEN
      UPDATE TABLE(s)(x)
         SET x = 400 WHERE CURRENT OF cursor1;
      EXIT FOREACH;
   ELSE
      CONTINUE FOREACH;
   END IF;
END FOREACH
```

Figure 11-83. Update the collection element.

The UPDATE statement uses the collection variable **s** as a collection-derived table. To specify a collection-derived table, use the TABLE keyword. The value (x) that follows (s) in the UPDATE statement is a *derived column*, a column name you supply because the SET clause requires it, even though the collection-derived table does not have columns.

Think of the collection-derived table as having one row and looking something like the following example:

```
100      200      300      500
```

In this example, `x` is a fictitious column name for the "column" that contains the value `500`. You only specify a derived column if you are updating a collection of built-in, opaque, distinct, or collection type elements. If you are updating a collection of row types, use a field name instead of a derived column, as "Update a collection of row types" on page 11-47 describes.

Update a collection with a variable

You can also update a collection with the value stored in a variable instead of a literal value.

The SPL procedure in the following figure uses statements that are similar to the ones that Figure 11-83 on page 11-45 shows, except that this procedure updates the SET in the **direct_reports** column of the **manager** table with a variable, rather than with a literal value. Figure 11-53 on page 11-27 defines the **manager** table.

```
CREATE PROCEDURE new_report(mgr VARCHAR(30),
   old VARCHAR(30), new VARCHAR(30) )

   DEFINE s SET (VARCHAR(30) NOT NULL);
   DEFINE n VARCHAR(30);

   SELECT direct_reports INTO s FROM manager
      WHERE mgr_name = mgr;

   FOREACH cursor1 FOR
      SELECT * INTO n FROM TABLE(s)
      IF ( n == old ) THEN
         UPDATE TABLE(s)(x)
            SET x = new WHERE CURRENT OF cursor1;
         EXIT FOREACH;
      ELSE
         CONTINUE FOREACH;
      END IF;
   END FOREACH

   UPDATE manager SET mgr_name = s
      WHERE mgr_name = mgr;

END PROCEDURE;
```

Figure 11-84. Update a collection with a variable.

The UPDATE statement nested in the FOREACH loop uses the collection- derived table **s** and the derived column **x**. If the current value of *n* is the same as **old**, the UPDATE statement changes it to the value of **new**. The second UPDATE statement stores the new collection in the **manager** table.

Update the entire collection

If you want to update all the elements of a collection to the same value, or if the collection contains only one element, you do not need to use a cursor. The statements in the following figure show how you can retrieve the collection into a collection variable and then update it with one statement.

```
DEFINE s SET (INTEGER NOT NULL);

SELECT numbers INTO s FROM orders
   WHERE order_num = 10;

UPDATE TABLE(s)(x) SET x = 0;

UPDATE orders SET numbers = s
   WHERE order_num = 10;
```

Figure 11-85. Retrieve and update the collection.

The first UPDATE statement in this example uses a derived column named **x** with the collection-derived table **s** and gives all the elements in the collection the value 0. The second UPDATE statement stores the new collection in the database.

Update a collection of row types

To update a collection of ROW types, you can take these steps:

1. Declare a collection variable whose field data types match those of the ROW types in the collection.
2. Set the individual fields of the collection variable to the correct data values for the ROW type.
3. For each ROW type, update the entire row of the collection derived table using the collection variable.

The **manager** table in Figure 11-53 on page 11-27 has a column named **projects** that contains a LIST of ROW types with the definition that the following figure shows.

```
projects   LIST( ROW( pro_name VARCHAR(15),
           pro_members SET(VARCHAR(20) NOT NULL) ) NOT NULL)
```

Figure 11-86. LIST of ROW types definition.

To access the ROW types in the LIST, declare a cursor and select the LIST into a collection variable. After you retrieve each ROW type value in the **projects** column, however, you cannot update the **pro_name** or **pro_members** fields individually. Instead, for each ROW value that needs to be updated in the collection, you must replace the entire ROW with values from a collection variable that include the new field values, as the following figure shows.

```
CREATE PROCEDURE update_pro( mgr VARCHAR(30),
   pro VARCHAR(15) )

   DEFINE p LIST(ROW(a VARCHAR(15), b SET(VARCHAR(20)
          NOT NULL) ) NOT NULL);
   DEFINE r ROW(p_name VARCHAR(15), p_member SET(VARCHAR(20) NOT NULL) );
   LET r = ROW("project", "SET{'member'}");

SELECT projects INTO p FROM manager
      WHERE mgr_name = mgr;

   FOREACH cursor1 FOR
      SELECT * INTO r FROM TABLE(p)
      IF (r.p_name == 'Zephyr') THEN
         LET r.p_name = pro;
         UPDATE TABLE(p)(x) SET x = r
            WHERE CURRENT OF cursor1;
         EXIT FOREACH;
      END IF;
   END FOREACH

   UPDATE manager SET projects = p
      WHERE mgr_name = mgr;

END PROCEDURE;
```

Figure 11-87. Access the ROW types in the LIST.

Before you can use a row-type variable in an SPL program, you must initialize the row variable with a LET statement or a SELECT INTO statement. The UPDATE statement nested in the FOREACH loop of the previous figure sets the **pro_name** field of the row type to the value supplied in the variable **pro**.

Tip: To update a value in a SET in the **pro_members** field of the ROW type, declare a cursor and use an UPDATE statement with a derived column, as "Update a collection element" on page 11-45 explains.

Update a nested collection

If you want to update a collection of collections, you must declare a cursor to access the outer collection and then declare a nested cursor to access the inner collection.

For example, suppose that the **manager** table has an additional column, **scores**, which contains a LIST whose element type is a MULTISET of integers, as the following figure shows.

```
scores        LIST(MULTISET(INT NOT NULL) NOT NULL);
```

Figure 11-88. Update a collection of collections.

To update a value in the MULTISET, declare a cursor that moves through each value in the LIST and a nested cursor that moves through each value in the MULTISET, as the following figure shows.

```
CREATE FUNCTION check_scores ( mgr VARCHAR(30) )
   SPECIFIC NAME nested;
   RETURNING INT;

   DEFINE l LIST( MULTISET( INT NOT NULL ) NOT NULL );
   DEFINE m MULTISET( INT NOT NULL );
   DEFINE n INT;
   DEFINE c INT;

   SELECT scores INTO l FROM manager
      WHERE mgr_name = mgr;

   FOREACH list_cursor FOR
      SELECT * FROM TABLE(l) INTO m;

      FOREACH set_cursor FOR
         SELECT * FROM TABLE(m) INTO n;
         IF (n == 0) THEN
            DELETE FROM TABLE(m)
               WHERE CURRENT OF set_cursor;
         ENDIF;
      END FOREACH;
      LET c = CARDINALITY(m);
      RETURN c WITH RESUME;
   END FOREACH

END FUNCTION
   WITH LISTING IN '/tmp/nested.out';
```

Figure 11-89. Update a value in the MULTISET.

The SPL function selects each MULTISET in the **scores** column into **l**, and then each value in the MULTISET into **m**. If a value in **m** is 0, the function deletes it from the MULTISET. After the values of 0 are deleted, the function counts the remaining elements in each MULTISET and returns an integer.

Tip: Because this function returns a value for each MULTISET in the LIST, you must use a cursor to enclose the EXECUTE FUNCTION statement when you execute the function.

Insert into a collection

You can insert a value into a collection without declaring a cursor. If the collection is a SET or MULTISET, the value is added to the collection but the position of the new element is undefined because the collection has no particular order. If the value is a LIST, you can add the new element at a specific point in the LIST or at the end of the LIST.

In the **manager** table, the **direct_reports** column contains collections of SET type, and the **projects** column contains a LIST. To add a name to the SET in the **direct_reports** column, use an INSERT statement with a collection-derived table, as the following figure shows.

```
CREATE PROCEDURE new_emp( emp VARCHAR(30), mgr VARCHAR(30) )

   DEFINE r SET(VARCHAR(30) NOT NULL);

   SELECT direct_reports INTO r FROM manager
      WHERE mgr_name = mgr;

   INSERT INTO TABLE (r) VALUES(emp);

   UPDATE manager SET direct_reports = r
      WHERE mgr_name = mgr;

END PROCEDURE;
```

Figure 11-90. Insert a value into a collection.

This SPL procedure takes an employee name and a manager name as arguments. The procedure then selects the collection in the **direct_reports** column for the manager the user has entered, adds the employee name the user has entered, and updates the **manager** table with the new collection.

The INSERT statement in the previous figure inserts the new employee name that the user supplies into the SET contained in the collection variable **r**. The UPDATE statement then stores the new collection in the **manager** table.

Notice the syntax of the VALUES clause. The syntax rules for inserting literal data and variables into collection variables are as follows:

- Use parentheses after the VALUES keyword to enclose the complete list of values.
- If the collection is SET, MULTISET, or LIST, use the type constructor followed by brackets to enclose the list of values to be inserted. In addition, the collection value must be enclosed in quotes.
  ```
  VALUES( "SET{ 1,4,8,9 }" )
  ```
- If the collection contains a row type, use ROW followed by parentheses to enclose the list of values to be inserted:
  ```
  VALUES( ROW( 'Waters', 'voyager_project' ) )
  ```
- If the collection is a nested collection, nest keywords, parentheses, and brackets according to how the data type is defined:
  ```
  VALUES( "SET{ ROW('Waters', 'voyager_project'),
               ROW('Adams', 'horizon_project') }")
  ```

For more information on inserting values into collections, see Chapter 6, “Modify data,” on page 6-1.

Insert into a nested collection

If you want to insert into a nested collection, the syntax of the VALUES clause changes. Suppose, for example, that you want to insert a value into the **twin_primes** column of the **numbers** table that Figure 11-64 on page 11-35 shows.

With the **twin_primes** column, you might want to insert a SET into the LIST or an element into the inner SET. The following sections describe each of these tasks.

Insert a collection into the outer collection:
Inserting a SET into the LIST is similar to inserting a single value into a simple collection.

To insert a SET into the LIST, declare a collection variable to hold the LIST and select the entire collection into it. When you use the collection variable as a collection-derived table, each SET in the LIST becomes a row in the table. You can then insert another SET at the end of the LIST or at a specified point.

For example, the **twin_primes** column of one row of numbers might contain the following LIST, as the following figure shows.

```
LIST( SET{3,5}, SET{5,7}, SET{11,13} )
```

Figure 11-91. Sample LIST.

If you think of the LIST as a collection-derived table, it might look similar to the following.

```
{3,5}
{5,7}
{11,13}
```

Figure 11-92. Thinking of the LIST as a collection-derived table.

You might want to insert the value "SET{17,19}" as a second item in the LIST. The statements in the following figure show how to do this.

```
CREATE PROCEDURE add_set()

   DEFINE l_var LIST( SET( INTEGER NOT NULL ) NOT NULL );

   SELECT twin_primes INTO l_var FROM numbers
      WHERE id = 100;

   INSERT AT 2 INTO TABLE (l_var) VALUES( "SET{17,19}" );

   UPDATE numbers SET twin_primes = l
      WHERE id = 100;

END PROCEDURE;
```

Figure 11-93. Insert a value in the LIST.

In the INSERT statement, the VALUES clause inserts the value `SET {17,19}` at the second position of the LIST. Now the LIST looks like the following figure.

```
{3,5}
{17,19}
{5,7}
{11,13}
```

Figure 11-94. LIST items.

You can perform the same insert by passing a SET to an SPL routine as an argument, as the following figure shows.

```
CREATE PROCEDURE add_set( set_var SET(INTEGER NOT NULL),
   row_id INTEGER );

   DEFINE list_var LIST( SET(INTEGER NOT NULL) NOT NULL );
   DEFINE n SMALLINT;

   SELECT CARDINALITY(twin_primes) INTO n FROM numbers
      WHERE id = row_id;

   LET n = n + 1;

   SELECT twin_primes INTO list_var FROM numbers
      WHERE id = row_id;

   INSERT AT n INTO TABLE( list_var ) VALUES( set_var );

   UPDATE numbers SET twin_primes = list_var
      WHERE id = row_id;

END PROCEDURE;
```

Figure 11-95. Passing a SET to an SPL routine as an argument.

In **add_set()**, the user supplies a SET to add to the LIST and an INTEGER value that is the **id** of the row in which the SET will be inserted.

Insert a value into the inner collection:
In an SPL routine, you can also insert a value into the inner collection of a nested collection. In general, to access the inner collection of a nested collection and add a value to it, perform the following steps:

1. Declare a collection variable to hold the entire collection stored in one row of a table.
2. Declare an element variable to hold one element of the outer collection. The element variable is itself a collection variable.
3. Select the entire collection from one row of a table into the collection variable.
4. Declare a cursor so that you can move through the elements of the outer collection.
5. Select one element at a time into the element variable.
6. Use a branch or loop to locate the inner collection you want to update.
7. Insert the new value into the inner collection.
8. Close the cursor.
9. Update the database table with the new collection.

As an example, you can use this process on the **twin_primes** column of **numbers**. For example, suppose that **twin_primes** contains the values that the following figure shows, and you want to insert the value 18 into the last SET in the LIST.

```
LIST( SET( {3,5}, {5,7}, {11,13}, {17,19} ) )
```

Figure 11-96. The twin_primes list.

The following figure shows the beginning of a procedure that inserts the value.

```
CREATE PROCEDURE add_int()

   DEFINE list_var LIST( SET( INTEGER NOT NULL ) NOT NULL );
   DEFINE set_var SET( INTEGER NOT NULL );

   SELECT twin_primes INTO list_var FROM numbers
         WHERE id = 100;
```

Figure 11-97. Procedure that inserts the value.

So far, the **attaint** procedure has performed steps 1 on page 11-52, 2 on page 11-52, and 3 on page 11-52. The first DEFINE statement declares a collection variable that holds the entire collection stored in one row of numbers.

The second DEFINE statement declares an element variable that holds an element of the collection. In this case, the element variable is itself a collection variable because it holds a SET. The SELECT statement selects the entire collection from one row into the collection variable, **list_var**.

The following figure shows how to declare a cursor so that you can move through the elements of the outer collection.

```
FOREACH list_cursor FOR
   SELECT * INTO set_var FROM TABLE( list_var);

   FOREACH element_cursor FOR
```

Figure 11-98. Declare a cursor to move through the elements of the outer collection.

Executing routines

You can execute an SPL routine or external routine in any of these ways:

- Using a stand-alone EXECUTE PROCEDURE or EXECUTE FUNCTION statement that you execute from DB-Access
- Calling the routine explicitly from another SPL routine or an external routine
- Using the routine name with an expression in an SQL statement

An additional mechanism for executing routines supports only the **sysdbopen** and **sysdbclose** procedures, which the DBA can define. If a **sysdbopen** procedure whose owner matches the login identifier of a user exists in the database when the user connects to the database by the CONNECT or DATABASE statement, that routine is executed automatically. If no **sysdbopen** routine has an owner that matches the login identifier of the user, but a PUBLIC**.sysdbopen** routine exists, that routine is executed. This automatic invocation enables the DBA to customize the session environment for users at connection time. The **sysdbclose** routine is similarly invoked when the user disconnects from the database. (For more information about these session configuration routines, see the *IBM Informix Guide to SQL: Syntax* and the *IBM Informix Administrator's Guide*.)

An *external routine* is a routine written in C or some other external language.

The EXECUTE statements

You can use EXECUTE PROCEDURE or EXECUTE FUNCTION to execute an SPL routine or external routine. In general, it is best to use EXECUTE PROCEDURE with procedures and EXECUTE FUNCTION with functions.

Tip: For backward compatibility, the EXECUTE PROCEDURE statement allows you to use an SPL function name and an INTO clause to return values. However, *it is* recommended that you use EXECUTE PROCEDURE only with procedures and EXECUTE FUNCTION only with functions.

You can issue EXECUTE PROCEDURE and EXECUTE FUNCTION statements as stand-alone statements from DB-Access or from within an SPL routine or external routine. If the routine name is unique within the database, and if it does not require arguments, you can execute it by entering just its name and parentheses after EXECUTE PROCEDURE, as he following figure shows.

```
EXECUTE PROCEDURE update_orders();
```

Figure 11-99. Execute a procedure.

The INTO clause is never present when you invoke a procedure with the EXECUTE statement because a procedure does not return a value.

If the routine expects arguments, you must enter the argument values within parentheses, as the following figure shows.

```
EXECUTE FUNCTION scale_rectangles(107, 1.9)
   INTO new;
```

Figure 11-100. Execute a procedure with arguments.

The statement executes a function. Because a function returns a value, EXECUTE FUNCTION uses an INTO clause that specifies a variable where the return value is stored. The INTO clause must always be present when you use an EXECUTE statement to execute a function.

If the database has more than one procedure or function of the same name, IBM Informix locates the right function based on the data types of the arguments. For example, the statement in the previous figure supplies INTEGER and REAL values as arguments, so if your database contains multiple routines named **scale_rectangles()**, the database server executes only the **scale_rectangles()** function that accepts INTEGER and REAL data types.

The parameter list of an SPL routine always has parameter names as well as data types. When you execute the routine, the parameter names are optional. However, if you pass arguments by name (instead of just by value) to EXECUTE PROCEDURE or EXECUTE FUNCTION, as in the following figure, Informix resolves the routine-by-routine name and arguments only, a process known as *partial routine resolution*.

```
EXECUTE FUNCTION scale_rectangles( rectid = 107,
   scale = 1.9 ) INTO new_rectangle;
```

Figure 11-101. Execute a routine passing arguments by name.

You can also execute an SPL routine stored on another database server by adding a *qualified routine name* to the statement; that is, a name in the form `database@dbserver:owner_name.routine_name`, as in the following figure.

```
EXECUTE PROCEDURE informix@davinci:bsmith.update_orders();
```

Figure 11-102. Execute an SPL routine stored on another database server.

When you execute a routine remotely, the `owner_name` in the qualified routine name is optional.

The CALL statement

You can call an SPL routine or an external routine from an SPL routine using the CALL statement. CALL can execute both procedures and functions. If you use CALL to execute a function, add a RETURNING clause and the name of an SPL variable (or variables) that will receive the value (or values) the function returns.

Suppose, for example, that you want the **scale_rectangles** function to call an external function that calculates the area of the rectangle and then returns the area with the rectangle description, as in the following figure.

```
CREATE FUNCTION scale_rectangles( rectid INTEGER,
      scale REAL )
   RETURNING rectangle_t, REAL;

   DEFINE rectv rectangle_t;
   DEFINE a REAL;
   SELECT rect INTO rectv
      FROM rectangles WHERE id = rectid;
   IF ( rectv IS NULL ) THEN
      LET rectv.start = (0.0,0.0);
      LET rectv.length = 1.0;
      LET rectv.width = 1.0;
      LET a = 1.0;
      RETURN rectv, a;
   ELSE
      LET rectv.length = scale * rectv.length;
      LET rectv.width = scale * rectv.width;
      CALL area(rectv.length, rectv.width) RETURNING a;
      RETURN rectv, a;
   END IF;

END FUNCTION;
```

Figure 11-103. Call an external function.

The SPL function uses a CALL statement that executes the external function **area()**. The value **area()** returns is stored in **a** and returned to the calling routine by the RETURN statement.

In this example, **area()** is an external function, but you can use CALL in the same manner with an SPL function.

Execute routines in expressions

Just as with built-in functions, you can execute SPL routines (and external routines from SPL routines) by using them in expressions in SQL and SPL statements. A routine used in an expression is usually a function, because it returns a value to the rest of the statement.

For example, you might execute a function by a LET statement that assigns the return value to a variable. The statements in the following figure perform the same task. They execute an external function within an SPL routine and assign the return value to the variable **a**.

```
LET a = area( rectv.length, rectv.width );

CALL area( rectv.length, rectv.width ) RETURNING a;
   -- these statements are equivalent
```

Figure 11-104. Execute an external function within an SPL routine.

You can also execute an SPL routine from an SQL statement, as the following figure shows. Suppose you write an SPL function, **increase_by_pct**, which increases a given price by a given percentage. After you write an SPL routine, it is available for use in any other SPL routine.

```
CREATE FUNCTION raise_price ( num INT )
   RETURNING DECIMAL;

   DEFINE p DECIMAL;

   SELECT increase_by_pct(price, 20) INTO p
      FROM inventory WHERE prod_num = num;

   RETURN p;

END FUNCTION;
```

Figure 11-105. Execute an SPL routine from an SQL statement.

The example selects the **price** column of a specified row of **inventory** and uses the value as an argument to the SPL function **increase_by_pct**. The function then returns the new value of **price**, increased by 20 percent, in the variable **p**.

Execute an external function with the RETURN statement

You can use a RETURN statement to execute any external function from within an SPL routine. The following figure shows an external function that is used in the RETURN statement of an SPL program.

```
CREATE FUNCTION c_func() RETURNS int
LANGUAGE C;

CREATE FUNCTION spl_func() RETURNS INT;
   RETURN(c_func());
END FUNCTION;

EXECUTE FUNCTION spl_func();
```

Figure 11-106. A RETURN statement to execute an external function from within an SPL routine.

When you execute the **spl_func()** function, the **c_func()** function is invoked, and the SPL function returns the value that the external function returns.

Execute cursor functions from an SPL routine

A cursor function is a user-defined function that returns one or more rows of data and therefore requires a cursor to execute. A cursor function can be either of the following functions:

- An SPL function whose RETURN statement includes WITH RESUME
- An external function that is defined as an iterator function

The behavior of a cursor function is the same whether the function is an SPL function or an external function. However, an SPL cursor function can return more than one value per iteration, whereas an external cursor function (iterator function) can return only one value per iteration.

To execute a cursor function from an SPL routine, you must include the function in a FOREACH loop of an SPL routine. The following examples show different ways to execute a cursor function in a FOREACH loop:

```
FOREACH SELECT cur_func1(col_name) INTO spl_var FROM tab1
   INSERT INTO tab2 VALUES (spl_var);
END FOREACH

FOREACH EXECUTE FUNCTION cur_func2() INTO spl_var
   INSERT INTO tab2 VALUES (spl_var);
END FOREACH
```

Dynamic routine-name specification

Dynamic routine-name specification allows you to execute an SPL routine from another SPL routine, by building the name of the called routine within the calling routine. Dynamic routine-name specification simplifies how you can write an SPL routine that calls another SPL routine whose name is not known until runtime. The database server lets you specify an SPL variable instead of the explicit name of an SPL routine in the EXECUTE PROCEDURE or EXECUTE FUNCTION statement.

In the following figure, the SPL procedure **company_proc** updates a large company sales table and then assigns an SPL variable named **salesperson_proc** to hold the dynamically created name of an SPL procedure that updates another, smaller table that contains the monthly sales of an individual salesperson.

```
CREATE PROCEDURE company_proc ( no_of_items INT,
   itm_quantity SMALLINT, sale_amount MONEY,
   customer VARCHAR(50), sales_person VARCHAR(30) )

DEFINE salesperson_proc VARCHAR(60);

-- Update the company table
INSERT INTO company_tbl VALUES (no_of_items, itm_quantity,
   sale_amount, customer, sales_person);

-- Generate the procedure name for the variable salesperson_proc
LET salesperson_proc = sales_person || "." || "tbl" ||
   current_month || "_" || current_year || "_proc" ;

-- Execute the SPL procedure that the salesperson_proc
-- variable specifies
EXECUTE PROCEDURE salesperson_proc (no_of_items,
   itm_quantity, sale_amount, customer)
END PROCEDURE;
```

Figure 11-107. Dynamic routine-name specification.

In example, the procedure **company_proc** accepts five arguments and inserts them into **company_tbl**. Then the LET statement uses various values and the concatenation operator `||` to generate the name of another SPL procedure to execute. In the LET statement:

sales_person
An argument passed to the **company_proc** procedure.

current_month
The current month in the system date.

current_year
The current year in the system date.

Therefore, if a salesperson named Bill makes a sale in July 1998, **company_proc** inserts a record in **company_tbl** and executes the SPL procedure **bill.tbl07_1998_proc**, which updates a smaller table that contains the monthly sales of an individual salesperson.

Rules for dynamic routine-name specification

You must define the SPL variable that holds the name of the dynamically executed SPL routine as CHAR, VARCHAR, NCHAR, or NVARCHAR type. You must also give the SPL variable a valid and non-NULL name.

The SPL routine that the dynamic routine-name specification identifies must exist before it can be executed. If you assign the SPL variable the name of a valid SPL routine, the EXECUTE PROCEDURE or EXECUTE FUNCTION statement executes the routine whose name is contained in the variable, even if a built-in function of the same name exists.

In an EXECUTE PROCEDURE or EXECUTE FUNCTION statement, you cannot use two SPL variables to create a variable name in the form *owner.routine_name*. However, you can use an SPL variable that contains a fully qualified routine name, for example, *bill.proc1*. The following figure shows both cases.

```
EXECUTE PROCEDURE owner_variable.proc_variable;
   -- this is not allowed

LET proc1 = bill.proc1;
EXECUTE PROCEDURE proc1; -- this is allowed
```

Figure 11-108. SPL variable that contains a fully qualified routine name.

Privileges on routines

Privileges differentiate users who can create a routine from users who can execute a routine. Some privileges accrue as part of other privileges. For example, the DBA privilege includes permissions to create routines, execute routines, and grant these privileges to other users.

Privileges for registering a routine

To register a routine in the database, an authorized user wraps the SPL commands in a CREATE FUNCTION or CREATE PROCEDURE statement. The database server stores a registered SPL routine internally. The following users qualify to register a new routine in the database:

- Any user with the DBA privilege can register a routine with or without the DBA keyword in the CREATE statement.

  For an explanation of the DBA keyword, see "DBA privileges for executing a routine" on page 11-62.
- A user who does not have the DBA privilege needs the Resource privilege to register an SPL routine. The creator is the owner of the routine.

  A user who does not have the DBA privilege cannot use the DBA keyword to register the routine.

  A DBA must give other users the Resource privilege needed to create routines. The DBA can also revoke the Resource privilege, preventing the user from creating further routines.
- Besides holding the DBA privilege or the Resource privilege on the database in which the UDR is registered, the user who creates a UDR must also hold the Usage privilege on the programming language in which the UDR is written. These SQL statements can grant language-level Usage privileges for specific programming languages:
  - `GRANT USAGE ON LANGUAGE C`
  - `GRANT USAGE ON LANGUAGE JAVA`
  - `GRANT USAGE ON LANGUAGE SPL`

  Besides an individual user, the grantee of these privileges can also be a user-defined role, or the PUBLIC group. After language-level Usage privileges are granted to a role, any user who holds that role can enable all the access privileges of the role by using the SET ROLE statement of SQL to specify that role as the current role.

For external routines written in the C language or the Java language, if the IFX_EXTEND_ROLE configuration parameter is enabled, only users to whom the DBSA has granted EXTERNAL role has been granted can register, drop, or alter external UDRs or DataBlade modules. This parameter is enabled by default. By setting the IFX_EXTEND_ROLE configuration parameter to `OFF` or to `0`, the DBSA can disable the requirement of holding the EXTEND role for DDL operations on DataBlade modules and external UDRs. This security feature has no effect, however, on SPL routines.

In summary, a user who holds the database-level and language-level discretionary access privileges that are identified above (and who also holds the EXTEND role, if IFX_EXTEND_ROLE is enabled and the UDR is an external routine) can reference UDRs in the following SQL statements:

- The DBA or a user can register a new UDR with the CREATE FUNCTION, CREATE FUNCTION FROM, CREATE PROCEDURE, CREATE PROCEDURE FROM, CREATE ROUTINE, or CREATE ROUTINE FROM statement.
- The DBA or the owner of an existing UDR can cancel the registration of that UDR with the DROP FUNCTION, DROP PROCEDURE, or DROP ROUTINE statement.
- The DBA or the owner of an existing UDR can modify the definition of that UDR with the ALTER FUNCTION, ALTER PROCEDURE, or ALTER ROUTINE statement.

Privileges for executing a routine

The Execute privilege enables users to invoke a routine. The routine might be invoked by the EXECUTE or CALL statements, or by using a function in an expression. The following users have a default Execute privilege, which enables them to invoke a routine:

- By default, any user with the DBA privilege can execute any routine in the database.
- If the routine is registered with the qualified CREATE DBA FUNCTION or CREATE DBA PROCEDURE statements, only users with the DBA privilege have a default Execute privilege for that routine.
- If the database is not ANSI compliant, user **public** (any user with Connect database privilege) automatically has the Execute privilege to a routine that is not registered with the DBA keyword.
- In an ANSI-compliant database, the procedure owner and any user with the DBA privilege can execute the routine without receiving additional privileges.

Grant and revoke the Execute privilege

Routines have the following GRANT and REVOKE requirements:

- The DBA can grant or revoke the Execute privilege to any routine in the database.
- The creator of a routine can grant or revoke the Execute privilege on that particular routine. The creator forfeits the ability to grant or revoke by including the AS *grantor* clause with the GRANT EXECUTE ON statement.
- Another user can grant the Execute privilege if the owner applied the WITH GRANT keywords in the GRANT EXECUTE ON statement.

A DBA or the routine owner must explicitly grant the Execute privilege to non-DBA users for the following conditions:

- A routine in an ANSI-compliant database
- A database with the **`NODEFDAC`** environment variable set to `yes`
- A routine that was created with the DBA keyword

An owner can restrict the Execute privilege on a routine even though the database server grants that privilege to public by default. To do this, issue the REVOKE

EXECUTE ON PUBLIC statement. The DBA and owner can still execute the routine and can grant the Execute privilege to specific users, if applicable.

Execute privileges with COMMUTATOR and NEGATOR functions

Important: If you explicitly grant the Execute privilege on an SPL function that is the commutator or negator function of a UDR, you must also grant that privilege on the commutator or the negator function before the grantee can use either. You cannot specify COMMUTATOR or NEGATOR modifiers with SPL procedures.

The following example demonstrates both limiting privileges for a function and its negator to one group of users. Suppose you create the following pair of negator functions:

```
CREATE FUNCTION greater(y PERCENT, z PERCENT)
RETURNS BOOLEAN
NEGATOR= less(y PERCENT, z PERCENT);
. . .
CREATE FUNCTION less(y PERCENT, z PERCENT)
RETURNS BOOLEAN
NEGATOR= greater(y PERCENT, z PERCENT);
```

By default, any user can execute both the function and negator. The following statements allow only **accounting** to execute these functions:

```
REVOKE EXECUTE ON FUNCTION greater FROM PUBLIC;
REVOKE EXECUTE ON FUNCTION less FROM PUBLIC;
GRANT accounting TO mary, jim, ted;
GRANT EXECUTE ON FUNCTION greater TO accounting;
GRANT EXECUTE ON FUNCTION less TO accounting;
```

A user might receive the Execute privilege accompanied by the WITH GRANT OPTION authority to grant the Execute privilege to other users. If a user loses the Execute privilege on a routine, the Execute privilege is also revoked from all users who were granted the Execute privilege by that user.

For more information, see the GRANT and REVOKE statement descriptions in the *IBM Informix Guide to SQL: Syntax*.

Privileges on objects associated with a routine

The database server checks the existence of any referenced objects and verifies that the user invoking the routine has the necessary privileges to access the referenced objects.

Objects referenced by a routine can include:

- Tables and columns
- Sequence objects
- User-defined data types
- Other routines executed by the routine

When a routine is run, the effective privilege is defined as the union of:

- The privileges of the user running the routine,
- The privileges that the owner has with the GRANT option.

By default, the database administrator has all the privileges in a database with the GRANT option. Therefore, users executing routines that are owned by database administrators can select from all of the tables in a given database.

A GRANT EXECUTE ON statement confers to the grantee any table-level privileges that the grantor received from a GRANT statement that contained the WITH GRANT keywords.

The owner of the routine, and not the user who runs the routine, owns the unqualified objects created in the course of executing the routine. For example, assume user **howie** registers an SPL routine that creates two tables, with the following SPL routine:

```
CREATE PROCEDURE promo()
. . .
   CREATE TABLE newcatalog
   (
   catlog_num INTEGER
   cat_advert VARCHAR(255, 65)
   cat_picture BLOB
   ) ;
   CREATE TABLE dawn.mailers
   (
   cust_num INTEGER
   interested_in SET(catlog_num INTEGER)
   );
END PROCEDURE;
```

User **julia** runs the routine, which creates the table **newcatalog**. Because no owner name qualifies table name **newcatalog**, the routine owner (**howie**) owns **newcatalog**. By contrast, the qualified name **dawn.maillist** identifies **dawn** as the owner of **maillist**.

DBA privileges for executing a routine

If a DBA creates a routine using the DBA keyword, the database server automatically grants the Execute privilege only to other users with the DBA privilege. A DBA can, however, explicitly grant the Execute privilege on a DBA routine to a user who does not have the DBA privilege.

When a user executes a routine that was registered with the DBA keyword, that user assumes the privileges of a DBA for the duration of the routine. If a user who does not have the DBA privilege runs a DBA routine, the database server implicitly grants a temporary DBA privilege to the invoker. Before exiting a DBA routine, the database server implicitly revokes the temporary DBA privilege.

Objects created in the course of running a DBA routine are owned by the user who executes the routine, unless a statement in the routine explicitly names someone else as the owner. For example, suppose that **tony** registers the **promo()** routine with the DBA keyword, as follows:

```
CREATE DBA PROCEDURE promo()
   . . .
   CREATE TABLE catalog
   . . .
   CREATE TABLE libby.mailers
   . . .
END PROCEDURE;
```

Although **tony** owns the routine, if **marty** runs it, then **marty** owns the **catalog** table, but user **libby** owns **libby.mailers** because her name qualifies the table name, making her the table owner.

A called routine does not inherit the DBA privilege. If a DBA routine executes a routine that was created without the DBA keyword, the DBA privileges do not affect the called routine.

If a routine that is registered without the DBA keyword calls a DBA routine, the caller must have Execute privileges on the called DBA routine. Statements within the DBA routine execute as they would within any DBA routine.

The following example demonstrates what occurs when a DBA and non-DBA routine interact. Suppose procedure **dbspc_cleanup()** executes another procedure **clust_catalog()**. Suppose also that the procedure **clust_catalog()** creates an index and that the SPL source code for **clust_catalog()** includes the following statements:

```
CREATE CLUSTER INDEX c_clust_ix ON catalog (catalog_num);
```

The DBA procedure **dbspc_cleanup()** invokes the other routine with the following statement:

```
EXECUTE PROCEDURE clust_catalog(catalog);
```

Assume **tony** registered **dbspc_cleanup()** as a DBA procedure and **clust_catalog()** is registered without the DBA keyword, as the following statements show:

```
CREATE DBA PROCEDURE dbspc_cleanup(loc CHAR)
CREATE PROCEDURE clust_catalog(catalog CHAR)
GRANT EXECUTE ON dbspc_cleanup(CHAR) to marty;
```

Suppose user **marty** runs **dbspc_cleanup()**. Because index **c_clust_ix** is created by a non-DBA routine, **tony**, who owns both routines, also owns **c_clust_ix**. By contrast, **marty** would own index **c_clust_ix** if **clust_catalog()** is a DBA procedure, as the following registering and grant statements show:

```
CREATE PROCEDURE dbspc_cleanup(loc CHAR);
CREATE DBA PROCEDURE clust_catalog(catalog CHAR);
GRANT EXECUTE ON clust_catalog(CHAR) to marty;
```

Notice that **dbspc_cleanup()** need not be a DBA procedure to call a DBA procedure.

Find errors in an SPL routine

When you use CREATE PROCEDURE or CREATE FUNCTION to write an SPL routine with DB-Access, the statement fails when you select **Run** from the menu, if a syntax error occurs in the body of the routine.

If you are creating the routine in DB-Access, when you choose the **Modify** option from the menu, the cursor moves to the line that contains the syntax error. You can select **Run** and **Modify** again to check subsequent lines.

Compile-time warnings

If the database server detects a potential problem, but the syntax of the SPL routine is correct, the database server generates a warning and places it in a listing file. You can examine this file to check for potential problems before you execute the routine.

The file name and path name of the listing file are specified in the WITH LISTING IN clause of the CREATE PROCEDURE or CREATE FUNCTION statement. For information about how to specify the path name of the listing file, see “Specify a DOCUMENT clause” on page 11-9.

If you are working on a network, the listing file is created on the system where the database resides. If you provide an absolute path name and file name for the file, the file is created at the location you specify.

For UNIX, if you provide a relative path name for the listing file, the file is created in your home directory on the computer where the database resides. (If you do not have a home directory, the file is created in the **root** directory.)

For Windows, if you provide a relative path name for the listing file, the default directory is your current working directory if the database is on the local computer. Otherwise the default directory is `%INFORMIXDIR%\bin`.

After you create the routine, you can view the file that is specified in the WITH LISTING IN clause to see the warnings that it contains.

Generate the text of the routine

After you create an SPL routine, it is stored in the **sysprocbody** system catalog table. The **sysprocbody** system catalog table contains the executable routine, as well as its text.

To retrieve the text of the routine, select the **data** column from the **sysprocbody** system catalog table. The **datakey** column for a text entry has the code **T**.

The SELECT statement in the following figure reads the text of the SPL routine **read_address**.

```
SELECT data FROM informix.sysprocbody
   WHERE datakey = 'T'                  -- find text lines
   AND procid =
      ( SELECT procid
      FROM informix.sysprocedures
      WHERE informix.sysprocedures.procname =
         'read_address' )
```

Figure 11-109. SELECT statement to read the text of the SPL routine.

Debug an SPL routine

After you successfully create and run an SPL routine, you can encounter logic errors. If the routine has logic errors, use the TRACE statement to help find them. You can trace the values of the following items:
- Variables
- Arguments
- Return values
- SQL error codes
- ISAM error codes

To generate a listing of traced values, first use the SQL statement SET DEBUG FILE to name the file that is to contain the traced output. When you create the SPL routine, include a TRACE statement.

The following methods specify the form of TRACE output.

Statement
Action

TRACE ON
Traces all statements except SQL statements. Prints the contents of variables before they are used. Traces routine calls and returned values.

TRACE PROCEDURE
Traces only the routine calls and returned values.

TRACE *expression*
Prints a literal or an expression. If necessary, the value of the expression is calculated before it is sent to the file.

The following figure demonstrates how you can use the TRACE statement to monitor how an SPL function executes.

```
CREATE FUNCTION read_many  (lastname CHAR(15))
  RETURNING CHAR(15), CHAR(15), CHAR(20), CHAR(15),
    CHAR(2), CHAR(5);

  DEFINE p_lname,p_fname, p_city CHAR(15);
  DEFINE p_add CHAR(20);
  DEFINE p_state CHAR(2);
  DEFINE p_zip CHAR(5);
  DEFINE lcount, i INT;

  LET lcount = 1;

  TRACE ON;      -- Trace every expression from here on
  TRACE 'Foreach starts';  -- Trace statement with a literal

  FOREACH
  SELECT fname, lname, address1, city, state, zipcode
    INTO p_fname, p_lname, p_add, p_city, p_state, p_zip

    FROM customer
        WHERE lname = lastname
  RETURN p_fname, p_lname, p_add, p_city, p_state, p_zip
    WITH RESUME;
  LET lcount = lcount + 1;   -- count of returned addresses
  END FOREACH

  TRACE 'Loop starts';       -- Another literal
  FOR i IN (1 TO 5)
    BEGIN
      RETURN i  , i+1, i*i, i/i, i-1,i WITH RESUME;
    END
  END FOR;

END FUNCTION;
```

Figure 11-110. The TRACE statement.

With the TRACE ON statement, each time you execute the traced routine, entries are added to the file you specified in the SET DEBUG FILE statement. To see the debug entries, view the output file with any text editor.

The following list contains some of the output that the function in previous example generates. Next to each traced statement is an explanation of its contents.

Statement
: **Action**

TRACE ON
: Echoes TRACE ON statement.

TRACE Foreach starts
: Traces expression, in this case, the literal string Foreach starts.

start select cursor
: Provides notification that a cursor is opened to handle a FOREACH loop.

select cursor iteration
: Provides notification of the start of each iteration of the select cursor.

expression: (+lcount, 1)
: Evaluates the encountered expression, (lcount+1), to 2.

let lcount = 2
: Echoes each LET statement with the value.

Exception handling

You can use the ON EXCEPTION statement to trap any exception (or error) that the database server returns to your SPL routine or any exception that the routine raises. The RAISE EXCEPTION statement lets you generate an exception within the SPL routine.

In an SPL routine, you cannot use exception handling to handle the following conditions:

- Success (row returned)
- Success (no rows returned)

Error trapping and recovering

The ON EXCEPTION statement provides a mechanism to trap any error.

To trap an error, enclose a group of statements in a statement block marked with BEGIN and END and add an ON EXCEPTION IN statement at the beginning of the statement block. If an error occurs in the block that follows the ON EXCEPTION statement, you can take recovery action.

The following figure shows an ON EXCEPTION statement within a statement block.

```
BEGIN
DEFINE c INT;
ON EXCEPTION IN
  (
  -206, -- table does not exist
  -217  -- column does not exist
  ) SET err_num

IF err_num = -206 THEN
    CREATE TABLE t (c INT);
    INSERT INTO t VALUES (10);
    -- continue after the insert statement
  ELSE
    ALTER TABLE t ADD(d INT);
    LET c = (SELECT d FROM t);
    -- continue after the select statement.
  END IF
END EXCEPTION WITH RESUME

INSERT INTO t VALUES (10);  -- fails if t does not exist

LET c = (SELECT d FROM t);  -- fails if d does not exist
END
```

Figure 11-111. Trap errors.

When an error occurs, the SPL interpreter searches for the innermost ON EXCEPTION declaration that traps the error. The first action after trapping the error is to reset the error. When execution of the error action code is complete, and if the ON EXCEPTION declaration that was raised included the WITH RESUME keywords, execution resumes automatically with the statement *following* the statement that generated the error. If the ON EXCEPTION declaration did not include the WITH RESUME keywords, execution exits the current block entirely.

Scope of control of an ON EXCEPTION statement

The scope of the ON EXCEPTION statement extends from the statement that immediately follows the ON EXCEPTION statement, and ends at the end of the statement block in which the ON EXCEPTION statement is issued. If the SPL routine includes no explicit statement blocks, the scope is all subsequent statements in the routine.

For the exceptions specified in the IN clause (or for all exceptions, if no IN clause is specified), the scope of the ON EXCEPTION statement includes all statements that follow the ON EXCEPTION statement within the same statement block. If other statement blocks are nested within that block, the scope also includes all statements in the nested statement blocks that follow the ON EXCEPTION statement, and any statements in statement blocks that are nested within those nested blocks.

The following pseudocode shows where the exception is valid within the routine. That is, if error `201` occurs in any of the indicated blocks, the action labeled *a201* occurs.

```
CREATE PROCEDURE scope()
  DEFINE i INT;
       . . .
  BEGIN         -- begin statement block A
       . . .
    ON EXCEPTION IN (201)
    -- do action a201
    END EXCEPTION
    BEGIN        -- nested statement block aa
      -- do action, a201 valid here
    END
    BEGIN        -- nested statement block bb
      -- do action, a201 valid here
    END
    WHILE i < 10
      -- do something, a201 is valid here
    END WHILE

  END    -- end of statement block A
  BEGIN          -- begin statement block B
    -- do something
    -- a201 is NOT valid here
  END
END PROCEDURE;
```

Figure 11-112. ON EXCEPTION statement scope of control.

User-generated exceptions

You can generate your own error using the RAISE EXCEPTION statement, as the following figure shows.

```
BEGIN
  ON EXCEPTION SET esql, eisam   -- trap all errors
    IF esql = -206 THEN          -- table not found
      -- recover somehow
    ELSE
      RAISE exception esql, eisam;  -- pass the error up
    END IF
  END EXCEPTION
    -- do something
END
```

Figure 11-113. The RAISE EXCEPTION statement.

In the example, the ON EXCEPTION statement uses two variables, **esql** and **eisam**, to hold the error numbers that the database server returns. The IF clause executes if an error occurs and if the SQL error number is -206. If any other SQL error is caught, it is passed out of this BEGINEND block to the last BEGINEND block of the previous example.

Simulate SQL errors

You can generate errors to simulate SQL errors, as the following figure shows. If the user is **pault**, then the SPL routine acts as if that user has no update privileges, even if the user really does have that privilege.

```
BEGIN
  IF user = 'pault' THEN
     RAISE EXCEPTION -273;  -- deny Paul update privilege
  END IF
END
```

Figure 11-114. Simulate SQL errors.

RAISE EXCEPTION to exit nested code

The following figure shows how you can use the RAISE EXCEPTION statement to break out of a deeply nested block.

```
BEGIN
  ON EXCEPTION IN (1)
  END EXCEPTION WITH RESUME -- do nothing significant (cont)

  BEGIN
    FOR i IN (1 TO 1000)
      FOREACH select ..INTO aa FROM t
        IF aa < 0 THEN
          RAISE EXCEPTION 1;     -- emergency exit
        END IF
      END FOREACH
    END FOR
    RETURN 1;
  END

  --do something;              -- emergency exit to
                               -- this statement.
  TRACE 'Negative value returned';
  RETURN -10;
END
```

Figure 11-115. The RAISE EXCEPTION statement.

If the innermost condition is true (if **aa** is negative), then the exception is raised and execution jumps to the code following the END of the block. In this case, execution jumps to the TRACE statement.

Remember that a BEGINEND block is a *single* statement. If an error occurs somewhere inside a block and the trap is outside the block, the rest of the block is skipped when execution resumes, and execution begins at the next statement.

Unless you set a trap for this error somewhere in the block, the error condition is passed back to the block that contains the call and back to any blocks that contain the block. If no ON EXCEPTION statement exists that is set to handle the error, execution of the SPL routine stops, creating an error for the routine that is executing the SPL routine.

Check the number of rows processed in an SPL routine

Within SPL routines, you can use the **DBINFO** function to find out the number of rows that have been processed in SELECT, INSERT, UPDATE, DELETE, EXECUTE PROCEDURE, and EXECUTE FUNCTION statements.

The following figure shows an SPL function that uses the **DBINFO** function with the 'sqlca.sqlerrd2' option to determine the number of rows that are deleted from a table.

```
CREATE FUNCTION del_rows ( pnumb INT )
RETURNING INT;

DEFINE nrows INT;

DELETE FROM sec_tab WHERE part_num = pnumb;
LET nrows = DBINFO('sqlca.sqlerrd2');

RETURN nrows;

END FUNCTION;
```

Figure 11-116. Determine the number of rows deleted from a table.

To ensure valid results, use this option after SELECT and EXECUTE PROCEDURE or EXECUTE FUNCTION statements have completed executing. In addition, if you use the 'sqlca.sqlerrd2' option within cursors, make sure that all rows are fetched before the cursors are closed, to ensure valid results.

Summary

SPL routines provide many opportunities for streamlining your database process, including enhanced database performance, simplified applications, and limited or monitored access to data. You can also use SPL routines to handle extended data types, such as collection types, row types, opaque types, and distinct types. For syntax diagrams of SPL statements, see the *IBM Informix Guide to SQL: Syntax*.

Chapter 12. Create and use triggers

This section describes each component of the CREATE TRIGGER statement, illustrates some uses for triggers, and describes the advantages of using an SPL routine as a triggered action.

In addition, this section describes INSTEAD OF trigger that can be defined on views.

An SQL trigger is a mechanism that resides in the database. It is available to any user who has permission to use it. An SQL trigger specifies that when a data-manipulation language (DML) operation (an INSERT, SELECT, DELETE, or UPDATE statement) occurs on a particular table, the database server automatically performs one or more additional actions. For triggers defined on views, the triggered action on the base tables of the view replaces the triggering event. For triggers on tables or views, the triggered actions can be INSERT, DELETE, UPDATE, EXECUTE PROCEDURE or EXECUTE FUNCTION statements.

IBM Informix also supports user-defined routines written in C or in Java as triggered actions.

For information on how to write a C UDR to obtain metadata information about trigger events, see the *IBM Informix DataBlade API Programmer's Guide*.

When to use triggers

Because a trigger resides in the database and anyone who has the required privilege can use it, a trigger lets you write a set of SQL statements that multiple applications can use. It lets you avoid redundant code when multiple programs need to perform the same database operation.

You can use triggers to perform the following actions, as well as others that are not found in this list:

- Create an audit trail of activity in the database. For example, you can track updates to the orders table by updating corroborating information to an audit table.
- Implement a business rule. For example, you can determine when an order exceeds a customer's credit limit and display a message to that effect.
- Derive additional data that is not available within a table or within the database. For example, when an update occurs to the **quantity** column of the **items** table, you can calculate the corresponding adjustment to the **total_price** column.
- Enforce referential integrity. When you delete a customer, for example, you can use a trigger to delete corresponding rows that have the same customer number in the **orders** table.

How to create a trigger

You use the CREATE TRIGGER statement to define a new trigger. The CREATE TRIGGER statement is a data-definition statement that associates SQL statements, called the *triggered action*, with a precipitating event on a table. When the event occurs, it triggers the associated SQL statements, which are stored in the database.

In this example, the triggering event is an UPDATE statement that references the **quantity** column of the **items** table. The following figure illustrates the relationship of the DML operation that activates the trigger, called the trigger event, to the triggered action.

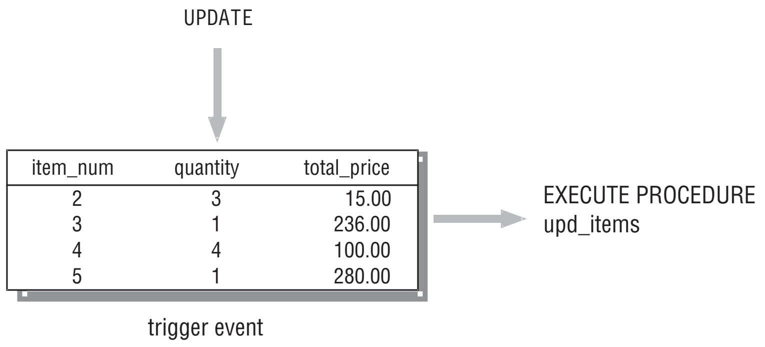


Figure 12-1. Trigger event and triggered action

The CREATE TRIGGER statement consists of clauses that perform the following actions:

- Declare a name for the trigger .
- Specify the DML operation on a specified table or view as the triggering event.
- Define the SQL operations that this event triggers.

An optional clause, called the REFERENCING clause, is discussed in "FOR EACH ROW triggered actions" on page 12-4.

To create a trigger, use DB-Access or one of the SQL APIs. This section describes the CREATE TRIGGER statement as you enter it with the interactive Query-language option in DB-Access. In an SQL API, you precede the statement with the symbol or keywords that identify it as an embedded statement.

Declare a trigger name

The trigger name identifies the trigger, and must be unique among trigger names within the database. The trigger name follows the words CREATE TRIGGER in the statement. Like any SQL identifier, can be up to 128 bytes in length, beginning with a letter and consisting of letters, digits, and the underscore (_) symbol. In the following example, the portion of the CREATE TRIGGER statement that is shown declares the name **upqty** for the trigger:

```
CREATE TRIGGER upqty       -- declare trigger name
```

Specify the trigger event

The *trigger event* is the type of DML statement that activates the trigger. When a statement of this type is performed on the table, the database server executes the SQL statements that make up the triggered action. For tables, the trigger event can be an INSERT, SELECT, DELETE, or UPDATE statement. For UPDATE or SELECT trigger event, you can specify one or more columns in the table to activate the trigger. If you do not specify any columns, then an UPDATE or SELECT of any column in the table activates the trigger. You can define multiple INSERT, DELETE, UPDATE and SELECT triggers on the same table, and multiple INSERT, DELETE, and UPDATE triggers on the same view.

You can only create a trigger on a table or view in the current database. Triggers cannot reference a remote table or view.

In the following excerpt from a CREATE TRIGGER statement, the trigger event is defined as an update of the **quantity** column in the **items** table:

```
CREATE TRIGGER upqty
   UPDATE OF quantity ON items     -- an UPDATE trigger event
```

This portion of the statement identifies the table on which you define the trigger. If the trigger event is an insert or delete operation, only the type of statement and the table name are required, as the following example shows:

```
CREATE TRIGGER ins_qty
   INSERT ON items                  -- an INSERT trigger event
```

Define the triggered actions

The *triggered actions* are the SQL statements that are performed when the trigger event occurs. The triggered actions can consist of INSERT, DELETE, UPDATE, EXECUTE FUNCTION and EXECUTE PROCEDURE statements. In addition to specifying what actions are to be performed, however, you must also specify when they are to be performed in relation to the triggering statement. You have the following choices:

- Before the triggering statement executes
- After the triggering statement executes
- For each row that is affected by the triggering statement

A single trigger on a table can define actions for each of these times.

To define a triggered action, specify when it occurs and then provide the SQL statement or statements to execute. You specify when the action is to occur with the keywords BEFORE, AFTER, or FOR EACH ROW. The triggered actions follow, enclosed in parentheses. The following triggered-action definition specifies that the SPL routine **upd_items_p1** is to be executed before the triggering statement:

```
BEFORE(EXECUTE PROCEDURE upd_items_p1) -- a BEFORE action
```

A complete CREATE TRIGGER statement

To define a complete CREATE TRIGGER statement, combine the trigger-name clause, the trigger-event clause, and the triggered-action clause. The following CREATE TRIGGER statement is the result of combining the components of the statement from the preceding examples. This trigger executes the SPL routine **upd_items_p1** whenever the **quantity** column of the **items** table is updated.

```
CREATE TRIGGER upqty
   UPDATE OF quantity ON items
   BEFORE(EXECUTE PROCEDURE upd_items_p1);
```

If a database object in the trigger definition, such as the SPL routine **upd_items_p1** in this example, does not exist when the database server processes the CREATE TRIGGER statement, it returns an error.

Triggered actions

To use triggers effectively, you need to understand the relationship between the triggering statement and the resulting triggered actions. You define this relationship when you specify the time that the triggered action occurs; that is, BEFORE, AFTER, or FOR EACH ROW.

BEFORE and AFTER triggered actions

Triggered actions that occur before or after the trigger event execute only once. A BEFORE triggered action executes before the *triggering statement*, that is, before the occurrence of the trigger event. An AFTER triggered action executes after the action of the triggering statement is complete. BEFORE and AFTER triggered actions execute even if the triggering statement does not process any rows.

Among other uses, you can use BEFORE and AFTER triggered actions to determine the effect of the triggering statement. For example, before you update the **quantity** column in the **items** table, you could call the SPL routine **upd_items_p1** to calculate the total quantity on order for all items in the table, as the following example shows. The procedure stores the total in a global variable called **old_qty**.

```
CREATE PROCEDURE upd_items_p1()
   DEFINE GLOBAL old_qty INT DEFAULT 0;
   LET old_qty = (SELECT SUM(quantity) FROM items);
END PROCEDURE;
```

After the triggering update completes, you can calculate the total again to see how much it has changed. The following SPL routine, **upd_items_p2**, calculates the total of **quantity** again and stores the result in the local variable **new_qty**. Then it compares **new_qty** to the global variable **old_qty** to see if the total quantity for all orders has increased by more than 50 percent. If so, the procedure uses the RAISE EXCEPTION statement to simulate an SQL error.

```
CREATE PROCEDURE upd_items_p2()
   DEFINE GLOBAL old_qty INT DEFAULT 0;
   DEFINE new_qty INT;
   LET new_qty = (SELECT SUM(quantity) FROM items);
   IF new_qty > old_qty * 1.50 THEN
      RAISE EXCEPTION -746, 0, 'Not allowed - rule violation';
   END IF
END PROCEDURE;
```

The following trigger calls **upd_items_p1** and **upd_items_p2** to prevent an extraordinary update on the **quantity** column of the **items** table:

```
CREATE TRIGGER up_items
   UPDATE OF quantity ON items
      BEFORE(EXECUTE PROCEDURE upd_items_p1())
      AFTER(EXECUTE PROCEDURE upd_items_p2());
```

If an update raises the total quantity on order for all items by more than 50 percent, the RAISE EXCEPTION statement in **upd_items_p2** terminates the trigger with an error. When a trigger fails in a database that has transaction logging, the database server rolls back the changes that both the triggering statement and the triggered actions make. For more information on what happens when a trigger fails, see the CREATE TRIGGER statement in the *IBM Informix Guide to SQL: Syntax*.

FOR EACH ROW triggered actions

A FOR EACH ROW triggered action executes once for each row that the triggering statement affects. For example, if the triggering statement has the following syntax, a FOR EACH ROW triggered action executes once for each row in the **items** table in which the **manu_code** column has a value of 'KAR':

```
UPDATE items SET quantity = quantity * 2
   WHERE manu_code = 'KAR';
```

If the triggering event does not process any rows, a FOR EACH ROW triggered action does not execute.

For a trigger on a table, if the triggering event is a SELECT statement, the trigger is a called a Select trigger, and the triggered actions execute after all processing on the retrieved row is complete. The triggered actions might not execute immediately; however, because a FOR EACH ROW action executes for every instance of a row that the query returns. For example, in a SELECT statement with an ORDER BY clause, all rows must be qualified against the WHERE clause before they are sorted and returned.

The REFERENCING clause

When you create a FOR EACH ROW triggered action, you must usually indicate in the triggered action statements whether you are referring to the value of a column before or after the effect of the triggering statement. For example, imagine that you want to track updates to the **quantity** column of the **items** table. To do this, create the following table to record the activity:

```
CREATE TABLE log_record
   (item_num     SMALLINT,
   ord_num       INTEGER,
   username      CHARACTER(8),
   update_time   DATETIME YEAR TO MINUTE,
   old_qty       SMALLINT,
   new_qty       SMALLINT);
```

To supply values for the **old_qty** and **new_qty** columns in this table, you must be able to refer to the old and new values of **quantity** in the **items** table; that is, the values before and after the effect of the triggering statement. The REFERENCING clause enables you to do this.

The REFERENCING clause lets you create two prefixes that you can combine with a column name, one to reference the old value of the column, and one to reference its new value. These prefixes are called *correlation names*. You can create one or both correlation names, depending on your requirements. You indicate which one you are creating with the keywords OLD and NEW. The following REFERENCING clause creates the correlation names **pre_upd** and **post_upd** to refer to the old and new values in a row:

```
REFERENCING OLD AS pre_upd NEW AS post_upd
```

The following triggered action creates a row in **log_record** when **quantity** is updated in a row of the **items** table. The INSERT statement refers to the old values of the **item_num** and **order_num** columns and to both the old and new values of the **quantity** column.

```
FOR EACH ROW(INSERT INTO log_record
  VALUES (pre_upd.item_num, pre_upd.order_num, USER,
         CURRENT, pre_upd.quantity, post_upd.quantity));
```

The correlation names defined in the REFERENCING clause apply to all rows that the triggering statement affects.

Important: If you refer to a column name that is not qualified by a correlation name, the database server makes no special effort to search for the column in the definition of the triggering table. You must always use a correlation name with a column name in SQL statements in a FOR EACH ROW triggered action, unless the statement is valid independent of the triggered action. For more information, see the CREATE TRIGGER statement in the *IBM Informix Guide to SQL: Syntax*.

The WHEN condition

As an option for triggers on tables, you can precede a triggered action with a WHEN clause to make the action dependent on the outcome of a test. The WHEN clause consists of the keyword WHEN followed by the condition statement given in parentheses. In the CREATE TRIGGER statement, the WHEN clause follows the keywords BEFORE, AFTER, or FOR EACH ROW and precedes the triggered-action list.

When a WHEN condition is present, if it evaluates to *true*, the triggered actions execute in the order in which they appear. If the WHEN condition evaluates to *false* or *unknown*, the actions in the triggered-action list do not execute. If the trigger specifies FOR EACH ROW, the condition is evaluated for each row also.

In the following trigger example, the triggered action executes only if the condition in the WHEN clause is true; that is, if the post-update unit price is greater than two times the pre-update unit price:

```
CREATE TRIGGER up_price
   UPDATE OF unit_price ON stock
   REFERENCING OLD AS pre NEW AS post
   FOR EACH ROW WHEN(post.unit_price > pre.unit_price * 2)
   (INSERT INTO warn_tab
    VALUES(pre.stock_num, pre.manu_code, pre.unit_price,
          post.unit_price, CURRENT));
```

For more information on the WHEN condition, see the CREATE TRIGGER statement in the *IBM Informix Guide to SQL: Syntax*.

SPL routines as triggered actions

Probably the most powerful feature of triggers is the ability to call an SPL routine as a triggered action. The EXECUTE PROCEDURE or EXECUTE FUNCTION statement, which calls an SPL routine, lets you pass data from the triggering table to the SPL routine and also to update the triggering table with data returned by the SPL routine. SPL also lets you define variables, assign data to them, make comparisons, and use procedural statements to accomplish complex tasks within a triggered action.

Pass data to an SPL routine

You can pass data to an SPL routine in the argument list of the EXECUTE PROCEDURE or EXECUTE FUNCTION statement. The EXECUTE PROCEDURE statement in the following example passes values from the **quantity** and **total_price** columns of the **items** table to the SPL routine **calc_totpr**:

```
CREATE TRIGGER upd_totpr
   UPDATE OF quantity ON items
   REFERENCING OLD AS pre_upd NEW AS post_upd
   FOR EACH ROW(EXECUTE PROCEDURE calc_totpr(pre_upd.quantity,
      post_upd.quantity, pre_upd.total_price) INTO total_price);
```

Passing data to an SPL routine lets you use data values in the operations that the routine performs.

Using SPL

The EXECUTE PROCEDURE statement in the preceding trigger calls the SPL routine that the following example shows. The procedure uses SPL to calculate the change that needs to be made to the **total_price** column when **quantity** is updated in the **items** table. The procedure receives both the old and new values of **quantity** and the old value of **total_price**. It divides the old total price by the old quantity to derive the unit price. It then multiplies the unit price by the new quantity to obtain the new total price.

```
CREATE PROCEDURE calc_totpr(old_qty SMALLINT, new_qty SMALLINT,
   total MONEY(8)) RETURNING MONEY(8);
   DEFINE u_price LIKE items.total_price;
   DEFINE n_total LIKE items.total_price;
   LET u_price = total / old_qty;
   LET n_total = new_qty * u_price;
   RETURN n_total;
END PROCEDURE;
```

In this example, SPL lets the trigger derive data that is not directly available from the triggering table.

Update nontriggering columns with data from an SPL routine

Within a triggered action, the INTO clause of the EXECUTE PROCEDURE statement lets you update nontriggering columns in the triggering table. The EXECUTE PROCEDURE statement in the following example calls the **calc_totpr** SPL procedure that contains an INTO clause, which references the column **total_price**:

```
FOR EACH ROW(EXECUTE PROCEDURE calc_totpr(pre_upd.quantity,
   post_upd.quantity, pre_upd.total_price) INTO total_price);
```

The value that is updated into **total_price** is returned by the RETURN statement at the conclusion of the SPL procedure. The **total_price** column is updated for each row that the triggering statement affects.

Trigger routines

You can define specialized SPL routines, called *trigger routines*, that can be invoked only from the FOR EACH ROW section of the triggered action. Unlike ordinary UDRs that EXECUTE FUNCTION or EXECUTE PROCEDURE routines can call from the triggered action list, trigger routines include their own REFERENCING clause that defines correlation names for the old and new column values in rows that the triggered action modifies. These correlation names can be referenced in SPL statements within the trigger routine, providing greater flexibility in how the triggered action can modify data in the table or view.

Trigger routines can also use trigger-type Boolean operators, called DELETING, INSERTING, SELECTING, and UPDATING, to identify what type of trigger has called the trigger routine. Trigger routines can also invoke the **mi_trigger*** routines, which are sometimes called *trigger introspection routines,* to obtain information about the context in which the trigger routine has been called.

Trigger routines are invoked by EXECUTE FUNCTION or EXECUTE PROCEDURE statements that include the WITH TRIGGER REFERENCES keywords. These statements must call the trigger routine from the FOR EACH ROW section of the triggered action, rather than from the BEFORE or AFTER sections.

For information about syntax features that the CREATE FUNCTION, CREATE PROCEDURE, EXECUTE FUNCTION, and EXECUTE PROCEDURE statements of SQL support for defining and executing trigger routines, see your *IBM Informix Guide to SQL: Syntax*. For more information about the **mi_trigger*** routines, see your *IBM Informix DataBlade API Programmer's Guide*.

Triggers in a table hierarchy

When you define a trigger on a supertable, any subtables in the table hierarchy also inherit the trigger. Consequently when you perform operations on tables in the hierarchy, triggers can execute for any table in the hierarchy that is a subtable of the table on which a trigger is defined.

Select triggers

When the CREATE TRIGGER statement defines as its triggering event any query on a specific table (

```
SELECT ON table
```

or

```
SELECT ON column-list ON table
```

), the resulting trigger object is a *Select trigger* on the specified *table*. The same trigger can also be activated by queries on a view that includes triggering columns from *table* as its base table. SELECT statements cannot, however, be the trigger events for INSTEAD OF triggers on a view.

If the CREATE TRIGGER statement also includes a *column-list* in the definition of an enabled Select trigger event, and the Projection list of a subsequent query on the specified table does not include any of the specified columns, that query cannot be a triggering event for the Select trigger.

Note:

Select triggers are not reliable for auditing. Do not attempt to create a Select trigger on a table, or on a subset of its columns, for the purpose of performing application-specific auditing. In general, it is not possible, to track the number of SELECT actions on a table by creating a Select trigger to insert an audit record into an audit table each time a user queries a certain table.

For example, suppose that you define a Select trigger on the table **AuditedTable** and that a user who holds Select privileges on **AuditedTable** issues the following query:

```
SELECT a.* FROM (SELECT * FROM AuditedTable) AS a;
```

The database server issues no error, but the SELECT trigger on **AuditedTable** will not be activated by this query. A query that included a set operator, such as UNION or INTERSECT, or any other syntax that Select triggers do not support, would be similarly invisible to an audit-record strategy that is based on Select triggers.

Because of the numerous restrictions on the execution of Select triggers, as partially listed in this chapter, the resulting Select trigger actions will typically correspond to only a subset (that might be empty) of whatever logical Select events you are attempting to enumerate.

SELECT statements that execute triggered actions

When you create a select trigger, only certain types of select statements can execute the actions defined on that trigger. A select trigger executes for the following types of SELECT statements only:

- Stand-alone SELECT statements

- Collection subqueries in the select list of a SELECT statement
- SELECT statements embedded in user-defined routines
- Views

Stand-alone SELECT statements

Suppose you define the following Select trigger on a table:

```
CREATE TRIGGER hits_trig SELECT OF col_a ON tab_a
   REFERENCING OLD AS hit
   FOR EACH ROW (INSERT INTO hits_log
                 VALUES (hit.col_a, CURRENT, USER));
```

A Select trigger executes when the triggering column appears in the select list of a stand-alone SELECT statement. The following statement executes a triggered action on the **hits_trig** trigger for each instance of a row that the database server returns:

```
SELECT col_a FROM tab_a;
```

Collection subqueries in the projection list of a query

A Select trigger executes when the triggering column appears in a collection subquery that occurs in the projection list of another SELECT statement. The following statement executes a triggered action on the **hits_trig** trigger for each instance of a row that the collection subquery returns:

```
SELECT MULTISET(SELECT col_a FROM tab_a) FROM ...
```

SELECT statements embedded in user-defined routines

A select trigger that is defined on a SELECT statement embedded in a user defined routine (UDR) executes a triggered action in the following instances only:

- The UDR appears in the select list of a SELECT statement
- The UDR is invoked with an EXECUTE PROCEDURE statement

Suppose you create a routine **new_proc** that contains the statement `SELECT col_a FROM tab_a`. Each of the following statements executes a triggered action on the **hits_trig** trigger for each instance of a row that the embedded SELECT statement returns:

```
SELECT new_proc() FROM tab_b;
EXECUTE PROCEDURE new_proc;
```

Views

Select triggers execute a triggered action for views whose base tables contain a reference to a triggering column. You cannot, however, define a Select trigger on a view.

Suppose you create the following view:

```
CREATE VIEW view_tab AS
   SELECT * FROM tab_a;
```

The following statements execute a triggered action on the **hits_trig** trigger for each instance of a row that the view returns:

```
SELECT * FROM view_tab;

SELECT col_a FROM tab_a;
```

Restrictions on execution of Select triggers

The following types of SELECT statements do not trigger any actions when they reference a table or column on which an enabled Select trigger is defined.

- No triggering column is referenced in the Projection list (for example, a column that appears only in the WHERE clause of a SELECT statement does not execute a Select trigger).
- The SELECT statement references a remote table.
- The SELECT statement calls an aggregate function or an OLAP window aggregation function.
- The SELECT statement includes a set operator (UNION, UNION ALL, INTERSECT, MINUS, or EXCEPT)
- The SELECT statement includes the DISTINCT or UNIQUE keyword.
- The UDR expression that contains the SELECT statement is not in the Projection list.
- The SELECT statement appears within an INSERT INTO statement.
- The SELECT statement appears within a scroll cursor.
- The trigger is a cascading Select trigger.

  A cascading Select trigger is a trigger whose actions includes an SPL routine that itself has a triggering SELECT statement. The actions of a cascading Select trigger do not execute, however, and the database server does not return an error.

Select triggers on tables in a table hierarchy

When you define a select trigger on a supertable, any subtables in the table hierarchy also inherit the trigger.

For information about overriding and disabling inherited triggers, see "Triggers in a table hierarchy" on page 12-8.

Re-entrant triggers

A *re-entrant trigger* refers to a case in which the triggered action can reference the triggering table. In other words, both the triggering event and the triggered action can operate on the same table. For example, suppose the following UPDATE statement represents the triggering event:

```
UPDATE tab1 SET (col_a, col_b) = (col_a + 1, col_b + 1);
```

The following triggered action is legal because column **col_c** is not a column that the triggering event has updated:

```
UPDATE tab1 SET (col_c) = (col_c + 3);
```

In the preceding example, a triggered action on **col_a** or **col_b** would be illegal because a triggered action cannot be an UPDATE statement that references a column that was updated by the triggering event.

Important: Select triggers cannot be re-entrant triggers. If the triggering event is a SELECT statement, the triggered action cannot operate on the same table.

For a list of the rules that describe those situations in which a trigger can and cannot be re-entrant, see the CREATE TRIGGER statement in the *IBM Informix Guide to SQL: Syntax*.

INSTEAD OF triggers on views

A view is a synthetic table that you create with the CREATE VIEW statement and define with a SELECT statement. Each view consists of the set of rows and columns that the SELECT statement in the view definition returns each time you refer to the view in a query. To insert, update, or delete rows in the base tables of a view, you can define an INSTEAD OF trigger.

Unlike a trigger on a table, the INSTEAD OF trigger on a view causes IBM Informix to ignore the triggering event, and instead perform only the triggered action.

For information on the CREATE VIEW statement and the INSTEAD OF trigger syntax and rules, including an example of an INSTEAD OF trigger that will insert rows on a view, see the *IBM Informix Guide to SQL: Syntax*.

INSTEAD OF trigger to update on a view

After you create one or more tables (like those named **dept** and **emp** in the following example), and then created a view (like the one named **manager_info**) from **dept** and **emp**, you can use an INSTEAD OF trigger to update that view.

The following CREATE TRIGGER statement creates **manager_info_update**, an INSTEAD OF trigger that is designed to update rows within the **dept** and **emp** tables through the **manager_info** view.

```
CREATE TRIGGER manager_info_update
   INSTEAD OF UPDATE ON manager_info
      REFERENCING NEW AS n
   FOR EACH ROW
      (EXECUTE PROCEDURE updtab (n.empno, n.empname, n.deptno,));

CREATE PROCEDURE updtab (eno INT, ename CHAR(20), dno INT,)
   DEFINE deptcode INT;
   UPDATE dept SET manager_num = eno where deptno = dno;
   SELECT deptno INTO deptcode FROM emp WHERE empno = eno;
   IF dno !=deptcode THEN
      UPDATE emp SET deptno = dno WHERE empno = eno;
   END IF;
   END PROCEDURE;
```

After the tables, view, trigger, and SPL routine have been created, the database server treats the following UPDATE statement as a triggering event:

```
UPDATE manager_info
   SET empno = 3666, empname = "Steve"
   WHERE deptno = 01;
```

This triggering UPDATE statement is not executed, but this event causes the trigger action to be executed instead, invoking the **updtab()** SPL routine. The UPDATE statements in the SPL routine update values into both the **emp** and **dept** base tables of the **manager_info** view.

Trace triggered actions

If a triggered action does not behave as you expect, place it in an SPL routine and use the SPL TRACE statement to monitor its operation. Before you start the trace, you must direct the output to a file with the SET DEBUG FILE TO statement.

Example of TRACE statements in an SPL routine

The following example shows TRACE statements that you add to the SPL routine **items_pct**. The SET DEBUG FILE TO statement directs the trace output to the file that the path name specifies. The TRACE ON statement begins tracing the statements and variables within the procedure.

```
CREATE PROCEDURE items_pct(mac CHAR(3))
DEFINE tp MONEY;
DEFINE mc_tot MONEY;
DEFINE pct DECIMAL;
SET DEBUG FILE TO 'pathname';

TRACE 'begin trace';
TRACE ON;
LET tp = (SELECT SUM(total_price) FROM items);
LET mc_tot = (SELECT SUM(total_price) FROM items
   WHERE manu_code = mac);
LET pct = mc_tot / tp;
IF pct > .10 THEN
   RAISE EXCEPTION -745;
END IF
TRACE OFF;
END PROCEDURE;

CREATE TRIGGER items_ins
INSERT ON items
REFERENCING NEW AS post_ins
FOR EACH ROW(EXECUTE PROCEDURE items_pct (post_ins.manu_code));
```

Example of TRACE output

The following example shows sample trace output from the **items_pct** procedure as it appears in the file that was named in the SET DEBUG FILE TO statement. The output reveals the values of procedure variables, procedure arguments, return values, and error codes.

```
trace expression :begin trace
trace on
expression:
  (select (sum total_price)
    from items)
evaluates to $18280.77 ;
let  tp = $18280.77
expression:
  (select (sum total_price)
    from items
    where (= manu_code, mac))
evaluates to $3008.00 ;
let  mc_tot = $3008.00
expression:(/ mc_tot, tp)
evaluates to 0.16
let  pct = 0.16
expression:(> pct, 0.1)
evaluates to 1
expression:(- 745)
evaluates to -745
raise exception :-745, 0, ''
exception : looking for handler
SQL error = -745 ISAM error = 0  error string =  = ''
exception : no appropriate handler
```

For more information about how to use the TRACE statement to diagnose logic errors in SPL routines, see Chapter 11, “Create and use SPL routines,” on page 11-1.

Generate error messages

When a trigger fails because of an SQL statement, the database server returns the SQL error number that applies to the specific cause of the failure.

When the triggered action is an SPL routine, you can generate error messages for other error conditions with one of two reserved error numbers. The first one is error number -745, which has a generalized and fixed error message. The second one is error number -746, which allows you to supply the message text, up to a maximum of 70 bytes.

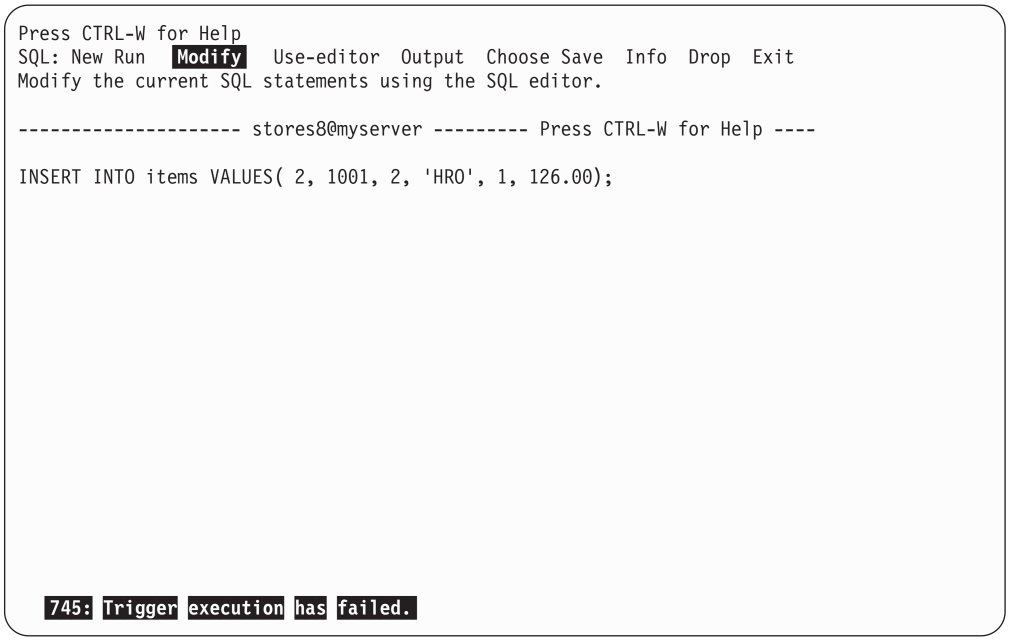
Apply a fixed error message

You can apply error number -745 to any trigger failure that is not an SQL error. The following fixed message is for this error: `-745 Trigger execution has failed.`

You can apply this message with the RAISE EXCEPTION statement in SPL. The following example generates error -745 if **new_qty** is greater than **old_qty** multiplied by 1.50:

```
CREATE PROCEDURE upd_items_p2()
   DEFINE GLOBAL old_qty INT DEFAULT 0;
   DEFINE new_qty INT;
   LET new_qty = (SELECT SUM(quantity) FROM items);
   IF new_qty > old_qty * 1.50 THEN
      RAISE EXCEPTION -745;
   END IF
END PROCEDURE
```

If you are using DB-Access, the text of the message for error -745 displays on the bottom of the screen, as the following figure shows.



```
Press CTRL-W for Help
SQL: New Run  Modify  Use-editor  Output  Choose Save  Info  Drop  Exit
Modify the current SQL statements using the SQL editor.

-------------------- stores8@myserver --------- Press CTRL-W for Help ----

INSERT INTO items VALUES( 2, 1001, 2, 'HRO', 1, 126.00);











   745: Trigger execution has failed.
```

Figure 12-2. Error message -745 with fixed message

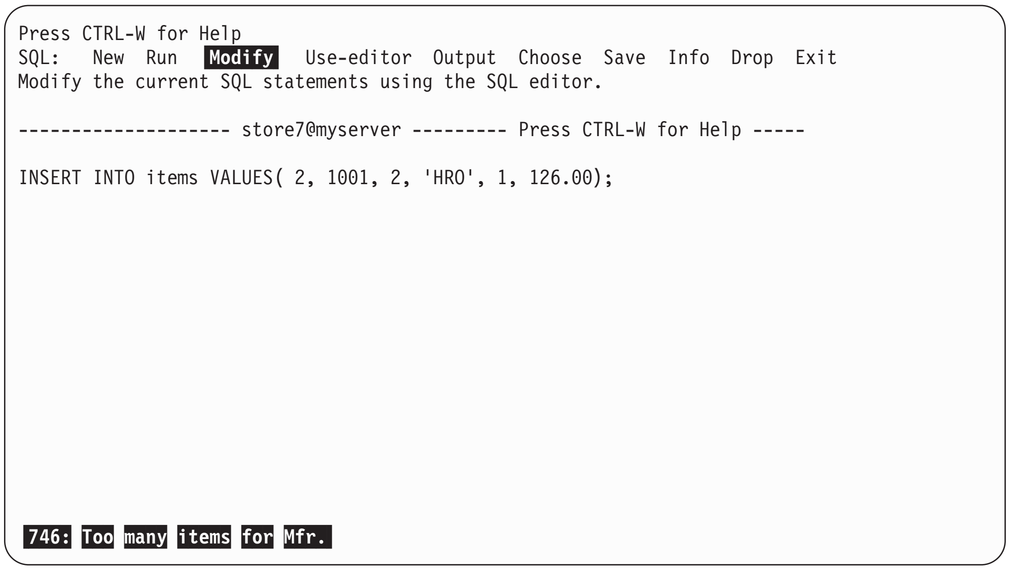
If your trigger calls a procedure that contains an error through an SQL statement in your SQL API, the database server sets the SQL error status variable to -745 and returns it to your program. To display the text of the message, follow the procedure that your IBM Informix application development tool provides for retrieving the text of an SQL error message.

Generate a variable error message

Error number -746 allows you to provide the text of the error message. Like the preceding example, the following one also generates an error if **new_qty** is greater than **old_qty** multiplied by 1.50. However, in this case the error number is -746, and the message text `Too many items for Mfr.` is supplied as the third argument in the RAISE EXCEPTION statement. For more information on the syntax and use of this statement, see the RAISE EXCEPTION statement in Chapter 11, "Create and use SPL routines," on page 11-1.

```
CREATE PROCEDURE upd_items_p2()
   DEFINE GLOBAL old_qty INT DEFAULT 0;
   DEFINE new_qty INT;
   LET new_qty = (SELECT SUM(quantity) FROM items);
   IF new_qty > old_qty * 1.50 THEN
      RAISE EXCEPTION -746, 0, 'Too many items for Mfr.';
   END IF
END PROCEDURE;
```

If you use DB-Access to submit the triggering statement, and if **new_qty** is greater than **old_qty**, you will get the result that the following figure shows.



```
Press CTRL-W for Help
SQL:   New  Run  Modify  Use-editor  Output  Choose  Save  Info  Drop  Exit
Modify the current SQL statements using the SQL editor.

------------------- store7@myserver --------- Press CTRL-W for Help -----

INSERT INTO items VALUES( 2, 1001, 2, 'HRO', 1, 126.00);











 746: Too many items for Mfr.
```

Figure 12-3. Error Number -746 with User-Specified message Text

If you invoke the trigger through an SQL statement in an SQL API, the database server sets **sqlcode** to `-746` and returns the message text in the **sqlerrm** field of the SQL communications area (SQL;CA). For more information about how to use the SQL;CA, see your SQL API publication.

Summary

To introduce triggers, this chapter discussed the following topics:

- The components of the CREATE TRIGGER statement
- Types of DML statements that can be triggering events
- Types of SQL statements that can be triggered actions

- How to create BEFORE and AFTER triggered actions and how to use them to determine the impact of the triggering statement
- How to create a FOR EACH ROW triggered action and how to use the REFERENCING clause to refer to the values of columns both before and after the action of the triggering statement
- INSTEAD OF triggers on views, whose triggering event is ignored, but whose triggered actions can modify the base tables of the view
- The advantages of using SPL routines as triggered actions
- Special features of calls to trigger routines as triggered actions
- How to trace triggered actions if they behave unexpectedly
- How to generate two types of error messages within a triggered action.

Appendix. Accessibility

IBM strives to provide products with usable access for everyone, regardless of age or ability.

Accessibility features for IBM Informix products

Accessibility features help a user who has a physical disability, such as restricted mobility or limited vision, to use information technology products successfully.

Accessibility features

The following list includes the major accessibility features in IBM Informix products. These features support:

- Keyboard-only operation.
- Interfaces that are commonly used by screen readers.
- The attachment of alternative input and output devices.

Keyboard navigation

This product uses standard Microsoft Windows navigation keys.

Related accessibility information

IBM is committed to making our documentation accessible to persons with disabilities. Our publications are available in HTML format so that they can be accessed with assistive technology such as screen reader software.

IBM and accessibility

For more information about the IBM commitment to accessibility, see the *IBM Accessibility Center* at http://www.ibm.com/able.

Dotted decimal syntax diagrams

The syntax diagrams in our publications are available in dotted decimal format, which is an accessible format that is available only if you are using a screen reader.

In dotted decimal format, each syntax element is written on a separate line. If two or more syntax elements are always present together (or always absent together), the elements can appear on the same line, because they can be considered as a single compound syntax element.

Each line starts with a dotted decimal number; for example, `3` or `3.1` or `3.1.1`. To hear these numbers correctly, make sure that your screen reader is set to read punctuation. All syntax elements that have the same dotted decimal number (for example, all syntax elements that have the number `3.1`) are mutually exclusive alternatives. If you hear the lines `3.1 USERID` and `3.1 SYSTEMID`, your syntax can include either `USERID` or `SYSTEMID`, but not both.

The dotted decimal numbering level denotes the level of nesting. For example, if a syntax element with dotted decimal number `3` is followed by a series of syntax elements with dotted decimal number `3.1`, all the syntax elements numbered `3.1` are subordinate to the syntax element numbered `3`.

Certain words and symbols are used next to the dotted decimal numbers to add information about the syntax elements. Occasionally, these words and symbols might occur at the beginning of the element itself. For ease of identification, if the word or symbol is a part of the syntax element, the word or symbol is preceded by the backslash (\) character. The * symbol can be used next to a dotted decimal number to indicate that the syntax element repeats. For example, syntax element *FILE with dotted decimal number 3 is read as 3 * FILE. Format 3* FILE indicates that syntax element FILE repeats. Format 3* * FILE indicates that syntax element * FILE repeats.

Characters such as commas, which are used to separate a string of syntax elements, are shown in the syntax just before the items they separate. These characters can appear on the same line as each item, or on a separate line with the same dotted decimal number as the relevant items. The line can also show another symbol that provides information about the syntax elements. For example, the lines 5.1*, 5.1 LASTRUN, and 5.1 DELETE mean that if you use more than one of the LASTRUN and DELETE syntax elements, the elements must be separated by a comma. If no separator is given, assume that you use a blank to separate each syntax element.

If a syntax element is preceded by the % symbol, that element is defined elsewhere. The string that follows the % symbol is the name of a syntax fragment rather than a literal. For example, the line 2.1 %OP1 refers to a separate syntax fragment OP1.

The following words and symbols are used next to the dotted decimal numbers:

? Specifies an optional syntax element. A dotted decimal number followed by the ? symbol indicates that all the syntax elements with a corresponding dotted decimal number, and any subordinate syntax elements, are optional. If there is only one syntax element with a dotted decimal number, the ? symbol is displayed on the same line as the syntax element (for example, 5? NOTIFY). If there is more than one syntax element with a dotted decimal number, the ? symbol is displayed on a line by itself, followed by the syntax elements that are optional. For example, if you hear the lines 5 ?, 5 NOTIFY, and 5 UPDATE, you know that syntax elements NOTIFY and UPDATE are optional; that is, you can choose one or none of them. The ? symbol is equivalent to a bypass line in a railroad diagram.

! Specifies a default syntax element. A dotted decimal number followed by the ! symbol and a syntax element indicates that the syntax element is the default option for all syntax elements that share the same dotted decimal number. Only one of the syntax elements that share the same dotted decimal number can specify a ! symbol. For example, if you hear the lines 2? FILE, 2.1! (KEEP), and 2.1 (DELETE), you know that (KEEP) is the default option for the FILE keyword. In this example, if you include the FILE keyword but do not specify an option, default option KEEP is applied. A default option also applies to the next higher dotted decimal number. In this example, if the FILE keyword is omitted, default FILE(KEEP) is used. However, if you hear the lines 2? FILE, 2.1, 2.1.1! (KEEP), and 2.1.1 (DELETE), the default option KEEP only applies to the next higher dotted decimal number, 2.1 (which does not have an associated keyword), and does not apply to 2? FILE. Nothing is used if the keyword FILE is omitted.

***** Specifies a syntax element that can be repeated zero or more times. A dotted decimal number followed by the * symbol indicates that this syntax element can be used zero or more times; that is, it is optional and can be repeated. For example, if you hear the line `5.1* data-area`, you know that you can include more than one data area or you can include none. If you hear the lines `3*`, `3 HOST`, and `3 STATE`, you know that you can include `HOST`, `STATE`, both together, or nothing.

Notes:

1. If a dotted decimal number has an asterisk (*) next to it and there is only one item with that dotted decimal number, you can repeat that same item more than once.
2. If a dotted decimal number has an asterisk next to it and several items have that dotted decimal number, you can use more than one item from the list, but you cannot use the items more than once each. In the previous example, you can write `HOST STATE`, but you cannot write `HOST HOST`.
3. The `*` symbol is equivalent to a loop-back line in a railroad syntax diagram.

+ Specifies a syntax element that must be included one or more times. A dotted decimal number followed by the + symbol indicates that this syntax element must be included one or more times. For example, if you hear the line `6.1+ data-area`, you must include at least one data area. If you hear the lines `2+`, `2 HOST`, and `2 STATE`, you know that you must include `HOST`, `STATE`, or both. As for the * symbol, you can repeat a particular item if it is the only item with that dotted decimal number. The `+` symbol, like the `*` symbol, is equivalent to a loop-back line in a railroad syntax diagram.

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