Informix Guide to SQL

Tutorial

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Introduction

This chapter introduces the *Informix Guide to SQL: Tutorial*. Read this chapter for an overview of the information provided in this manual and for an understanding of the conventions used throughout this manual.

About This Manual

The *Informix Guide to SQL: Tutorial* manual is intended to be used as companion volume to the *Informix Guide to SQL: Reference* and the *Informix Guide to SQL: Syntax*. Once you finish reading the *Informix Guide to SQL: Tutorial*, you can use the *Informix Guide to SQL: Reference* and the *Informix Guide to SQL: Syntax* as references to help you with daily SQL issues.

This tutorial includes instructions for using basic and advanced Structured Query Language (SQL) as well as for designing and managing your database.

Organization of This Manual

This manual includes the following chapters:

- This Introduction provides an overview of the manual and describes the documentation conventions used.
- Chapter 1, "Informix Databases," covers the fundamental concepts of databases and defines some terms that are used throughout the book. Chapter 1 discusses how a database is different from a collection of files; what terms are used to describe the main components of a database; what language is used to create, query, and modify a database; what the main parts of the software that manages a database are; and how these parts work with each other.

- Chapter 2, "Composing Simple SELECT Statements," shows how you can use the SELECT statement to query and retrieve data. It discusses how to tailor your statements to select columns or rows of data from one or more tables, how to include expressions and functions in SELECT statements, and how to create various join conditions between relational database tables.
- Chapter 3, "Composing Advanced SELECT Statements," 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 4, "Modifying Data," discusses solutions to problems such as the security of user access to the database and its tables. It also explains how to minimize the risk of system failure caused by external events.
- Chapter 5, "Programming with SQL," is an introduction to the concepts that are common to SQL programming. Before you can write a successful program in a particular programming language, you must become fluent in that language. Then, because the details of the process are slightly different in every language, you must become familiar with the manual for the Informix SQL API specific to that language or your NewEra or INFORMIX-4GL documentation.
- Chapter 6, "Modifying Data Through SQL Programs," covers the issues that arise when a program needs to modify the database by deleting, inserting, or updating rows. This chapter aims to prepare you for reading your Informix SQL API, NewEra, or 4GL product manual.
- Chapter 7, "Programming for a Multiuser Environment," addresses concurrency, locking, and isolation level issues as they pertain to a database that is accessed simultaneously by multiple users.
- Chapter 8, "Building Your Data Model," contains a cursory overview the first step towards constructing a data model—a precise, complete definition of the data to be stored. To understand the material in this chapter, you should have a basic understanding of SQL and relational database theory.
- Chapter 9, "Implementing Your Data Model," covers the decisions that you must make to implement the model.

- Chapter 10, "Granting and Limiting Access to Your Database," discusses how you can restrict access to your database. By using statements such as GRANT, REVOKE, and CREATE VIEW, you can deny access to some or all of the data to specified users.
- Chapter 11, "Understanding Informix Networking," explains how databases are used on a computer network. It introduces some commonly used terminology and illustrates various network configurations. The chapter also presents an overview of how the components of either a local connection or a network connection fit together so that a client application can find data on a database server.
- Chapter 12, "Creating and Using Stored Procedures," discusses how you can write procedures using SQL and some additional statements belonging to the Stored Procedure Language (SPL), and store the procedures in the database. These stored procedures are effective tools for controlling SQL activity.
- Chapter 13, "Creating and Using Triggers," describes the purpose of each component of the CREATE TRIGGER statement, illustrates some uses for triggers, and describes the advantages of using a stored procedure as a triggered action.

Types of Users

This manual is written for people who use Informix products and SQL on a regular basis. The primary audience for this manual consists of SQL developers and database administrators. The secondary audience consists of end users and anyone else who needs to know how to use SQL statements.

Software Dependencies

You must have the following Informix software to enter and execute SQL and SPL statements:

- An INFORMIX-OnLine Dynamic Server database server or an INFORMIX-SE database server

  The database server must be installed either on your computer or on another computer to which your computer is connected over a network.

- Either an Informix application development tool, such as INFORMIX-4GL; an SQL application programming interface (API), such as INFORMIX-ESQL/C; or the DB-Access database access utility, which is shipped as part of your database server.

  The application development tool, the SQL API, or DB-Access enables you to compose queries, send them to the database server, and view the results that the database server returns.

  You can use DB-Access to try out many of the SQL statements described in this manual. See the *DB-Access User Manual* for a list of all the SQL statements that you can run from DB-Access.

Demonstration Database

The DB-Access utility, which is provided with your Informix database server products, includes a demonstration database called **stores7** that contains information about a fictitious wholesale sporting-goods distributor. The sample command files that make up a demonstration application are also included.

Most examples in this manual are based on the **stores7** demonstration database. The **stores7** database is described in detail and its contents are listed in Appendix A of the *Informix Guide to SQL: Reference*.

The script that you use to install the demonstration database is called **dbaccessdemo7** and is located in the **$INFORMIXDIR/bin** directory. The database name that you supply is the name given to the demonstration database. If you do not supply a database name, the name defaults to **stores7**. Use the following rules for naming your database:

- Names can have a maximum of 18 characters for INFORMIX-OnLine Dynamic Server databases and a maximum of 10 characters for INFORMIX-SE databases.
- The first character of a name must be a letter or an underscore (_).
- You can use letters, characters, and underscores (_) for the rest of the name.
- DB-Access makes no distinction between uppercase and lowercase letters.
- The database name must be unique.

When you run **dbaccessdemo7**, as the creator of the database, you are the owner and Database Administrator (DBA) of that database.

If you install your Informix database server according to the installation instructions, the files that constitute the demonstration database are protected so that you cannot make any changes to the original database.

You can run the **dbaccessdemo7** script again whenever you want to work with a fresh demonstration database. The script prompts you when the creation of the database is complete and asks if you would like to copy the sample command files to the current directory. Enter `N` if you have made changes to the sample files and do not want them replaced with the original versions. Enter `Y` if you want to copy over the sample command files.

To create and populate the stores7 demonstration database

1. Set the **INFORMIXDIR** environment variable so that it contains the name of the directory in which your Informix products are installed.
2. Set **INFORMIXSERVER** to the name of the default database server.

   The name of the default database server must exist in the **$INFORMIXDIR/etc/sqlhosts** file. (For a full description of environment variables, see Chapter 4 of the *Informix Guide to SQL: Reference*.) For information about **sqlhosts**, see the *INFORMIX-OnLine Dynamic Server Administrator's Guide* or the *INFORMIX-SE Administrator's Guide*.
3. Create a new directory for the SQL command files. Create the directory by entering the following command:

   ```
   mkdir dirname
   ```
4. Make the new directory the current directory by entering the following command:

   ```
   cd dirname
   ```

5. Create the demonstration database, and copy over the sample command files by entering the **dbaccessdemo7** command.

   To create the database without logging, enter the following command:

   ```
   dbaccessdemo7 dbname
   ```

   To create the demonstration database with logging, enter the following command:

   ```
   dbaccessdemo7 -log dbname
   ```

   If you are using INFORMIX-OnLine Dynamic Server, by default the data for the database is put into the root dbspace. If you wish, you can specify a dbspace for the demonstration database.

   To create a demonstration database in a particular dbspace, enter the following command:

   ```
   dbaccessdemo7 dbname -dbspace dbspacename
   ```

   You can specify all of the options in one command, as shown in the following command:

   ```
   dbaccessdemo7 -log dbname -dbspace dbspacename
   ```

   If you are using INFORMIX-SE, a subdirectory called ***dbname*.dbs** is created in your current directory, and the database files associated with **stores7** are placed there. You will see both data (**.dat**) and index (**.idx**) files in the ***dbname*.dbs** directory. (If you specify a dbspace name, it is ignored.)

   To use the database and the command files that have been copied to your directory, you must have UNIX read and execute permissions for each directory in the pathname of the directory from which you ran the **dbaccessdemo7** script. Check with your system administrator for more information about operating-system file and directory permissions. UNIX permissions are discussed in the *INFORMIX-OnLine Dynamic Server Administrator's Guide* and the *INFORMIX-SE Administrator's Guide*.

6. To give someone else the permissions to access the command files in your directory, use the UNIX **chmod** command.

7. To give someone else access to the database that you have created, grant them the appropriate privileges using the GRANT statement.

   To revoke privileges, use the REVOKE statement. The GRANT and REVOKE statements are described in Chapter 1 of the *Informix Guide to SQL: Syntax*.

New Features of This Product

The Introduction to each Version 7.2 product manual contains a list of new features for that product. The Introduction to each manual in the Version 7.2 *Informix Guide to SQL* series contains a list of new SQL features.

A comprehensive list of all of the new features for Informix Version 7.2 products is in the release-notes file called **SERVERS_7.2**.

This section highlights the major new features implemented in Version 7.2 of Informix products that use SQL:

- Addition of Global Language Support (GLS)

  The GLS feature allows you to work in any supported language and to conform to the customs of a specific territory by setting certain environment variables. In support of GLS, CHAR and VARCHAR, columns of the system catalog tables are created as NCHAR and NVARCHAR columns in this release. In addition, hidden rows have been added to the **systables** system catalog table. See the discussion of GLS in Chapter 1 of the *Informix Guide to SQL: Reference*.

- ANSI flagger

  The ANSI flagger that Informix products use has been modified to eliminate the flagging of certain SQL items as Informix extensions. These items include the AS keyword in the SELECT clause of the SELECT statement and delimited identifiers in the Identifier segment.

- Bidirectional indexes

  The database server can now traverse an index in either ascending or descending order. So you no longer need to create both an ascending index and a descending index for a column when you use this column in both SELECT...ORDER BY *column name* ASC statements and SELECT...ORDER BY *column name* DESC statements. You only need to create a single ascending or descending index for these queries. See the CREATE INDEX and SELECT statements.

- Column matches in conditions

  When you specify a LIKE or MATCHES condition in the SELECT statement or other statements, you can specify a column name on both sides of the LIKE or MATCHES keyword. The database server retrieves a row when the values of the specified columns match. See the Condition segment and the SELECT statement.

- Column substrings in queries

  You can specify column subscripts for the column named in a SELECT...ORDER BY statement. The database server sorts the query results by the value of the column substring rather than the value of the entire column.

- Column updates after a fetch

  When you use the FOR UPDATE clause of the SELECT statement, you can use the OF *column name* option of this clause to limit the columns that can be updated after a fetch.

- Connectivity information

  You can use the **INFORMIXSQLHOSTS** environment variable to specify the pathname of the file where the client or the database server looks for connectivity information.

- COUNT function

  The ALL *column name* option of the COUNT function returns the total number of non-null values in the specified column or expression. See the Expression segment.

- Data distributions

  You can suppress the construction of index information in the MEDIUM and HIGH modes of the UPDATE STATISTICS statement. When you use the new DISTRIBUTIONS ONLY option of this statement, the database server gathers only distributions information and table infomation.

- Database renaming

  You can rename local databases. See the new RENAME DATABASE statement.

- DBINFO function

  You can use the 'sessionid' option of the DBINFO function to return the session ID of your current session. See the Expression segment.

- Decimal digits in client applications

  Informix client applications (including the DB-Access utility or any ESQL program that you write) by default display 16 decimal digits of data types FLOAT, SMALLFLOAT, and DECIMAL. The actual digits that are displayed can vary according to the size of the character buffer. The new **DBFLTMASK** environment variable allows you to override the default of 16 decimal digits in the display.

- Default privileges on tables

  You can use the new **NODEFDAC** environment variable to prevent default table privileges from being granted to PUBLIC when a new table is created in a database that is not ANSI compliant.

- Fragment authorization

  You can grant and revoke privileges on individual fragments of tables. See the new GRANT FRAGMENT and REVOKE FRAGMENT statements and the new **sysfragauth** system catalog table.

- High-Performance Loader (HPL) configuration

  You can use the new **DBONPLOAD** and **PLCONFIG** environment variables to specify the names of files and databases to be used by HPL.

- In-place alter algorithm

  INFORMIX-OnLine Dynamic Server uses a new in-place alter algorithm for altering tables when you add a column to the end of the table. See the ALTER TABLE statement.

- Next century in year values

  You can use the next century to expand two-digit year values. See the new **DBCENTURY** environment variable, the Literal DATETIME segment, the DATE data type, and the DATETIME data type.

- Not null constraints

  You can now create not null constraints with the CREATE TABLE and ALTER TABLE statements. The database server records not null constraints in the **sysconstraints** and **syscoldepend** system catalog tables.

- Object modes

  You can specify the object mode of database objects with the new SET statement. This statement permits you to set the object mode of constraints, indexes, and triggers or the transaction mode of constraints. See the SET statement, the new **sysobjstate** system catalog table, and the new syntax for object modes in ALTER TABLE, CREATE INDEX, CREATE TABLE, and CREATE TRIGGER.

- Optical StageBlob area

  You can use the new **INFORMIXOPCACHE** environment variable to specify the size of the memory cache for the Optical StageBlob area of the client application.

- RANGE, STDEV, and VARIANCE functions

  You can use the new aggregate functions RANGE, STDEV, and VARIANCE. See the new syntax for Aggregate Expressions in the Expression segment.

- Roles

  You can create, drop, and enable roles. You can grant roles to individual users and to other roles, and you can grant privileges to roles. You can revoke a role from individual users and from another role, and you can revoke privileges from a role. See the new CREATE ROLE, DROP ROLE, and SET ROLE statements and the new **sysroleauth** system catalog table. Also see the new syntax for roles in the GRANT and REVOKE statements and the new information in the **sysusers** system catalog table.

- Separation of administrative tasks

  The security feature of role separation allows you to separate administrative tasks performed by different groups that are running and auditing OnLine. The **INF_ROLE_SEP** environment variable allows you to implement role separation during installation of OnLine.

- Session authorization

  You can change the user name under which database operations are performed in the current session and thus assume the privileges of the specified user during the session. See the new SET SESSION AUTHORIZATION statement.

- Table access after loads

  The FOR READ ONLY clause of the SELECT statement allows you to access data in the tables of an ANSI-mode database after you have loaded the data with the High-Performance Loader but before you have performed a level-0 backup of the data. After you have performed the level-0 backup, you no longer need to use the FOR READ ONLY clause. See the SELECT and DECLARE statements.

- Thread-safe applications

  You can use the new **THREADLIB** environment variable to compile thread-safe ESQL/C applications. In a thread-safe ESQL/C application, you can use the DORMANT option of the SET CONNECTION statement to make an active connection dormant.

- Tutorials

  Tutorial information on new features has been added to this manual. The new tutorials cover Global Language Support (GLS), thread-safe applications, object modes, violation detection, fragment authorization, and roles.

- Utilities

  The **dbexport**, **dbimport**, **dbload**, and **dbschema** utilities have been moved from the *Informix Guide to SQL: Reference* to the *Informix Migration Guide*.

- Violation detection

  You can create special tables called violations and diagnostics tables to detect integrity violations. See the new START VIOLATIONS TABLE and STOP VIOLATIONS TABLE statements and the new **sysviolations** system catalog table.

- XPG4 compliance

  SQL statements and data structures have been modified to provide enhanced compliance with the *X/Open Portability Guide 4* (XPG4) specification for SQL. The **sqlwarn** array within the SQL Communications Area (SQLCA) has been modified. A new SQLSTATE code (01007) has been added. The behavior of the ALL keyword in the GRANT statement and the behavior of the ALL and RESTRICT keywords in the REVOKE statement has changed.

See the *Informix Guide to SQL: Syntax* manual for SQL statements and segments. See the *Informix Guide to SQL: Reference* for data types, system catalog tables, and environment variables. See this manual for tutorial information.

Conventions

This section describes the conventions that are used in this manual. By becoming familiar with these conventions, you will find it easier to gather information from this and other volumes in the documentation set.

The following conventions are covered:

- Typographical conventions
- Icon conventions
- Sample-code conventions
- Terminology conventions

Typographical Conventions

This manual uses a standard set of conventions to introduce new terms, illustrate screen displays, describe command syntax, and so forth. The following typographical conventions are used throughout this manual.

Convention	Meaning
italics	Within text, new terms and emphasized words are printed in italics. Within syntax diagrams, values that you are to specify are printed in italics.
boldface	Identifiers (names of classes, objects, constants, events, functions, program variables, forms, labels, and reports), environment variables, database names, table names, column names, menu items, command names, and other similar terms are printed in boldface.
`monospace`	Information that the product displays and information that you enter are printed in a monospace typeface.
KEYWORD	All keywords appear in uppercase letters.
♦	This symbol indicates the end of product- or platform-specific information.

Tip: *When you are instructed to "enter" characters or to "execute" a command, immediately press* RETURN *after the entry. When you are instructed to "type" the text or to "press" other keys, no* RETURN *is required.*

Icon Conventions

Throughout the documentation, you will find text that is identified by several different types of icons. This section describes these icons.

Comment Icons

Comment icons identify three types of information, as described in the following table. This information is always displayed in italics.

Icon	Description
⚠	Identifies paragraphs that contain vital instructions, cautions, or critical information.
➡	Identifies paragraphs that contain significant information about the feature or operation that is being described.
💡	Identifies paragraphs that offer additional details or shortcuts for the functionality that is being described.

Product and Platform Icons

Product and platform icons identify paragraphs that describe product-specific or platform-specific information. The following table describes the product and platform icons that are used in this manual.

Icon	Description
SE	Identifies information that is valid only for INFORMIX-SE.
D/B	Identifies information that is valid only for DB-Access.
ESQL	Identifies information that is valid only for SQL statements in INFORMIX-ESQL/C and INFORMIX-ESQL/COBOL.
E/C	Identifies information that is valid only for INFORMIX-ESQL/C.

Icon	Description
E/CO	Identifies information that is valid only for INFORMIX-ESQL/COBOL.
SPL	Identifies information that is valid only if you are using Informix Stored Procedure Language (SPL).
OP	Identifies information that is valid only for INFORMIX-OnLine/Optical.

These icons can apply to a row in a table, one or more paragraphs, or an entire section. A ♦ symbol indicates the end of the product- or platform-specific information.

Compliance Icons

Compliance icons indicate paragraphs that provide guidelines for complying with a standard.

Icon	Description
ANSI	Identifies information that is specific to an ANSI-compliant database.
GLS	Identifies information that is valid only if your database or application uses a nondefault GLS locale.
X/O	Indicates that the functionality described in the text conforms to X/Open specifications for dynamic SQL. This functionality is available when you compile your SQL API with the **-xopen** flag.

These icons can apply to a row in a table, one or more paragraphs, or an entire section. A ♦ symbol indicates the end of the compliance information.

Sample-Code Conventions

Examples of SQL code occur throughout this manual. Except where noted, the code is not specific to any single Informix application development tool. If only SQL statements are listed in the example, they are not delimited by semicolons. To use this SQL code for a specific product, you must apply the syntax rules for that product. For example, if you are using the Query-language option of DB-Access, you must delimit multiple statements with semicolons. If you are using an SQL API, you must use EXEC SQL and a semicolon (or other appropriate delimiters) at the start and end of each statement, respectively.

For instance, you might see the code in the following example:

```
CONNECT TO stores7
.
.
.
DELETE FROM customer
    WHERE customer_num = 121
.
.
.
COMMIT WORK
DISCONNECT CURRENT
```

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

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

Terminology Conventions

This manual uses a standard set of conventions for terms and abbreviations.

Definitions of Terms

For definitions of terms used in this manual and the other manuals of the SQL series, see the Glossary in the *Informix Guide to SQL: Reference*.

Abbreviations of Product Names

The following abbreviations for product names appear in this manual.

Abbreviation	Complete Product Name
GLS	Global Language Support
OnLine	INFORMIX-OnLine Dynamic Server
SE	INFORMIX-SE
SQL	Structured Query Language

Additional Documentation

This section describes the following pieces of the documentation set:

- Printed documentation
- On-line documentation
- Related reading

Printed Documentation

In addition to this manual, the following printed manuals are included in the SQL manual series:

- A companion volume to this manual, the *Informix Guide to SQL: Reference*, provides reference information on the types of Informix databases you can create, the data types supported in Informix products, system catalog tables associated with the database, and environment variables you can set to use your Informix products properly. This manual also provides a detailed description of the **stores7** demonstration database and contains a glossary.
- An additional companion volume, the *Informix Guide to SQL: Syntax*, provides a detailed description of all the SQL statements supported by Informix products. This guide also provides a detailed description of Stored Procedure Language (SPL) statements.
- The *SQL Quick Syntax Guide* contains syntax diagrams for all statements and segments described in the *Informix Guide to SQL: Syntax*.

The following related Informix documents complement the information in this manual set:

- *Getting Started with Informix Database Server Products* provides an orientation to the Informix client/server environment and describes the manuals for Informix products. If you are a new user of Informix products, it is helpful to read this manual before you read any of the manuals in the SQL manual series.
- The *Guide to GLS Functionality* explains the impact of GLS on Informix products. This manual includes a chapter on SQL features and a chapter on GLS environment variables.
- You, or whoever installs your Informix products, should refer to the *UNIX Products Installation guide* for your particular release to ensure that your Informix product is set up properly before you begin to work with it. A matrix that depicts possible client/server configurations is included in the *UNIX Products Installation guide*.
- Depending on the database server you are using, you or your system administrator need either the *INFORMIX-SE Administrator's Guide* or the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

- The *DB-Access User Manual* describes how to invoke the DB-Access utility to access, modify, and retrieve information from Informix database servers.
- When errors occur, you can look them up by number and learn their cause and solution in the *Informix Error Messages* manual. If you prefer, you can look up the error messages in the on-line message file described in the section "Error Message Files" below and in the Introduction to the *Informix Error Messages* manual.

On-Line Documentation

The following online files supplement this document:

- On-line error messages
- Release notes, documentation notes, and machine notes

Error Message Files

Informix software products provide ASCII files that contain all of the Informix error messages and their corrective actions. To read the error messages in the ASCII file, Informix provides scripts that let you display error messages on the screen (**finderr**) or print formatted error messages (**rofferr**). See the Introduction to the *Informix Error Messages* manual for a detailed description of these scripts.

The optional Informix Messages and Corrections product provides PostScript files that contain the error messages and their corrective actions. If you have installed this product, you can print the PostScript files on a PostScript printer. The PostScript error messages are distributed in a number of files of the format **errmsg1.ps**, **errmsg2.ps**, and so on. These files are located in the **$INFORMIXDIR/msg** directory.

Release Notes, Documentation Notes, Machine Notes

In addition to the Informix set of manuals, the following on-line files, located in the **$INFORMIXDIR/release/en_us/0333** directory, supplement the information in this manual.

On-Line File	Purpose
Documentation Notes	Describes features not covered in the manual or that have been modified since publication. The file that contains the documentation notes for this product is called **SQLTDOC_7.2**.
Release Notes	Describes feature differences from earlier versions of Informix products and how these differences might affect current products. The file that contains the release notes for Version 7.2 of Informix database server products is called **SERVERS_7.2**.
Machine Notes	Describes any special actions required to configure and use Informix products on your computer. Machine notes are named for the product described. For example, the machine notes file for INFORMIX-OnLine Dynamic Server is **ONLINE_7.2.**

Please examine these files because they contain vital information about application and performance issues.

Related Reading

For additional technical information on database management, consult the following books. The first book is an introductory text for readers who are new to database management, while the second book is a more complex technical work for SQL programmers and database administrators:

- *Database: A Primer* by C. J. Date (Addison-Wesley Publishing, 1983)
- *An Introduction to Database Systems* by C. J. Date (Addison-Wesley Publishing, 1994).

To learn more about the SQL language, consider the following books:

- *A Guide to the SQL Standard* by C. J. Date with H. Darwen (Addison-Wesley Publishing, 1993)
- *Understanding the New SQL: A Complete Guide* by J. Melton and A. Simon (Morgan Kaufmann Publishers, 1993)
- *Using SQL* by J. Groff and P. Weinberg (Osborne McGraw-Hill, 1990)

This manual assumes that you are familiar with your computer operating system. If you have limited UNIX system experience, consult your operating system manual or a good introductory text before you read this manual. The following texts provide a good introduction to UNIX systems:

- *Introducing the UNIX System* by H. McGilton and R. Morgan (McGraw-Hill Book Company, 1983)
- *Learning the UNIX Operating System* by G. Todino, J. Strang, and J. Peek (O'Reilly & Associates, 1993)
- *A Practical Guide to the UNIX System* by M. Sobell (Benjamin/Cummings Publishing, 1989)
- *UNIX for People* by P. Birns, P. Brown, and J. Muster (Prentice-Hall, 1985)
- *UNIX System V: A Practical Guide* by M. Sobell (Benjamin/Cummings Publishing, 1995)

Compliance with Industry Standards

The American National Standards Institute (ANSI) has established a set of industry standards for SQL. 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 on INFORMIX-OnLine Dynamic Server. In addition, many features of OnLine comply with the SQL-92 Intermediate and Full Level and X/Open CAE (common applications environment) standards.

Informix SQL-based products are compliant with ANSI SQL-92 Entry Level (published as ANSI X3.135-1992) on INFORMIX-SE with the following exceptions:

- Effective checking of constraints
- Serializable transactions

Informix Welcomes Your Comments

Please let us know what you like or dislike about our manuals. To help us with future versions of our manuals, please tell us about any corrections or clarifications that you would find useful. Write to us at the following address:

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- Any comments that you have about the manual
- Your name, address, and phone number

We appreciate your feedback.

Section I

Using Basic SQL

Chapter

Informix Databases

1

This book is about databases and about how you can exploit them using Informix software. As you start reading, keep in mind the following fundamental database characteristics: a database comprises not only data but also a plan, or *model*, of the data; a database can be a common resource, used concurrently by many people. Your real use of a database begins with the SELECT statement, which is described in Chapter 2, "Composing Simple SELECT Statements." If you are in a hurry, and if you know at least a little about databases, turn to it now.

This chapter covers the fundamental concepts of databases and defines some terms that are used throughout the book, emphasizing the following topics:

- What terms are used to describe the main components of a database?
- What language is used to create, query, and modify a database?
- What are the main parts of the software that manages a database, and how do these parts work with each other?

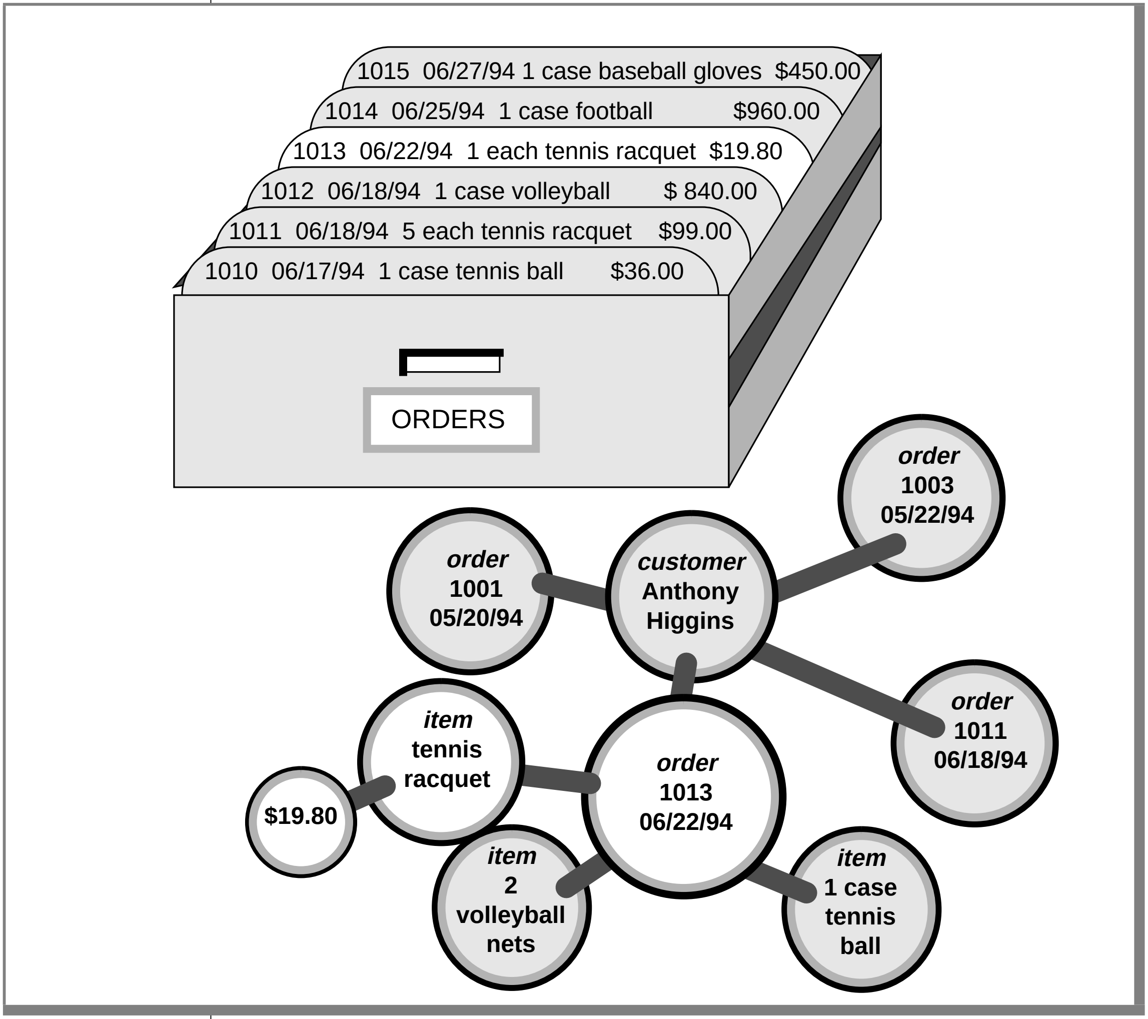
The Data Illustration of a Data Model

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 is related 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. It might be a *price* that is associated with a *product* that was sold as one *item* of an *order* that was placed by a *customer*. Each of these components, price, product, item, order, and customer, also has a role that the data model specifies. See Figure 1-1.

The data model is designed when the database is created. Units of data are then inserted according to the plan that the model lays out. Some books use the term *schema* instead of *data model*.

Figure 1-1
The Advantage of Using a Data Model


1015 06/27/94 1 case baseball gloves $450.00
1014 06/25/94 1 case football $960.00
1013 06/22/94 1 each tennis racquet $19.80
1012 06/18/94 1 case volleyball $ 840.00
1011 06/18/94 5 each tennis racquet $99.00
1010 06/17/94 1 case tennis ball $36.00
ORDERS
order 1003 05/22/94
order 1001 05/20/94
customer Anthony Higgins
order 1011 06/18/94
item tennis racquet
order 1013 06/22/94
$19.80
item 2 volleyball nets
item 1 case tennis ball

Storing 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 very detailed structures describing 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 5, "Programming with SQL," and Chapter 6, "Modifying Data Through SQL Programs."

Querying Data

Another difference between a database and a file is the way you can interrogate 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 a file, "What records have numbers under 20 in the fifth field?" Figure 1-2 shows this type of search.

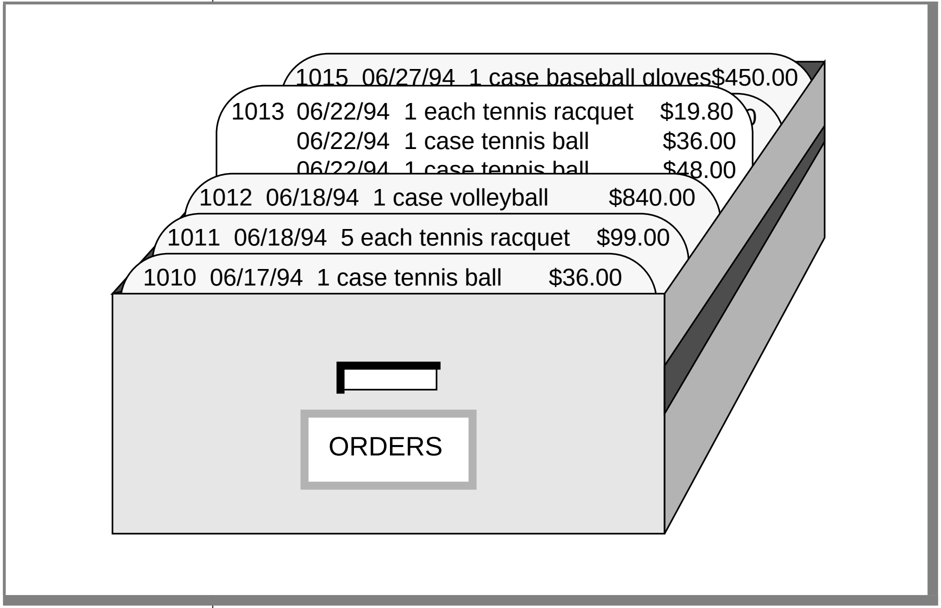

1015 06/27/94 1 case baseball gloves $450.00
1013 06/22/94 1 each tennis racquet $19.80
06/22/94 1 case tennis ball $36.00
06/22/94 1 case tennis ball $48.00
1012 06/18/94 1 case volleyball $840.00
1011 06/18/94 5 each tennis racquet $99.00
1010 06/17/94 1 case tennis ball $36.00
ORDERS

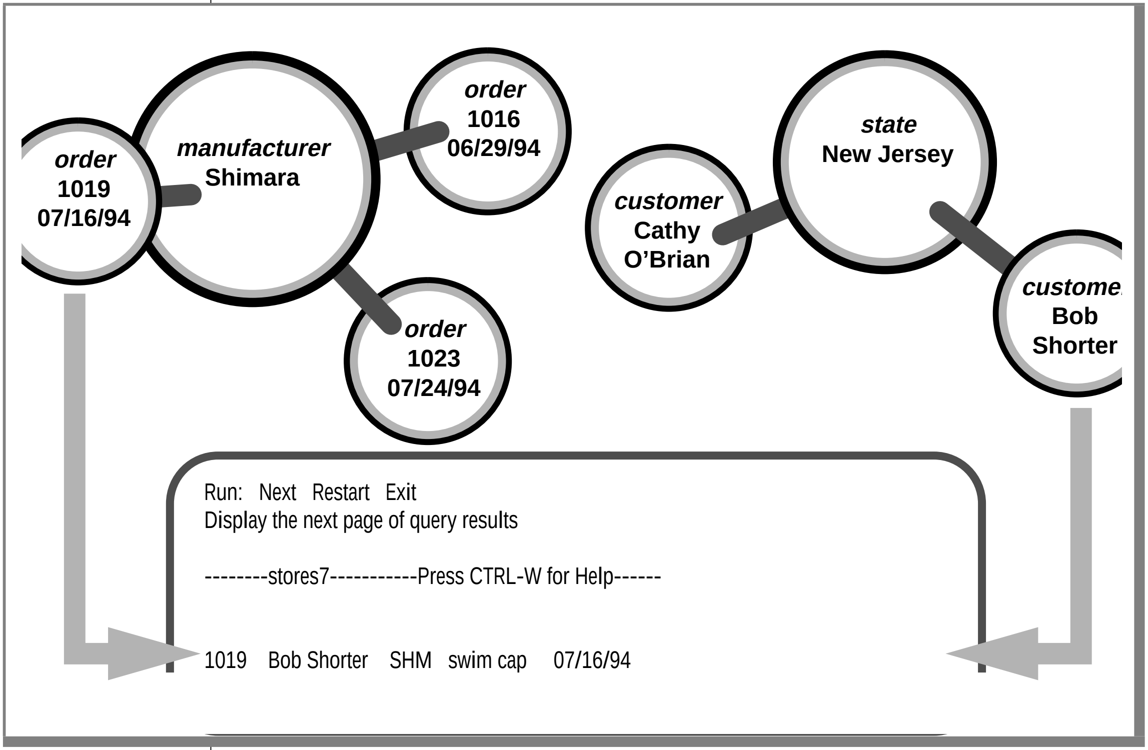
Figure 1-2
Searching a File Sequentially

In contrast, when you query a database, you use the terms that its 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?" Figure 1-3 shows this type of query.

In other words, when you interrogate 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.

In this manual, Chapter 2 and Chapter 3 discuss the language you use for making queries. Chapter 8 and Chapter 9 discuss designing an accurate, robust data model for other users to query.

Figure 1-3
Querying a Database



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

--------stores7-----------Press CTRL-W for Help------


1019   Bob Shorter   SHM   swim cap    07/16/94
```

Modifying Data

The 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 less.

The statements you use to modify stored data are covered in Chapter 5, "Programming with SQL."

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 among only a select group of persons; still other databases provide public access.

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 (In fact, you can reveal entirely 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

The facilities that make these and other things possible are discussed in Chapter 10, "Granting and Limiting Access to Your Database."

Centralized Management

Databases that are used by many people are highly valuable and must be protected as important business assets. Compiling a store of valuable data and simultaneously allowing many employees to access it creates a significant problem: protecting data while maintaining performance. The INFORMIX-OnLine Dynamic Server 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 good will while users cannot work. A plan for regular backups helps avoid or mitigate these potential disasters.

A large database used by many people 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.

Group and Private Databases

Some Informix database servers are designed to manage relatively small databases that individuals use privately or that a small group of users share.

These database servers (for example, INFORMIX-SE for the UNIX operating system) store databases in files that the host operating system manages. These databases can be backed up using the same procedures for backing up files that work with other computer files; that is, copying the files to another medium when they are not in use. The only difference is that when a database is backed up its transaction log file must be reset to empty. (The use of transaction logs is discussed in Chapter 7, "Programming for a Multiuser Environment." The *INFORMIX-OnLine Dynamic Server Administrator's Guide* and *INFORMIX-OnLine Dynamic Server Archive and Backup Guide* provide more information on backups.)

Performance problems that arise in group and private databases are usually related to particular queries that take too long. The *INFORMIX-OnLine Dynamic Server Performance Guide* deals in depth with the reasons a query takes more or less time. After you understand all the features of the SELECT statement and the alternative ways of stating a query, as covered in Chapter 2, "Composing Simple SELECT Statements," and Chapter 3, "Composing Advanced SELECT Statements" in this manual, you can use the information in the *INFORMIX-OnLine Dynamic Server Performance Guide* to understand the performance impact of queries.

Essential Databases

The INFORMIX-OnLine Dynamic Server database server is designed to manage large databases with requirements for high reliability, high availability, and high performance. Although INFORMIX-OnLine Dynamic Server supports private and group databases very well, it is at its best managing the databases that are essential for your organization to carry out its work.

INFORMIX-OnLine Dynamic Server lets you make backups while the databases are in use. It also allows incremental backups (backing up only modified data), an important feature when you are making a complete copy that could take many tapes.

INFORMIX-OnLine Dynamic Server has an interactive monitor program that lets its operator (or any user) monitor the activities within the database server to see when bottlenecks are developing. It also comes with utility programs to analyze its use of disk storage. In addition, OnLine provides the **sysmaster** tables that contain information about an entire OnLine database server, which might manage many databases. For more information about the **sysmaster** tables, see the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

The *INFORMIX-OnLine Dynamic Server Performance Guide* contains tips on optimizing placement of tables on disk. All the details of using and managing OnLine are contained in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

Important Database Terms

You should know two sets of terms before you begin the next chapter. One set of terms describes the database and the data model; the other set describes the computer programs that manage the database.

The Relational Model

Informix databases are *relational* databases. In technical terms, that means that the data model by which an Informix database is organized is based on the relational calculus devised by E. F. Codd. In practical terms, it means that all data is presented in the form of *tables* with *rows* and *columns*.

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 Informix 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 is known about one *entity*, one type of thing that the database describes. The example table, **stock**, represents all that is known about the merchandise that is stocked by a sporting-goods store. Other tables in the demonstration database represent such entities as **customer** and **orders**.

Think of a database as a collection of tables. To create a database is to create a set of tables. The right to query or modify tables can be controlled on a table-by-table basis, so that some users can view or modify some tables but not others.

Columns

Each column of a table stands for one *attribute*, which is one characteristic, feature, or fact that is true of 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 stands for 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.

Tables, Rows, and Columns

Now you understand that the relational model is a way of organizing data to reflect the world. It uses the following simple corresponding relationships:

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. (Database design is covered in Chapter 8 and Chapter 9.) The data model in an existing database already is 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.

Operations on Tables

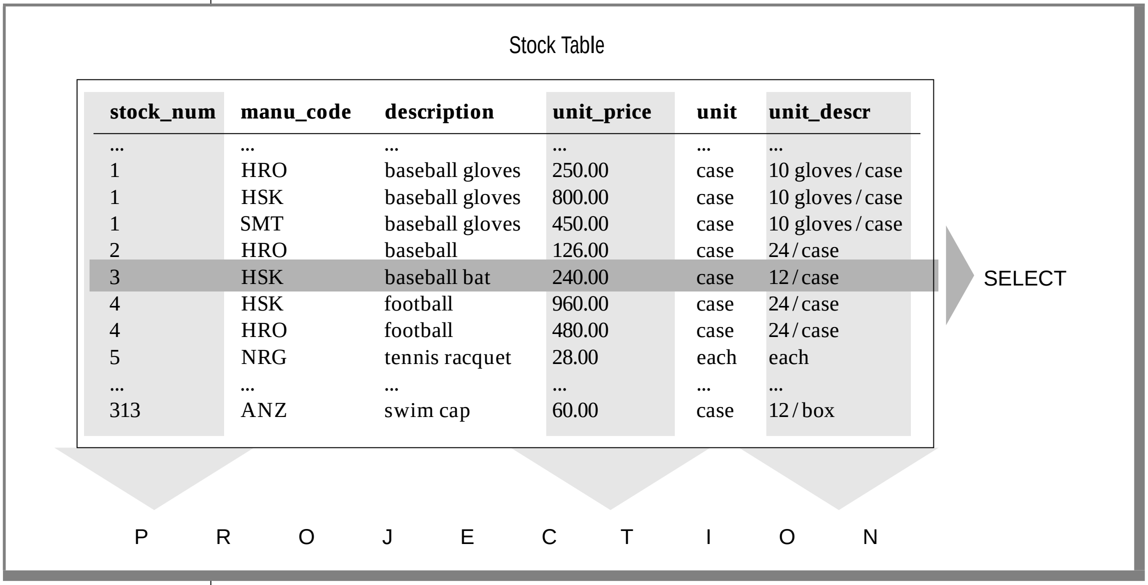
Because a database is really a collection of tables, database operations are operations on tables. The relational model supports three fundamental operations, two of which are shown in the following illustration. (All three operations are defined in more detail, with many examples, in Chapter 2, “Composing Simple SELECT Statements,” and Chapter 3, “Composing Advanced SELECT Statements.”)

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 HRO and the unit price is between 100.00 and 200.00.”

When you *project* from a table, you are choosing certain columns and ignoring others. For example, you can query the 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. (The join operation is the subject of Chapter 3, “Composing Advanced SELECT Statements.”) See Figure 1-4.

Figure 1-4
Illustration of Selection and Projection



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

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 second 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('7/1/94') AND DATE('7/30/94')
```

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 Informix implementation of SQL includes about 76 statements, from ALLOCATE DESCRIPTOR to WHENEVER.

All the SQL statements are specified in detail in the *Informix Guide to SQL: Syntax*. Most of the statements are used infrequently, when you set up or tune a database. People generally use three or four statements to query or update databases.

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

SQL and the relational model 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 vendors began to provide similar products for non-IBM computers.

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 SQL version that Informix products support is highly compatible with standard SQL (it is also compatible with the IBM version of the language). However, it does contain *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 the SQL use for a typical person.

However, the extensions do exist and create a conflict. Thousands of Informix customers have embedded Informix-style SQL in programs and stored queries. They rely on Informix to keep its language the same. Other customers require the ability to use databases in a way that conforms exactly to the ANSI standard. They rely on Informix to change its language to conform.

Informix resolved the conflict with the following compromise:

- The Informix version of SQL, with its extensions to the standard, is available by default.
- You can ask any Informix SQL language processor to check your use of SQL and post a warning flag whenever you use an Informix extension.

This resolution is fair but makes the SQL documentation more complicated. Wherever a difference exists between Informix and ANSI SQL, the *Informix Guide to SQL: Syntax* describes both versions. Because you probably intend to use only one version, simply ignore the version you do not need.

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 standard apply. For example, all actions that modify data automatically take place within a transaction, 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 *Informix Guide to SQL: Syntax*.

GLS Databases

GLS

The Version 7.2 Informix database server products provide Global Language Support (GLS). In addition to U.S. ASCII English, GLS allows you to work in other locales. You can use GLS to conform to the customs of a specific locale. The locale files contain unique information such as various money and date formats and multibyte characters used in identification or data names.

For additional information on GLS databases, see Chapter 1 in the *Informix Guide to SQL: Reference*. For complete GLS information, see the *Guide to GLS Functionality*. ♦

The Database Software

You access your database through two layers of sophisticated software. The top layer, or *application*, sends commands or queries to the database server. The application calls on the bottom layer, or *database server*, and gets back information. You command both layers when you use SQL.

The Applications

A *database application*, or simply *application*, is a program that uses the database. It does so by communicating with the database server. At its simplest, the application sends SQL commands to the database server, and the database server sends rows of data back to the application. Then the application displays the rows to you, its user.

Alternatively, you command the application to add new data to the database. It incorporates the new data as part of an SQL command to insert a row and passes this command to the database server for execution.

Several types of applications exist. Some allow you to access the database interactively with SQL; others present the stored data in different forms related to its use.

The Database Server

The *database server* is the program that manages the contents of the database as they are stored on disk. The database server knows how tables, rows, and columns are actually organized in physical computer storage. The database server also interprets and executes all SQL commands.

Interactive SQL

To carry out the examples in this book, and to experiment with SQL and database design for yourself, you need a program that lets you execute SQL statements interactively. DB-Access and INFORMIX-SQL are two such programs. They assist you in composing SQL statements; then they pass your SQL statements to the database server for execution and display the results to you.

Reports and Forms

After you perfect a query to return precisely the data that you want, you need to format the data for display as a report or form on the terminal screen. ACE is the report generator for INFORMIX-SQL. You provide to ACE a SELECT statement that returns the rows of data and a report specification that indicates how the pages are laid out. ACE compiles this information into a program that you can run whenever you want to produce that report. With INFORMIX-4GL and INFORMIX-NewEra, you can use the 4GL report language to create formatted display.

PERFORM is the module of INFORMIX-SQL that generates interactive screen forms. You prepare a form specification that relates display fields on the screen to columns within tables in the database. PERFORM compiles this specification into a program that you can run at any time. When run, the form program interrogates the database to display a row or rows of data on the screen in the format you specified. You can arrange the form so that the user can type in sample values and have matching rows returned from the database (the *query-by-example* feature).

NewEra provides a Form Painter and a Visual Class Library for display of data in a graphical environment. INFORMIX-4GL also supports form specification files for screen display of data. For more information on these products, refer to the manuals that come with them.

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 also can write programs that take data from any source in any format, prepare it, and insert it into the database.

The most convenient programming languages for this kind of work are NewEra, with an object-oriented language, and INFORMIX-4GL, with a procedural language. Both are designed expressly for writing database applications. However, you can also communicate with an Informix database server from programs that contain embedded SQL written in C and COBOL.

You also can write programs called stored procedures to work with database data and objects. The stored procedures that you write are stored directly in a database within tables. You can then execute a stored procedure from DB-Access or an SQL API.

Chapter 5, "Programming with SQL," and Chapter 6, "Modifying Data Through SQL Programs," present an overview of how SQL is used in programs.

Applications and Database Servers

Every program that uses data from a database operates the same way. Regardless of whether it is a packaged program such as ViewPoint Pro, a report program compiled by ACE, or a program that you wrote with INFORMIX-NewEra or an SQL API, you find the same two layers in every case:

- An application that interacts with the user, prepares and formats data, and sets up SQL statements
- A database server that manages the database and interprets the SQL

All the applications make requests of the database server, and only the database server manipulates the database files on disk.

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 their access to those contents can be restricted in several ways.

A database can be crucially important to the success of an organization and can require central administration and monitoring. The OnLine database server caters to the needs of *essential* applications; both OnLine and INFORMIX-SE support smaller databases for private or group use.

To manipulate and query a database use SQL. IBM pioneered SQL and ANSI standardized it. Informix added extensions to the ANSI-defined language, that you can use to your advantage. 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 Informix and some written by you or written by other vendors or your colleagues.

Chapter

2

Composing Simple SELECT Statements

SELECT is the most important and the most complex SQL statement. You can use it, along with the SQL statements INSERT, UPDATE, and DELETE, to manipulate data. You can use the SELECT statement in the following ways:

- By itself to retrieve data from a database
- As part of an INSERT statement to produce new rows
- 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, screen form, or spreadsheet.

This chapter shows how you can use the SELECT statement to query on and retrieve data in a variety of ways from a relational database. 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 relational database tables.

This chapter introduces the basic methods for retrieving data from a relational database. More complex uses of SELECT statements, such as subqueries, outer joins, and unions, are discussed in Chapter 3, "Composing Advanced SELECT Statements." The syntax and usage for the SELECT statement are described in detail in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Most examples in this chapter come from the tables in the **stores7** demonstration database, which is installed with the software for your 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. See Appendix A in the *Informix Guide to SQL: Reference* for information on the structure and contents of the **stores7** database. For emphasis, keywords are shown in uppercase letters in the examples, although SQL is not case sensitive.

Introducing the SELECT Statement

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. You must include these clauses in a SELECT statement in the following order:

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

Only the SELECT and FROM clauses are required. These two clauses form the basis for every database query because they specify the tables and columns to be retrieved. 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 3, "Composing Advanced SELECT Statements." Another clause, INTO, specifies the program or host variable to receive data from a SELECT statement in INFORMIX-NewEra, INFORMIX-4GL, and SQL APIs. Complete syntax and rules for using the SELECT statement are shown in Chapter 1 of the *Informix Guide to SQL: Syntax*.

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 on or *select* the data concurrently. The statements that modify data appear in Chapter 4, "Modifying Data." The INSERT, UPDATE, and DELETE statements appear in Chapter 1 of the *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 file 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 shown in Chapter 2 of the *Informix Guide to SQL: Reference*. Views are discussed in Chapter 10, "Granting and Limiting Access to Your Database," of this manual.

Privileges

Before you query data, make sure you have the database Connect privilege and the table Select privileges. These privileges are normally granted to all users. Database access privileges are discussed in Chapter 10, "Granting and Limiting Access to Your Database," of this manual and in the GRANT and REVOKE statements in Chapter 1 of the *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 of the columns in a table. Selection is implemented through the WHERE clause of a SELECT statement, as Query 2-1 shows.

Query 2-1

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

Query Result 2-1 contains the same number of columns as the **customer** table, but only a subset of its rows. Because the data in the selected columns does not fit on one line of the DB-Access or INFORMIX-SQL Interactive Schema Editor (ISED) screen, the data is displayed vertically instead of horizontally.

Query Result 2-1

```
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
```

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 of the rows in a table.

Projection is implemented through the select list in the SELECT clause of a SELECT statement, as Query 2-2 shows.

Query 2-2

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

Query Result 2-2 contains the same number of rows as the **customer** table, but it *projects* only a subset of the columns in the table.

Query Result 2-2

```
city            state zipcode

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

The most common kind of SELECT statement uses both selection and projection. A query of this kind, shown in Query 2-3, returns some of the rows and some of the columns in a table.

Query 2-3

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

Query Result 2-3 contains a subset of the rows and a subset of the columns in the **customer** table.

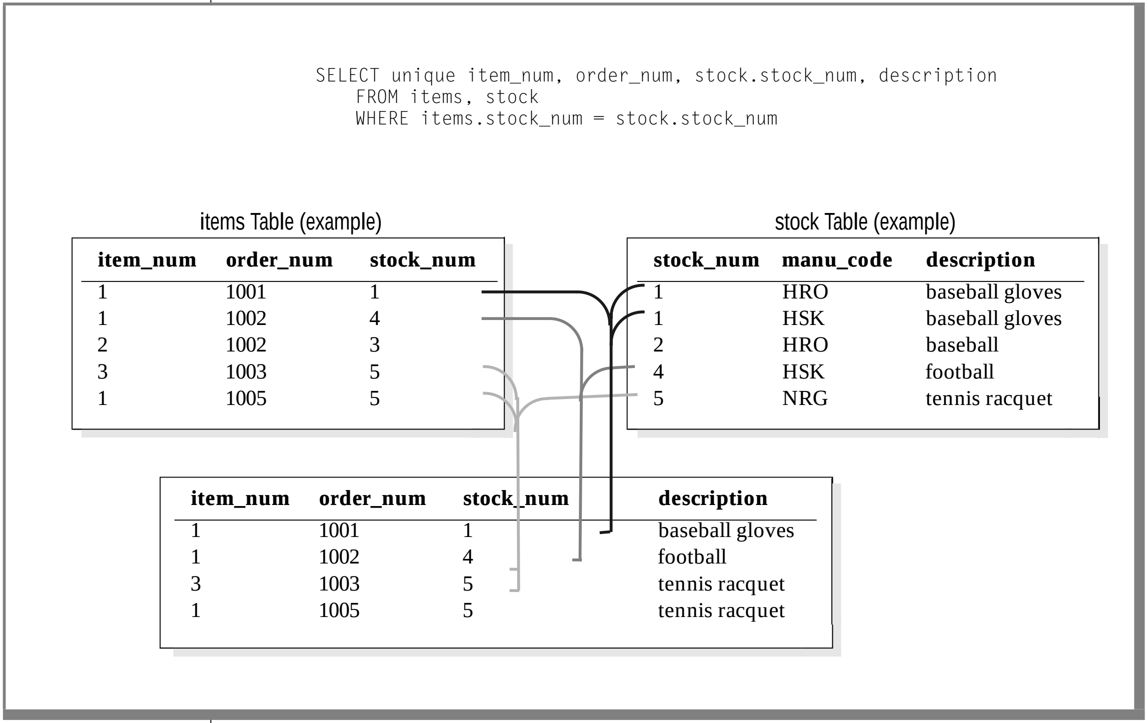
Query Result 2-3

```
city            state zipcode

Cherry Hill     NJ    08002
Princeton       NJ    08540
```

Joining

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

A Join Between Two Tables



```
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	order_num	stock_num	description
1	1001	1	baseball gloves
1	1002	4	football
3	1003	5	tennis racquet
1	1005	5	tennis racquet

Query 2-4 joins the **customer** and **state** tables.

Query 2-4

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

Query Result 2-4 consists of specified rows and columns from both the **customer** and **state** tables.

Query Result 2-4

```
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
```

The Forms of SELECT

Although the syntax remains the same across all Informix products, the form of a SELECT statement and the location and formatting of the resulting output depends on the application. The examples in this chapter and in Chapter 3, "Composing Advanced SELECT Statements," display the SELECT statements and their output as they appear when you use the interactive Query-language option in DB-Access or INFORMIX-SQL.

You also can use SELECT statements to query on data noninteractively through INFORMIX-SQL ACE reports. You can embed them in a language such as INFORMIX-ESQL/C (where they are treated as executable code), you can incorporate them in INFORMIX-4GL as part of its fourth-generation language, or you can either have them automatically generated or embed them with INFORMIX-NewEra.

Special Data Types

The examples in this chapter use the INFORMIX-OnLine Dynamic Server database server, which enables database applications to include the data types VARCHAR, TEXT, and BYTE. These data types are not available to applications that run on INFORMIX-SE.

With the DB-Access or INFORMIX-SQL Interactive Editor, when you issue a SELECT statement that includes one of these three data types, the results of the query are displayed differently.

- If you execute a query on a VARCHAR column, the entire VARCHAR value is displayed, just as CHARACTER values are displayed.
- If you select a TEXT column, the contents of the TEXT column are displayed, and you can scroll through them.
- If you query on a BYTE column, the words `<BYTE value>` are displayed instead of the actual value.

Differences specific to VARCHAR, TEXT, and BYTE are noted as appropriate throughout this chapter.

GLS

Whether you are using INFORMIX-OnLine Dynamic Server or INFORMIX-SE, you can issue a SELECT statement that queries on NCHAR columns instead of CHAR columns. If you are using OnLine, you can query on NVARCHAR columns instead of VARCHAR columns.

For complete GLS information, see the *Guide to GLS Functionality*. For additional information on GLS and other data types, see Chapter 9, "Implementing Your Data Model," in this manual, and Chapter 3 of the *Informix Guide to SQL: Reference*. ♦

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

Selecting All Columns and Rows

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

Using the Asterisk Symbol (*)

Query 2-5a specifies all the columns in the **manufact** table in a *select list*. A select list is a list of the column names or expressions that you want to project from a table.

Query 2-5a

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

Query 2-5b uses the *wildcard* asterisk symbol (*), which is shorthand for the select list. The * represents 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.

Query 2-5b

```
SELECT * FROM manufact
```

Query 2-5a and Query 2-5b are equivalent and display the same results; that is, a list of every column and row in the **manufact** table. Query Result 2-5 shows the results as they would appear on a DB-Access or INFORMIX-SQL ISED screen.

Query Result 2-5

```
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
```

Reordering the Columns

Query 2-6 shows how you can change the order in which the columns are listed by changing their order in your select list.

Query 2-6

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

Query Result 2-6 includes the same columns as the previous query result, but because the columns are specified in a different order, the display is also different.

Query Result 2-6

```
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
```

Sorting the Rows

You can add an ORDER BY clause to your SELECT statement to direct the system to sort the data in a specific order.You must include the columns that you want to use in the ORDER BY clause in the select list either explicitly or implicitly.

An *explicit* select list, shown in Query 2-7a, includes all the column names that you want to retrieve.

Query 2-7a

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

An *implicit* select list uses the asterisk symbol (*), as Query 2-7b shows.

Query 2-7b

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

Query 2-7a and Query 2-7b produce the same display. Query Result 2-7 shows a list of every column and row in the **manufact** table, in order of **lead_time**.

Query Result 2-7

```
manu_code manu_name       lead_time

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

Ascending Order

The retrieved data is sorted and displayed, by default, in *ascending* order. 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 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. Query 2-8 shows an example of descending order.

Query 2-8

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

The keyword DESC following a column name causes the retrieved data to be sorted in *descending* order, as Query Result 2-8 shows.

Query Result 2-8

```
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
```

You can specify any column (except TEXT or BYTE) 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, creating a *nested sort*. The default is still ascending, and the column that is listed first in the ORDER BY clause takes precedence.

Query 2-9 and Query 2-10 and 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.

Query 2-9

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

In Query Result 2-9, 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.

Query Result 2-9

```
stock_num manu_code description     unit_price unit unit_descr

        5 ANZ       tennis racquet      $19.80 each each
        9 ANZ       volleyball net      $20.00 each each
        6 ANZ       tennis ball         $48.00 case 24 cans/case
      313 ANZ       swim cap            $60.00 box  12/box
      201 ANZ       golf shoes          $75.00 each each
      310 ANZ       kick board          $84.00 case 12/case
      301 ANZ       running shoes       $95.00 each each
      304 ANZ       watch              $170.00 box  10/box
      110 ANZ       helmet             $244.00 case 4/case
      205 ANZ       3 golf balls       $312.00 case 24/case
        8 ANZ       volleyball         $840.00 case 24/case
      302 HRO       ice pack             $4.50 each each
      309 HRO       ear drops           $40.00 case 20/case
      .
      .
      .
      113 SHM       18-spd, assmbld    $685.90 each each
        5 SMT       tennis racquet      $25.00 each each
        6 SMT       tennis ball         $36.00 case 24 cans/case
        1 SMT       baseball gloves    $450.00 case 10 gloves/case
```

Query 2-10 shows the reversed order of the columns in the ORDER BY clause.

Query 2-10

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

In Query Result 2-10, 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.

Query Result 2-10

```
stock_num manu_code description     unit_price unit unit_descr

      302 HRO       ice pack             $4.50 each each
      302 KAR       ice pack             $5.00 each each
        5 ANZ       tennis racquet      $19.80 each each
        9 ANZ       volleyball net      $20.00 each each
      103 PRC       frnt derailleur     $20.00 each each
      106 PRC       bicycle stem        $23.00 each each
        5 SMT       tennis racquet      $25.00 each each
      .
      .
      .
      301 HRO       running shoes       $42.50 each each
      204 KAR       putter              $45.00 each each
      108 SHM       crankset            $45.00 each each
        6 ANZ       tennis ball         $48.00 case 24 cans/case
      305 HRO       first-aid kit       $48.00 case 4/case
      303 PRC       socks               $48.00 box  24 pairs/box
      311 SHM       water gloves        $48.00 box  4 pairs/box
      .
      .
      .
      110 HSK       helmet             $308.00 case 4/case
      205 ANZ       3 golf balls       $312.00 case 24/case
      205 HRO       3 golf balls       $312.00 case 24/case
      205 NKL       3 golf balls       $312.00 case 24/case
        1 SMT       baseball gloves    $450.00 case 10 gloves/case
        4 HRO       football           $480.00 case 24/case
      102 PRC       bicycle brakes     $480.00 case 4 sets/case
      111 SHM       10-spd, assmbld    $499.99 each each
      112 SHM       12-spd, assmbld    $549.00 each each
        7 HRO       basketball         $600.00 case 24/case
      203 NKL       irons/wedge        $670.00 case 2 sets/case
      113 SHM       18-spd, assmbld    $685.90 each each
        1 HSK       baseball gloves    $800.00 case 10 gloves/case
        8 ANZ       volleyball         $840.00 case 24/case
        4 HSK       football           $960.00 case 24/case
```

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 Query 2-11 contain the same components in the ORDER BY clause, each produces a different result (not shown).

Query 2-11

```
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
```

Selecting Specific Columns

The previous section showed 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 SELECT 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 Query 2-12.

Query 2-12

```
SELECT customer_num FROM orders
```

Query Result 2-12 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.

Query Result 2-12

```
customer_num

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

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, include the keyword DISTINCT or its synonym UNIQUE at the start of the select list, as Query 2-13 shows.

Query 2-13

```
SELECT DISTINCT customer_num FROM orders

SELECT UNIQUE customer_num FROM orders
```

To produce a more readable list, Query 2-13 limits the display to show each customer number in the **orders** table only once, as Query Result 2-13 shows.

Query Result 2-13

```
customer_num

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

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 one that Query 2-14 shows.

Query 2-14

```
SELECT po_num FROM orders
```

Query Result 2-14 shows how the statement retrieves data in the **po_num** column in the **orders** table.

Query Result 2-14

```
po_num

 B77836
 9270
 B77890
 8006
 2865
 Q13557
 278693
 LZ230
 4745
 429Q
 B77897
 278701
 B77930
 8052
 MA003
 PC6782
 DM354331
 S22942
 Z55709
 W2286
 C3288
 W9925
 KF2961
```

However, the list is not in a very 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 Query Result 2-15 shows.

Query 2-15

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

Query Result 2-15

```
po_num

 278693
 278701
 2865
 429Q
 4745
 8006
 8052
 9270
 B77836
 B77890
 B77897
 B77930
 C3288
 DM354331
 KF2961
 LZ230
 MA003
 PC6782
 Q13557
 S22942
 W2286
 W9925
 Z55709
```

To select multiple columns from a table, list them in the select list in the SELECT clause. Query 2-16 shows that the order in which the columns are selected is the order in which they are produced, from left to right.

Query 2-16

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

As shown in "Sorting on Multiple Columns" on page 2-15, you can use the ORDER BY clause to sort the data in ascending or descending order and perform nested sorts. Query Result 2-16 shows ascending order.

Query Result 2-16

```
paid_date  ship_date  order_date customer_num   order_num po_num

           05/30/1994 05/22/1994          106        1004 8006
                      05/30/1994          112        1006 Q13557
           06/05/1994 05/31/1994          117        1007 278693
           06/29/1994 06/18/1994          117        1012 278701
           07/12/1994 06/29/1994          119        1016 PC6782
           07/13/1994 07/09/1994          120        1017 DM354331
06/03/1994 05/26/1994 05/21/1994          101        1002 9270
06/14/1994 05/23/1994 05/22/1994          104        1003 B77890
06/21/1994 06/09/1994 05/24/1994          116        1005 2865
07/10/1994 07/03/1994 06/25/1994          106        1014 8052
07/21/1994 07/06/1994 06/07/1994          110        1008 LZ230
07/22/1994 06/01/1994 05/20/1994          104        1001 B77836
07/31/1994 07/10/1994 06/22/1994          104        1013 B77930
08/06/1994 07/13/1994 07/10/1994          121        1018 S22942
08/06/1994 07/16/1994 07/11/1994          122        1019 Z55709
08/21/1994 06/21/1994 06/14/1994          111        1009 4745
08/22/1994 06/29/1994 06/17/1994          115        1010 429Q
08/22/1994 07/25/1994 07/23/1994          124        1021 C3288
08/22/1994 07/30/1994 07/24/1994          127        1023 KF2961
08/29/1994 07/03/1994 06/18/1994          104        1011 B77897
08/31/1994 07/16/1994 06/27/1994          110        1015 MA003
09/02/1994 07/30/1994 07/24/1994          126        1022 W9925
09/20/1994 07/16/1994 07/11/1994          123        1020 W2286
```

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.The statements in Query 2-17 retrieve and display the same data, as Query Result 2-17 shows.

Query 2-17

```
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
```

Query Result 2-17

```
customer_num   order_num po_num     order_date

         104        1001 B77836     05/20/1994
         101        1002 9270       05/21/1994
         104        1003 B77890     05/22/1994
         106        1004 8006       05/22/1994
         116        1005 2865       05/24/1994
         112        1006 Q13557     05/30/1994
         117        1007 278693     05/31/1994
         110        1008 LZ230      06/07/1994
         111        1009 4745       06/14/1994
         115        1010 429Q       06/17/1994
         104        1011 B77897     06/18/1994
         117        1012 278701     06/18/1994
         104        1013 B77930     06/22/1994
         106        1014 8052       06/25/1994
         110        1015 MA003      06/27/1994
         119        1016 PC6782     06/29/1994
         120        1017 DM354331   07/09/1994
         121        1018 S22942     07/10/1994
         122        1019 Z55709     07/11/1994
         123        1020 W2286      07/11/1994
         124        1021 C3288      07/23/1994
         126        1022 W9925      07/24/1994
         127        1023 KF2961     07/24/1994
```

You can include the DESC keyword in the ORDER BY clause when you assign integers to column names, as Query 2-18 shows.

Query 2-18

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

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

GLS

ORDER BY and Non-English Data

By default, 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, the ORDER BY clause should return data in the order appropriate to that language. Query 2-19 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.

Query 2-19

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

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. Store non-English data in NCHAR (or NVARCHAR) columns to obtain results sorted by the language.
- Whether the database server is using the correct non-English locale when accessing 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 Query 2-19 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. Refer to the *Guide to GLS Functionality* for more information on non-English data and locales.

Query Result 2-19a and Query Result 2-19b show two sample sets of output.

Query Result 2-19a

```
numéro    nom         prénom

13612     Azevedo     Edouardo Freire
13606     Dupré       Michèle Françoise
13607     Hammer      Gerhard
13602     Hämmerle    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
```

Query Result 2-19a follows the ISO 8859-1 code-set order, which ranks uppercase letters before lowercase letters and moves the names that start with an accented character (Ålesund, Étaix, Ötker, and Øverst) to the end of the list.

Query Result 2-19b

```
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     Hämmerle    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
```

Query Result 2-19b shows that when the appropriate locale file is referenced by the data server, names starting with 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. ♦

Selecting Substrings

To select part of the value of a CHARACTER column, include a *substring* in the select list. Suppose your marketing department is planning a mailing to your customers and wants a rough idea of their geographical distribution based on zip codes. You could write a query similar to the one Query 2-20 shows.

Query 2-20

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

Query 2-20 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 Query Result 2-20 shows.

Query Result 2-20

```
zipcode customer_num

021              125
080              119
085              122
198              121
322              123
604              127
740              124
802              126
850              128
850              120
940              105
940              112
940              113
940              115
940              104
940              116
940              110
940              114
940              106
940              108
940              117
940              111
940              101
940              109
941              102
943              103
943              107
946              118
```

Using the WHERE Clause

Add a WHERE clause to a SELECT statement if you want to see only those 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.

The set of rows returned by a SELECT statement is its *active set*. A *singleton* SELECT statement returns a single row. Use a *cursor* to retrieve multiple rows in INFORMIX-4GL or an SQL API. In NewEra, you use a SuperTable to handle multiple-row retrieval. See Chapter 5, “Programming with SQL,” and Chapter 6, “Modifying Data Through SQL Programs.”

Creating a Comparison Condition

The WHERE clause of a SELECT statement specifies the rows 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 Chapter 1 of the *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 in string expressions, except when you 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 criteria listed below, 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.

Including Rows

Use the relational operator = to include rows in a WHERE clause, as Query 2-21 shows.

Query 2-21

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

Query 2-21 returns the set of rows that Query Result 2-21 shows.

Query Result 2-21

```
customer_num call_code call_dtime       res_dtime

         106  D         1994-06-12 08:20 1994-06-12 08:25
         121  O         1994-07-10 14:05 1994-07-10 14:06
         127  I         1994-07-31 14:30
```

Excluding Rows

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

Query 2-22 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 complete discussion of owner naming, see Chapter 1 in the *Informix Guide to SQL: Syntax*.

Query 2-22

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

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

Both statements in Query 2-22 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 Query Result 2-22 shows.

Query Result 2-22

```
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
```

Specifying Rows

Query 2-23 shows two ways to specify rows in a WHERE clause.

Query 2-23

```
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
```

Each statement in Query 2-23 specifies a range for **catalog_num** from 10005 through 10008, inclusive. The first statement uses keywords, and the second uses relational operators to retrieve the rows as Query Result 2-23 shows.

Query Result 2-23

```
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              Athle
tes

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
```

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 display TEXT and BYTE values by using the PROGRAM attribute when you use forms in INFORMIX-SQL or INFORMIX-4GL or write a NewEra, 4GL, or a SQL API application to do so.

Excluding a Range of Rows

Query 2-24 uses the keywords NOT BETWEEN to exclude rows that have the character range 94000 through 94999 in the **zipcode** column, as Query Result 2-24 shows.

Query 2-24

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

Query Result 2-24

```
fname          lname          company             city           state

Fred           Jewell         Century* Pro Shop   Phoenix        AZ
Frank          Lessor         Phoenix University  Phoenix        AZ
Eileen         Neelie         Neelie’s Discount Sp Denver        CO
Jason          Wallack        City Sports         Wilmington     DE
Marvin         Hanlon         Bay Sports          Jacksonville   FL
James          Henry          Total Fitness Sports Brighton      MA
Bob            Shorter        The Triathletes Club Cherry Hill   NJ
Cathy          O’Brian        The Sporting Life   Princeton      NJ
Kim            Satifer        Big Blue Bike Shop  Blue Island    NY
Chris          Putnum         Putnum’s Putters    Bartlesville   OK
```

Using a WHERE Clause to Find a Subset of Values

As shown in “Excluding Rows” on page 2-31, Query 2-25 also assumes the use of an ANSI-compliant database. The owner qualifier is in quotation marks to preserve the case sensitivity of the literal string.

Query 2-25

```
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
```

Each statement in Query 2-25 retrieves rows that include the subset of AZ or NJ in the **state** column of the **Aleta.customer** table, as Query Result 2-25 shows.

Query Result 2-25

```
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
```

You cannot test a TEXT or BYTE column with the IN keyword.

In Query 2-26, an example of a query on an ANSI-compliant database, no quotation marks exist around the table owner name. Whereas the two statements in Query 2-25 searched the **Aleta.customer** table, Query 2-26 searches the table **ALETA.customer**, which is a different table, because of the way ANSI-compliant databases look at owner names.

Query 2-26

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

Query 2-26 adds the keyword NOT IN, so the subset changes to exclude the subsets `AZ` and `NJ` in the **state** column. Query Result 2-26 shows the results in order of the **state** column.

Query Result 2-26

```
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
```

Identifying 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.

Query 2-27 returns all rows that have a null **paid_date**, as Query Result 2-27 shows.

Query 2-27

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

Query Result 2-27

```
order_num  customer_num  po_num   ship_date

     1004           106  8006     05/30/1994
     1006           112  Q13557
     1007           117  278693   06/05/1994
     1012           117  278701   06/29/1994
     1016           119  PC6782   07/12/1994
     1017           120  DM354331 07/13/1994
```

Forming Compound Conditions

To connect two or more comparison conditions, or *Boolean* expressions, by use the *logical operators* AND, OR, and NOT. A Boolean expression evaluates as `true` or `false` or, if null values are involved, as `unknown`. You can use TEXT or BYTE objects in a Boolean expression only when you test for a null value.

In Query 2-28, the operator AND combines two comparison expressions in the WHERE clause.

Query 2-28

```
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
```

The query returns all rows that have a null **paid_date** *and* the ones that do not also have a null **ship_date**, as Query Result 2-28 shows.

Query Result 2-28

```
order_num customer_num po_num     ship_date

     1004          106 8006       05/30/1994
     1007          117 278693     06/05/1994
     1012          117 278701     06/29/1994
     1016          119 PC6782     07/12/1994
     1017          120 DM354331   07/13/1994
```

Using Variable-Text Searches

You can use the keywords LIKE and MATCHES for *variable-text* queries that are based on substring searches of CHARACTER fields. Include the keyword NOT to indicate the opposite condition. The keyword LIKE is the ANSI standard, whereas MATCHES is an Informix extension.

Variable-text search strings can include the wildcards listed with LIKE or MATCHES in the following table.

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

You cannot test a TEXT or BYTE column with LIKE or MATCHES.

Using 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 on an *external* table in an ANSI-compliant database.

An external table is a table that is not in the current database. You can access only external tables that are part of an ANSI-compliant database.

Whereas the database used previously in this chapter was the demonstration database called **stores7**, 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 defining external tables, see Chapter 1 in the *Informix Guide to SQL: Syntax*.

Each statement in Query 2-29 retrieves all the rows that have the single word `helmet` in the **description** column as Query Result 2-29 shows.

Query 2-29

```
SELECT * FROM syzygy:bubba.manatee
    WHERE description = 'helmet'
    ORDER BY mfg_code

SELECT * FROM syzygy:bubba.manatee
    WHERE description LIKE 'helmet'
    ORDER BY mfg_code

SELECT * FROM syzygy:bubba.manatee
    WHERE description MATCHES 'helmet'
    ORDER BY mfg_code
```

Query Result 2-29

```
stock_no mfg_code  description     unit_price unit unit_type

     991 ANT       helmet             $222.00 case 4/case
     991 BKE       helmet             $269.00 case 4/case
     991 JSK       helmet             $311.00 each 4/case
     991 PRM       helmet             $234.00 case 4/case
     991 SHR       helmet             $245.00 case 4/case
```

Using a Single-Character Wildcard

The statements in Query 2-30 illustrate the use of a single-character wildcard in a WHERE clause. Further, they demonstrate a query on an external table. The **stock** table is in the external database **sloth**. Beside being outside the current **stores7** database, **sloth** is on a separate database server called **meerkat**.

For details on external tables, external databases, and networks, see Chapter 11, "Understanding Informix Networking," in this manual and Chapter 1 in the *Informix Guide to SQL: Syntax*.

Query 2-30

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

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

Each statement in Query 2-30 retrieves only those rows for which the middle letter of the **manu_code** is R, as Query Result 2-30 shows.

Query Result 2-30

```
stock_num manu_code description     unit_price unit unit_descr

      205 HRO       3 golf balls       $312.00 case 24/case
        2 HRO       baseball           $126.00 case 24/case
        1 HRO       baseball gloves    $250.00 case 10 gloves/case
        7 HRO       basketball         $600.00 case 24/case
      102 PRC       bicycle brakes     $480.00 case 4 sets/case
      114 PRC       bicycle gloves     $120.00 case 10 pairs/case
        4 HRO       football           $480.00 case 24/case
      110 PRC       helmet             $236.00 case 4/case
      110 HRO       helmet             $260.00 case 4/case
      307 PRC       infant jogger      $250.00 each each
      306 PRC       tandem adapter     $160.00 each each
      308 PRC       twin jogger        $280.00 each each
      304 HRO       watch              $280.00 box  10/box
```

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

WHERE Clause with Restricted Single-Character Wildcard

Query 2-31 selects only those rows where the **manu_code** begins with A through H and returns the rows Query Result 2-31 shows. The class test '[A-H]' specifies any single letter from A through H, inclusive. No equivalent wild-card symbol exists for the LIKE keyword.

Query 2-31

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

Query Result 2-31

```
stock_num manu_code descr pt on     un t_pr ce un t un t_descr

      205 ANZ       3 golf balls       $312.00 case 24/case
      205 HRO       3 golf balls       $312.00 case 24/case
        2 HRO       baseball           $126.00 case 24/case
        3 HSK       baseball bat       $240.00 case 12/case
        1 HRO       baseball gloves    $250.00 case 10 gloves/case
        1 HSK       baseball gloves    $800.00 case 10 gloves/case
        7 HRO       basketball         $600.00 case 24/case
      .
      .
      .
      110 ANZ       helmet             $244.00 case 4/case
      110 HRO       helmet             $260.00 case 4/case
      110 HSK       helmet             $308.00 case 4/case
      .
      .
      .
      301 ANZ       running shoes       $95.00 each each
      301 HRO       running shoes       $42.50 each each
      313 ANZ       swim cap            $60.00 box  12/box
        6 ANZ       tennis ball         $48.00 case 24 cans/case
        5 ANZ       tennis racquet      $19.80 each each
        8 ANZ       volleyball         $840.00 case 24/case
        9 ANZ       volleyball net      $20.00 each each
      304 ANZ       watch              $170.00 box  10/box
      304 HRO       watch              $280.00 box  10/box
```

WHERE Clause with Variable-Length Wildcard

The statements in Query 2-32 use a wildcard at the end of a string to retrieve all the rows where the **description** begins with the characters `bicycle`.

Query 2-32

```
SELECT * FROM stock
    WHERE description LIKE 'bicycle%'
    ORDER BY description, manu_code

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

Either statement returns the rows that Query Result 2-32 shows.

Query Result 2-32

```
stock_num manu_code description     unit_price unit unit_descr

      102 PRC       bicycle brakes     $480.00 case 4 sets/case
      102 SHM       bicycle brakes     $220.00 case 4 sets/case
      114 PRC       bicycle gloves     $120.00 case 10 pairs/case
      107 PRC       bicycle saddle      $70.00 pair pair
      106 PRC       bicycle stem        $23.00 each each
      101 PRC       bicycle tires       $88.00 box  4/box
      101 SHM       bicycle tires       $68.00 box  4/box
      105 PRC       bicycle wheels      $53.00 pair pair
      105 SHM       bicycle wheels      $80.00 pair pair
```

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.

Query 2-33 narrows the search by adding another comparison condition that excludes a **manu_code** of `PRC`.

Query 2-33

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

The statement retrieves only the rows that Query Result 2-33 shows.

Query Result 2-33

```
stock_num manu_code description     unit_price unit unit_descr

      102 SHM       bicycle brakes     $220.00 case 4 sets/case
      101 SHM       bicycle tires       $68.00 box  4/box
      105 SHM       bicycle wheels      $80.00 pair pair
```

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.

GLS

MATCHES and Non-English Data

By default, 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 contains non-English data, the MATCHES clause should use the correct non-English code set for that language. Query 2-34 uses a SELECT statement with a MATCHES clause in the WHERE clause to search the table, **abonnés**, and to compare the selected information with the data in the **nom** column.

Query 2-34

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

The result of the comparison in this query is the same whether **nom** is a CHAR or NCHAR column. The database server uses the sort order that the locale specifies to determine what characters are in the range E through P. This behavior is an exception to the rule that the database server collates CHAR and VARCHAR columns in code-set order and NCHAR and NVARCHAR columns in the sort order that the locale specifies.

In Query Result 2-34a, 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.

Query Result 2-34a

```
numéro  nom      prénom

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

The database server uses code-set order when the **nom** column is CHAR data type. It also uses localized ordering when the column is NCHAR data type, and you specify a nondefault locale.

In Query Result 2-34a, the rows for Étaix, Ötker, and Øverst *are* included in the list because the database server uses a locale-specific comparison.

Query Result 2-34b

```
numéro  nom      prénom

13608   Étaix    Émile
13607   Hammer   Gerhard
13602   Hämmerle 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
```

Refer to the *Guide to GLS Functionality* for more information on non-English data and locales. ♦

Comparing for Special Characters

Query 2-35 uses the keyword ESCAPE with LIKE or MATCHES so you can protect a special character from misinterpretation as a wildcard symbol.

Query 2-35

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

The ESCAPE keyword designates an *escape character* (it is ! 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 row that Query Result 2-35 shows.

Query Result 2-35

```
customer_num   116
call_dtime     1993-12-21 11:24
user_id        mannyn
call_code      I
call_descr     Second complaint from this customer! Received
               two cases right-handed outfielder gloves
               (1 HRO) instead of one case lefties.
res_dtime      1993-12-27 08:19
res_descr      Memo to shipping (Ava Brown) to send case of
               left-handed 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
```

Using 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 Query 2-36 shows.

Query 2-36

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

The subscript `[1,4]` causes Query 2-36 to retrieve all rows in which the first four letters of the **cat_advert** column are `High`, as Query Result 2-36 shows.

Query Result 2-36

```
 catalog_num  10004
 stock_num    2
 manu_code    HRO
 cat_advert   Highest Quality Ball Available, from
              Hand-Stitching 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  10008
 stock_num    4
 manu_code    HRO
 cat_advert   Highest Quality Football for High School and
              Collegiate Competitions
 cat_descr
NFL-style, pigskin.


 catalog_num  10012
 stock_num    6
 manu_code    SMT
 cat_advert   High-Visibility Tennis, Day or Night
 cat_descr
Soft yellow color for easy visibility in sunlight or
artificial light.

 catalog_num  10043
 stock_num    202
 manu_code    KAR
 cat_advert   High-Quality Woods Appropriate for High School
              Competitions or Serious Amateurs
 cat_descr
Full set of woods designed for precision control and
power performance.

 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.
```

Expressions and Derived Values

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

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. You cannot use TEXT or BYTE columns in arithmetic expressions.

Operator	Operation
+	addition
-	subtraction
*	multiplication
/	division

Operations of this nature 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. Query 2-37 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).

Query 2-37

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

If you are using DB-Access or INFORMIX-SQL ISED, the result is displayed in a column labeled *expression*, as Query Result 2-37 shows.

Query Result 2-37

```
stock_num description     unit unit_descr      unit_price   (expression)

        1 baseball gloves case 10 gloves/case     $800.00     $856.0000
        1 baseball gloves case 10 gloves/case     $450.00     $481.5000
        4 football        case 24/case            $960.00    $1027.2000
        4 football        case 24/case            $480.00     $513.6000
        7 basketball      case 24/case            $600.00     $642.0000
        8 volleyball      case 24/case            $840.00     $898.8000
      102 bicycle brakes  case 4 sets/case        $480.00     $513.6000
      111 10-spd, assmbld each each               $499.99     $534.9893
      112 12-spd, assmbld each each               $549.00     $587.4300
      113 18-spd, assmbld each each               $685.90     $733.9130
      203 irons/wedge     case 2 sets/case        $670.00     $716.9000
```

Query 2-38 calculates a surcharge of $6.50 on orders when the quantity ordered is less than 5.

Query 2-38

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

If you are using DB-Access or INFORMIX-SQL, the result appears in a column labeled *expression*, as Query Result 2-38 shows.

Query Result 2-38

```
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        1021        2      $75.00        $81.50
       2        1021        3     $225.00       $231.50
       3        1021        3     $690.00       $696.50
       4        1021        2     $624.00       $630.50
       1        1022        1      $40.00        $46.50
       2        1022        2      $96.00       $102.50
       3        1022        2      $96.00       $102.50
       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
```

Query 2-39 calculates and displays in an *expression* column (if you are using DB-Access or INFORMIX-SQL) the interval between when the customer call was received (**call_dtime**) and when the call was resolved (**res_dtime**), in days, hours, and minutes.

Query 2-39

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

Query Result 2-39

```
customer_num user_id          call_code call_dtime         (expression)

         116 mannyn           I         1993-12-21 11:24        5 20:55
         116 mannyn           I         1993-11-28 13:34        0 03:13
         106 maryj            D         1994-06-12 08:20        0 00:05
         121 maryj            O         1994-07-10 14:05        0 00:01
         127 maryj            I         1994-07-31 14:30
         110 richc            L         1994-07-07 10:24        0 00:06
         119 richc            B         1994-07-01 15:00        0 17:21
```

Using Display Labels

You can assign a *display label* to a computed or derived data column to replace the default column header *expression*. In Query 2-40, Query 2-41, and Query 2-42, the derived data is shown in a column called `(expression)`. Query 2-40 also presents derived values, but the column that displays the derived values now has the descriptive header `taxed`.

Query 2-40

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

Query Result 2-40 shows that the label `taxed` is assigned to the expression in the select list that displays the results of the operation `unit_price * 1.07`.

Query Result 2-40

```
stock_num description     unit unit_descr      unit_price        taxed

        1 baseball gloves case 10 gloves/case     $800.00    $856.0000
        1 baseball gloves case 10 gloves/case     $450.00    $481.5000
        4 football        case 24/case            $960.00   $1027.2000
        4 football        case 24/case            $480.00    $513.6000
        7 basketball      case 24/case            $600.00    $642.0000
        8 volleyball      case 24/case            $840.00    $898.8000
      102 bicycle brakes  case 4 sets/case        $480.00    $513.6000
      111 10-spd, assmbld each each               $499.99    $534.9893
      112 12-spd, assmbld each each               $549.00    $587.4300
      113 18-spd, assmbld each each               $685.90    $733.9130
      203 irons/wedge     case 2 sets/case        $670.00    $716.9000
```

In Query 2-41, the label **surcharge** is defined for the column that displays the results of the operation `total_price + 6.50`.

Query 2-41

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

The **surcharge** column is labeled in the output, as Query Result 2-41 shows.

Query Result 2-41

```
item_num   order_num quantity total_price    surcharge
      .
      .
      .
       2       1013        1      $36.00       $42.50
       3       1013        1      $48.00       $54.50
       4       1013        2      $40.00       $46.50
       1       1014        1     $960.00      $966.50
       2       1014        1     $480.00      $486.50
       1       1015        1     $450.00      $456.50
       1       1016        2     $136.00      $142.50
       2       1016        3      $90.00       $96.50
       3       1016        1     $308.00      $314.50
       4       1016        1     $120.00      $126.50
       1       1017        4     $150.00      $156.50
       2       1017        1     $230.00      $236.50
       .
       .
       .
```

Query 2-42 assigns the label **span** to the column that displays the results of subtracting the DATETIME column **call_dtime** from the DATETIME column **res_dtime**.

Query 2-42

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

The **span** column is labeled in the output, as Query Result 2-42 shows.

Query Result 2-42

```
customer_num user_id            call_code call_dtime              span

         116 mannyn             I         1993-12-21 11:24        5 20:55
         116 mannyn             I         1993-11-28 13:34        0 03:13
         106 maryj              D         1994-06-12 08:20        0 00:05
         121 maryj              O         1994-07-10 14:05        0 00:01
         127 maryj              I         1994-07-31 14:30
         110 richc              L         1994-07-07 10:24        0 00:06
         119 richc              B         1994-07-01 15:00        0 17:21
```

Sorting on Derived Columns

When you want to use ORDER BY as an expression, you can use either the display label assigned to the expression or an integer, as Query 2-43 shows.

Query 2-43

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

Query 2-43 retrieves the same data from the **cust_calls** table as Query 2-42. In Query 2-43, the ORDER BY clause causes the data to be displayed in ascending order of the derived values in the **span** column, as Query Result 2-43 shows.

Query Result 2-43

```
customer_num user_id            call_code call_dtime              span
         127 maryj              I         1994-07-31 14:30
         121 maryj              O         1994-07-10 14:05        0 00:01
         106 maryj              D         1994-06-12 08:20        0 00:05
         110 richc              L         1994-07-07 10:24        0 00:06
         116 mannyn             I         1992-11-28 13:34        0 03:13
         119 richc              B         1994-07-01 15:00        0 17:21
         116 mannyn             I         1992-12-21 11:24        5 20:55
```

Query 2-44 uses an integer to represent the result of the operation `res_dtime - call_dtime` and retrieves the same rows that appear in Query Result 2-43.

Query 2-44

```
SELECT customer_num, user_id, call_code,
       call_dtime, res_dtime - call_dtime span
    FROM cust_calls
    ORDER BY 5
```

Using Functions in SELECT Statements

In addition to column names and operators, an expression can also include one or more functions.

Expressions supported include aggregate, function (which include arithmetic functions), constant, and column expressions. These expressions are described in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Aggregate Functions

The *aggregate* functions are COUNT, AVG, MAX, MIN, and SUM. They take on values that depend on all the rows selected and return information about rows, not the rows themselves. You cannot use these functions with TEXT or BYTE columns.

Aggregates are often used to summarize information about groups of rows in a table. This use is discussed in Chapter 3, "Composing Advanced SELECT Statements." When you apply an aggregate function to an entire table, the result contains a single row that summarizes all of the selected rows.

Query 2-45 counts and displays the total number of rows in the **stock** table.

Query 2-45

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

Query Result 2-45

```
(count(*))

        73
```

Query 2-46 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.

Query 2-46

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

By including the keyword DISTINCT (or its synonym UNIQUE) and a column name in Query 2-47, you can tally the number of different manufacturer codes in the **stock** table.

Query 2-47

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

Query Result 2-47

```
   (count)

         9
```

Query 2-48 computes the average **unit_price** of all rows in the **stock** table.

Query 2-48

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

Query Result 2-48

```
    (avg)

 $197.14
```

Query 2-49 computes the average **unit_price** of just those rows in the **stock** table that have a **manu_code** of SHM.

Query 2-49

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

Query Result 2-49

```
   (avg)

 $204.93
```

You can combine aggregate functions as Query 2-50 shows.

Query 2-50

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

Query 2-50 finds and displays both the highest and lowest **ship_charge** in the **orders** table, as Query Result 2-50 shows.

Query Result 2-50

```
  (max)     (min)

 $25.20     $5.00
```

You can apply functions to expressions, and you can supply display labels for their results, as Query 2-51 shows.

Query 2-51

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

Query 2-51 finds and displays the maximum, minimum, and average amount of time (in days, hours, and minutes) between the reception and resolution of a customer call and labels the derived values appropriately. These amounts of time are shown in Query Result 2-51.

Query Result 2-51

```
maximum          minimum          average

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

Query 2-52 calculates the total **ship_weight** of orders that were shipped on July 13, 1994.

Query 2-52

```
SELECT SUM (ship_weight)
    FROM orders
    WHERE ship_date = '07/13/1994'
```

Query Result 2-52

```
(sum)

130.5
```

Time Functions

You can use the *time* functions DAY, MDY, MONTH, WEEKDAY, YEAR, and DATE in either the SELECT 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 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.

Using DAY and CURRENT

Query 2-53 returns the day of the month for the **call_dtime** and **res_dtime** columns in two *expression* columns, as Query Result 2-53 shows.

Query 2-53

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

Query Result 2-53

```
customer_num  (expression) (expression)

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

Query 2-54 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.

Query 2-54

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

Query Result 2-54

```
customer_num  (expression) (expression)

         106           12           12
         110            7            7
         119            1            2
         121           10           10
```

Query 2-55 shows another use of the CURRENT function, selecting rows where the day is earlier than the current one.

Query 2-55

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

Query Result 2-55

```
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  116
call_code     I
call_descr    Received plain white swim caps (313 ANZ) instead of navy with
              team logo (313 SHM)

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.
```

Using MONTH

Query 2-56 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.

Query 2-56

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

Query Result 2-56

```
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
```

Query 2-57 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.

Query 2-57

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

Query Result 2-57

```
customer_num     called   resolved

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

Using WEEKDAY

In Query 2-58, the WEEKDAY function is used 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.

Query 2-58

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

Query Result 2-58

```
customer_num     called   resolved

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

Query 2-59 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.

Query 2-59

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

Query Result 2-59

```
(count(*))

         4
```

Query 2-60 retrieves rows where the **call_dtime** is earlier than the beginning of the current year.

Query 2-60

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

Query Result 2-60

```
customer_num call_code call_year res_year

         116 I              1993     1993
         116 I              1993     1993
```

Formatting DATETIME Values

In Query 2-61, the EXTEND function restricts the two DATETIME values by displaying only the specified subfields.

Query 2-61

```
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
```

Query Result 2-61 returns the month-to-minute range for the columns labeled **call_time** and **res_time** and gives an indication of the workload.

Query Result 2-61

```
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
```

Using the DATE Function

Query 2-62 retrieves DATETIME values only when **call_dtime** is later than the specified DATE.

Query 2-62

```
SELECT customer_num, call_dtime, res_dtime
    FROM cust_calls
    WHERE call_dtime > DATE ('12/31/93')
```

Query Result 2-62 returns the following rows.

Query Result 2-62

```
customer_num call_dtime       res_dtime

         106 1994-06-12 08:20 1994-06-12 08:25
         110 1994-07-07 10:24 1994-07-07 10:30
         119 1994-07-01 15:00 1994-07-02 08:21
         121 1994-07-10 14:05 1994-07-10 14:06
         127 1994-07-31 14:30
```

Query 2-63 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.

Query 2-63

```
SELECT customer_num,
    DATE (call_dtime) called,
    DATE (res_dtime) resolved
    FROM cust_calls
    WHERE call_dtime >= DATE ('1/1/94')
```

Query Result 2-63

```
customer_num called       resolved

         106 06/12/1994   06/12/1994
         110 07/07/1994   07/07/1994
         119 07/01/1994   07/02/1994
         121 07/10/1994   07/10/1994
         127 07/31/1994
```

Other Functions and Keywords

You also can use the LENGTH, USER, CURRENT, and TODAY functions anywhere in an SQL expression that you would use a constant. In addition, with INFORMIX-OnLine Dynamic Server, you can include the DBSERVERNAME keyword in a SELECT statement to display the name of the database server where the current database resides.

You can use these functions and keywords 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.

In Query 2-64, 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.

Query 2-64

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

Query Result 2-64

```
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
```

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

The USER function can be handy when you want to define a restricted view of a table that contains only your rows. For information on creating views, see Chapter 10, "Granting and Limiting Access to Your Database," in this manual and the GRANT and CREATE VIEW statements in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Query 2-65a specifies the USER function and the **cust_calls** table.

Query 2-65a

```
SELECT USER from cust_calls
```

Query 2-65b returns the user name (login account name) of the user who executes the query. It is repeated once for each row in the table.

Query 2-65b

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

If the user name of the current user is **richc**, Query 2-65b retrieves only those rows in the **cust_calls** table that are owned by that user, as Query Result 2-65 shows.

Query Result 2-65

```
customer_num  110
call_dtime    1994-07-07 10:24
user_id       richc
call_code     L
call_descr    Order placed one month ago (6/7) not received.
res_dtime     1994-07-07 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    1994-07-01 15:00
user_id       richc
call_code     B
call_descr    Bill does not reflect credit from previous order
res_dtime     1994-07-02 08:21
res_descr     Spoke with Jane Akant in Finance. She found the error and is
              sending new bill to customer
```

If Query 2-66 is issued when the current system date is July 10, 1994, it returns this one row.

Query 2-66

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

Query Result 2-66

```
order_num      1018
order_date     07/10/1994
customer_num   121
ship_instruct  SW corner of Biltmore Mall
backlog        n
po_num         S22942
ship_date      07/13/1994
ship_weight    70.50
ship_charge    $20.00
paid_date      08/06/1994
```

You can include the keyword DBSERVERNAME (or its synonym, SITENAME) in a SELECT statement in INFORMIX-OnLine Dynamic Server to find the name of the database server. You can query on the DBSERVERNAME for any table that has rows, including system catalog tables.

In Query 2-67, 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 serial-interval table identifier.

Query 2-67

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

Query Result 2-67

```
server          tabid

montague            1
montague            2
montague            3
montague            4
```

Without the WHERE clause to restrict the values in the **tabid**, the database server name would be repeated for each row of the **systables** table.

In Query 2-68, the HEX function returns the hexadecimal format of three specified columns in the **customer** table.

Query 2-68

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

Query Result 2-68

```
hexnum     hexzip     hexrow

0x00000065 0x00016F86 0x00000001
0x00000066 0x00016FA5 0x00000002
0x00000067 0x0001705F 0x00000003
0x00000068 0x00016F4A 0x00000004
0x00000069 0x00016F46 0x00000005
0x0000006A 0x00016F6F 0x00000006
0x0000006B 0x00017060 0x00000007
0x0000006C 0x00016F6F 0x00000008
0x0000006D 0x00016F86 0x00000009
0x0000006E 0x00016F6E 0x0000000A
0x0000006F 0x00016F85 0x0000000B
0x00000070 0x00016F46 0x0000000C
0x00000071 0x00016F49 0x0000000D
0x00000072 0x00016F6E 0x0000000E
0x00000073 0x00016F49 0x0000000F
0x00000074 0x00016F58 0x00000010
0x00000075 0x00016F6F 0x00000011
0x00000076 0x00017191 0x00000012
0x00000077 0x00001F42 0x00000013
0x00000078 0x00014C18 0x00000014
0x00000079 0x00004DBA 0x00000015
0x0000007A 0x0000215C 0x00000016
0x0000007B 0x00007E00 0x00000017
0x0000007C 0x00012116 0x00000018
0x0000007D 0x00000857 0x00000019
0x0000007E 0x0001395B 0x0000001A
0x0000007F 0x0000EBF6 0x0000001B
0x00000080 0x00014C10 0x0000001C
```

Using Stored Procedures in SELECT Statements

We have seen examples of SELECT statement expressions that consist of column names, operators, and functions. Another type of expression contains a stored procedure call.

Stored procedures contain special Stored Procedure Language (SPL) statements as well as SQL statements. For more information on stored procedures, refer to Chapter 12, "Creating and Using Stored Procedures."

Stored procedures provide a way to extend the range of functions available; you can 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. Query 2-69 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** procedure, which queries the **orders** table for each **customer_num** and returns the number of corresponding orders (labeled **n_orders**).

Query 2-69

```
SELECT customer_num, lname, get_orders(customer_num) n_orders
        FROM customer
```

Query Result 2-69 shows the output from this stored procedure.

Query Result 2-69

```
customer_num lname n_orders

     101 Pauli     1
     102 Sadler    0
     103 Currie    0
     104 Higgins   4
     105 Vector    0
     106 Watson    2
     107 Ream      0
     108 Quinn     0
     109 Miller    0
     110 Jaeger    2
     111 Keyes     1
     112 Lawson    1
     113 Beatty    0
     114 Albertson 0
     115 Grant     1
     116 Parmelee  1
     117 Sipes     2
     118 Baxter    0
     119 Shorter   1
     120 Jewell    1
     121 Wallack   1
     122 O'Brian   1
     123 Hanlon    1
     124 Putnum    1
     125 Henry     0
     126 Neelie    1
     127 Satifer   1
     128 Lessor    0
```

Use stored procedures to encapsulate operations that you frequently perform in your queries. For example, the condition in Query 2-70 contains a procedure, **conv_price**, that converts the unit price of a stock item to a different currency and adds any import tariffs.

Query 2-70

```
SELECT stock_num, manu_code, description FROM stock
    WHERE conv_price(unit_price, ex_rate = 1.50, tariff = 50.00) < 1000
```

Multiple-Table SELECT Statements

To select data from two or more tables, name these tables 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 Chapter 3 of the *Informix Guide to SQL: Reference*; indexing is discussed in detail in the administrator's guide for your database server.

Creating 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 very large and unwieldy, and the data is inaccurate.

Query 2-71 selects from two tables and produces a Cartesian product.

Query 2-71

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

Although only 52 rows exist in the **state** table and 28 rows in the **customer** table, the effect of Query 2-71 is to multiply the rows of one table by the rows of the other and retrieve an impractical 1,456 rows, as Query 2-71 shows.

Query Result 2-71

```
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
.
.
.
```

Some of the data that is displayed in the concatenated rows is inaccurate. 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.

Creating 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 rows of data, include a WHERE clause with a valid join condition in your SELECT statement.

This section illustrates *equi-joins*, *natural joins*, and *multiple-table joins*. Additional complex forms, such as *self-joins* and *outer joins*, are covered in Chapter 3, "Composing Advanced SELECT Statements."

Equi-Join

An equi-join is a join based on equality or matching values. This equality is indicated with an equal sign (=) in the comparison operation in the WHERE clause, as Query 2-72 shows.

Query 2-72

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

Query 2-72 joins the **manufact** and **stock** tables on the **manu_code** column. It retrieves only those rows for which the values for the two columns are equal, as Query Result 2-72 shows.

Query Result 2-72

```
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
.
.
.
```

In this equi-join, Query Result 2-72 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, one where the comparison condition is based on the inequality of values in the joined columns. These joins use a relational operator other than the equal sign (=) in the comparison condition that is specified in the WHERE clause.

To join tables that contain columns with the same name, precede each column name with a period and its table name, as Query 2-73 shows.

Query 2-73

```
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 customer_num
```

Query 2-73 joins on 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. Query Result 2-73 shows the rows that it returns.

Query Result 2-73

```
order_num      1004
order_date     05/22/1994
ship_date      05/30/1994
customer_num   106
call_dtime     1994-06-12 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      1994-06-12 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     06/07/1994
ship_date      07/06/1994
customer_num   110
call_dtime     1994-07-07 10:24
user_id        richc
call_code      L
call_descr     Order placed one month ago (6/7) not received.
res_dtime      1994-07-07 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     07/24/1994
ship_date      07/30/1994
customer_num   127
call_dtime     1994-07-31 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
```

Natural Join

A natural join is structured so that the join column does not display data redundantly, as Query 2-74 shows.

Query 2-74

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

Like the example for equi-join, Query 2-74 joins the **manufact** and **stock** tables on the **manu_code** column. Because the select list is more closely defined, the **manu_code** is listed only once for each row retrieved, as Query Result 2-74 shows.

Query Result 2-74

```
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
.
.
.
```

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 of the statements in Query 2-75 create the same natural join.

Query 2-75

```
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
```

Each statement retrieves the row that Query Result 2-75 shows.

Query Result 2-75

```
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
```

Query 2-75 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.

Query 2-76 creates an equi-join on the **catalog**, **stock**, and **manufact** tables and retrieves the following row:

Query 2-76

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

Query 2-76 retrieves the rows Query Result 2-76 shows.

Query Result 2-76

```
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
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
```

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

Because of the considerable duplication of a multiple-table query in Query 2-76, define the SELECT statement more closely by including specific columns in the select list, as Query 2-77 shows.

Query 2-77

```
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
```

Query 2-77 uses a wildcard to select all columns from the table with the most columns and then specifies columns from the other two tables. Query Result 2-77 shows the natural join produced by Query 2-77. It displays the same information as the previous example, but without duplication.

Query Result 2-77

```
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
```

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.

Using Aliases

You can make multiple-table queries shorter and more readable by assigning *aliases* to the tables in a SELECT statement. An alias is a word that immediately follows the name of a table in the FROM clause. You can use it wherever the table name would be used, for instance, as a prefix to the column names in the other clauses.

Query 2-78a

```
SELECT s.stock_num, s.manu_code, s.description,
       s.unit_price, s.unit, c.catalog_num,
       c.cat_descr, 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
```

The associative nature of the SELECT statement allows you to use an alias before you define it. In Query 2-78a, 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 Query 2-78a with Query 2-78b, which does not use aliases.

Query 2-78b

```
SELECT stock.stock_num, stock.manu_code, stock.description,
       stock.unit_price, stock.unit, catalog.catalog_num,
       catalog.cat_descr, 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
```

Query 2-78a and Query 2-78b are equivalent and retrieve the data that is shown in Query Result 2-78.

Query Result 2-78

```
stock_num    110
manu_code    HRO
description  helmet
unit_price   $260.00
unit         case
catalog_num  10033
cat_descr
Newest ultralight helmet uses plastic shell. Largest ventilation
channels of any helmet on the market. 8.5 oz.
cat_advert   Lightweight Plastic Slatted with Vents Assures Cool
             Comfort Without Sacrificing Protection
lead_time       4

stock_num    110
manu_code    HSK
description  helmet
unit_price   $308.00
unit         each
catalog_num  10034
cat_descr
Aerodynamic (teardrop) helmet covered with anti-drag fabric.
Credited with shaving 2 seconds/mile from winner’s time in
Tour de France time-trial. 7.5 oz.
cat_advert   Teardrop Design Endorsed by Yellow Jerseys,
             You Can Time the Difference
lead_time       5

stock_num    205
manu_code    HRO
description  3 golf balls
unit_price   $312.00
unit         each
catalog_num  10048
cat_descr
Combination fluorescent yellow and standard white.
cat_advert   HiFlier Golf Balls: Case Includes Fluorescent
             Yellow and Standard White
lead_time       4

stock_num    301
manu_code    HRO
description  running shoes
unit_price   $42.50
unit         each
catalog_num  10050
cat_descr
Engineered for serious training with exceptional stability.
Fabulous shock absorption. Great durability. Specify
mens/womens, size.
cat_advert   Pronators and Supinators Take Heart: A Serious
             Training Shoe For Runners Who Need Motion Control
lead_time       4
```

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

You can also use aliases to shorten your queries on external tables that reside in external databases.

Query 2-79 joins columns from two tables that reside in different databases and systems, neither of which is the current database or system.

Query 2-79

```
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
```

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 Query Result 2-79 shows.

Query Result 2-79

```
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
```

For more information on external tables and external databases, see Chapter 11, "Understanding Informix Networking," in this manual and Chapter 1 in the *Informix Guide to SQL: Syntax*.

You also can use *synonyms* as shorthand references to the long names of external and current tables and views. For details on how to create and use synonyms, see Chapter 11, "Understanding Informix Networking," in this manual and the CREATE SYNONYM statement in Chapter 1 of the *Informix Guide to SQL: Syntax*.

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.

Query 2-80 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.

Query 2-80

```
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
```

Query Result 2-80

```
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
```

You can query on this table and join it with other tables, which avoids a multiple sort and lets you move more quickly through the database. Temporary tables are discussed at greater length in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

Summary

This chapter introduced sample syntax and results for basic kinds of SELECT statements that are used to query on a relational database. Earlier sections of the chapter showed how to perform the following actions:

- Select all columns and rows from a table with the SELECT and FROM clauses
- Select specific columns from a table with the SELECT and FROM clauses
- Select specific rows from a table with the SELECT, FROM, and WHERE clauses
- Use the DISTINCT or UNIQUE keyword in the SELECT clause to eliminate duplicate rows from query results
- Sort retrieved data with the ORDER BY clause and the DESC keyword
- Select and order data that contains non-English characters
- Use the BETWEEN, IN, MATCHES, and LIKE keywords and various relational operators in the WHERE clause to create a comparison condition
- 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
- Perform variable text searches by using exact-text comparisons, variable-length wildcards, and restricted and unrestricted wildcards
- 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 arithmetic operators in the SELECT clause to perform computations on number fields and display derived data
- Use substrings and subscripting to tailor your queries
- Assign display labels to computed columns as a formatting tool for reports

- Use the aggregate functions COUNT, AVG, MAX, MIN, and SUM in the SELECT 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
- Include stored procedures in your SELECT statements

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" described how to perform the following actions:

- Create a Cartesian product
- Constrain a Cartesian product by including a WHERE clause with a valid join condition in your query
- 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

The next chapter explains more complex queries and subqueries; self-joins and outer joins; the GROUP BY and HAVING clauses; and the UNION, INTERSECTION, and DIFFERENCE set operations.

Chapter

Composing Advanced SELECT Statements

3

The previous chapter, "Composing Simple SELECT Statements," demonstrates some basic ways to retrieve data from a relational database with the SELECT statement. This chapter increases the scope of what you can do with this powerful SQL statement and enables you to perform more complex database queries and data manipulation.

Whereas the previous chapter focused on five of the clauses in SELECT statement syntax, this chapter adds two more. 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 chapter 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 chapter show how to use some or all of the SELECT statement clauses in your queries. The clauses must appear in the following order:

1. SELECT
2. FROM
3. WHERE
4. GROUP BY
5. HAVING
6. ORDER BY
7. INTO TEMP

An additional SELECT statement clause, INTO, which you can use to specify program and host variables in INFORMIX-4GL and SQL APIs, is described in Chapter 5, "Programming with SQL," as well as in the manuals that come with the product.

Using 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 select list. 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.

Using 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, "Composing Simple SELECT Statements" show the use of aggregate functions applied to a whole table. This chapter 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. Chapter 2, "Composing Simple SELECT Statements," included the statement found in Query 3-1a.

Query 3-1a

```
SELECT DISTINCT customer_num FROM orders
```

You also could write the statement as Query 3-1b shows.

Query 3-1b

```
SELECT customer_num
    FROM orders
    GROUP BY customer_num
```

Query 3-1a and Query 3-1b return the rows that Query Result 3-1 shows.

Query Result 3-1

```
customer_num

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

The GROUP BY clause collects the rows into sets so that each row in each set has equal 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.

Query 3-2 retrieves the number of items and the total price of all items for each order.

Query 3-2

```
SELECT order_num, COUNT (*) number, SUM (total_price) price
    FROM items
    GROUP BY order_num
```

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 you form the groups, the aggregate functions COUNT and SUM are applied within each group.

Query 3-2 returns one row for each group. It uses labels to give names to the results of the COUNT and SUM expressions, as Query Result 3-2 shows.

Query Result 3-2

```
order_num      number         price

   1001           1         $250.00
   1002           2        $1200.00
   1003           3         $959.00
   1004           4        $1416.00
   1005           4         $562.00
   1006           5         $448.00
   1007           5        $1696.00
   1008           2         $940.00
   .
   .
   .
   1015           1         $450.00
   1016           4         $654.00
   1017           3         $584.00
   1018           5        $1131.00
   1019           1        $1499.97
   1020           2         $438.00
   1021           4        $1614.00
   1022           3         $232.00
   1023           6         $824.00
```

Query Result 3-2 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.

Note that you cannot include a column having a TEXT or BYTE data type in a GROUP BY clause. To *group*, you must be able to *sort*, and no natural sort order exists for TEXT or BYTE data.

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 select list.

Query 3-3 is the same as Query 3-2 but includes an ORDER BY clause to sort the retrieved rows in ascending order of **price**, as Query Result 3-3 shows.

Query 3-3

```
SELECT order_num, COUNT(*) number, SUM (total_price) price
    FROM items
    GROUP BY order_num
    ORDER BY price
```

Query Result 3-3

```
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
   1015           1          $450.00
   1009           1          $450.00
  .
  .
  .
   1018           5         $1131.00
   1002           2         $1200.00
   1004           4         $1416.00
   1014           2         $1440.00
   1019           1         $1499.97
   1021           4         $1614.00
   1007           5         $1696.00
```

As stated in Chapter 2, "Composing Simple SELECT Statements," you can use an integer in an ORDER BY clause to indicate the position of a column in the select list. You also can use an integer in a GROUP BY clause to indicate the position of column names or display labels in the group list.

Query 3-4 returns the same rows as Query 3-3, as Query Result 3-3 shows.

Query 3-4

```
SELECT order_num, COUNT(*) number, SUM (total_price) price
    FROM items
    GROUP BY 1
    ORDER BY 3
```

When you build a query, remember that all nonaggregate columns that are in the select list in the SELECT clause must also be included in the group list in the GROUP BY clause. The reason is that 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 a group.

As Query 3-5 shows, you can use the GROUP BY clause in a SELECT statement that joins tables.

Query 3-5

```
SELECT o.order_num, SUM (i.total_price)
    FROM orders o, items i
    WHERE o.order_date > '01/01/93'
        AND o.customer_num = 110
        AND o.order_num = i.order_num
    GROUP BY o.order_num
```

Query 3-5 joins the **orders** and **items** tables, assigns table aliases to them, and returns the rows that Query Result 3-5 shows.

Query Result 3-5

```
order_num             (sum)

     1008           $940.00
     1015           $450.00
```

Using the HAVING Clause

The HAVING clause usually complements a GROUP BY clause by applying one or more qualifying conditions to groups after they are formed, which is similar to the way the WHERE clause qualifies individual rows. One advantage to 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.

Query 3-6 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 that are those composed of two or more rows.

Query 3-6

```
SELECT order_num, COUNT(*) number, AVG (total_price) average
    FROM items
    GROUP BY order_num
    HAVING COUNT(*) > 2
```

Query Result 3-6

```
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
```

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.

Query 3-7, a modified version of Query 3-6, returns just one row, the average of all **total_price** values in the table.

Query 3-7

```
SELECT AVG (total_price) average
    FROM items
    HAVING count(*) > 2
```

Query Result 3-7

```
average

$270.97
```

If Query 3-7, like Query 3-6, had included the nonaggregate column **order_ num** in the select list, 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.

Query 3-8 contains all the SELECT statement clauses that you can use in the Informix version of interactive SQL (the INTO clause that names program or host variables is available only in INFORMIX-4GL or an SQL API).

Query 3-8

```
SELECT o.order_num, SUM (i.total_price) price,
      paid_date - order_date span
    FROM orders o, items i
    WHERE o.order_date > '01/01/93'
        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
```

Query 3-8 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 following results in a temporary table, as Query Result 3-8 shows.

Query Result 3-8

```
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
```

Creating Advanced Joins

Chapter 2, "Composing Simple SELECT Statements," 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 chapter discusses the uses of 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 SELECT and WHERE clauses as if it were two separate tables. (Aliases in SELECT statements are shown in Chapter 2, "Composing Simple SELECT Statements," in this manual and discussed in Chapter 1 of the *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.

Query 3-9 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**.

Query 3-9

```
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
```

Query Result 3-9

```
order_num ship_weight ship_date    order_num ship_weight ship_date

     1004       95.80 05/30/1994        1011       10.40 07/03/1994
     1004       95.80 05/30/1994        1020       14.00 07/16/1994
     1004       95.80 05/30/1994        1022       15.00 07/30/1994
     1007      125.90 06/05/1994        1015       20.60 07/16/1994
     1007      125.90 06/05/1994        1020       14.00 07/16/1994
     1007      125.90 06/05/1994        1022       15.00 07/30/1994
     1007      125.90 06/05/1994        1011       10.40 07/03/1994
     1007      125.90 06/05/1994        1001       20.40 06/01/1994
     1007      125.90 06/05/1994        1009       20.40 06/21/1994
     1005       80.80 06/09/1994        1011       10.40 07/03/1994
     1005       80.80 06/09/1994        1020       14.00 07/16/1994
     1005       80.80 06/09/1994        1022       15.00 07/30/1994
     1012       70.80 06/29/1994        1011       10.40 07/03/1994
     1012       70.80 06/29/1994        1020       14.00 07/16/1994
     1013       60.80 07/10/1994        1011       10.40 07/03/1994
     1017       60.00 07/13/1994        1011       10.40 07/03/1994
     1018       70.50 07/13/1994        1011       10.40 07/03/1994
```

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 rename at least one set of columns by assigning them display labels. Otherwise, the duplicate column names cause an error and the temporary table is not created.

Query 3-10, which is similar to Query 3-9, labels all columns selected from the **orders** table and puts them in a temporary table called **shipping**.

Query 3-10

```
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
```

If you query with `SELECT *` from that table, you see the rows that Query Result 3-10 shows.

Query Result 3-10

```
orders1 purch1     ship1          orders2 purch2     ship2

   1004 8006       05/30/1994        1011 B77897     07/03/1994
   1004 8006       05/30/1994        1020 W2286      07/16/1994
   1004 8006       05/30/1994        1022 W9925      07/30/1994
   1005 2865       06/09/1994        1011 B77897     07/03/1994
   1005 2865       06/09/1994        1020 W2286      07/16/1994
   1005 2865       06/09/1994        1022 W9925      07/30/1994
   1007 278693     06/05/1994        1001 B77836     06/01/1994
   1007 278693     06/05/1994        1009 4745       06/21/1994
   1007 278693     06/05/1994        1011 B77897     07/03/1994
   1007 278693     06/05/1994        1015 MA003      07/16/1994
   1007 278693     06/05/1994        1020 W2286      07/16/1994
   1007 278693     06/05/1994        1022 W9925      07/30/1994
   1012 278701     06/29/1994        1011 B77897     07/03/1994
   1012 278701     06/29/1994        1020 W2286      07/16/1994
   1013 B77930     07/10/1994        1011 B77897     07/03/1994
   1017 DM354331   07/13/1994        1011 B77897     07/03/1994
   1018 S22942     07/13/1994        1011 B77897     07/03/1994
   1018 S22942     07/13/1994        1020 W2286      07/16/1994
   1019 Z55709     07/16/1994        1011 B77897     07/03/1994
   1019 Z55709     07/16/1994        1020 W2286      07/16/1994
   1019 Z55709     07/16/1994        1022 W9925      07/30/1994
   1023 KF2961     07/30/1994        1011 B77897     07/03/1994
```

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 Query 3-11 creates a list of those items in the **stock** table that are supplied by three manufacturers. By including the last two conditions in the WHERE clause, it eliminates duplicate manufacturer codes in rows retrieved.

Query 3-11

```
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
```

Query Result 3-11

```
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
HSK       PRC       SHM             110 helmet
ANZ       KAR       NKL             201 golf shoes
ANZ       HRO       NKL             205 3 golf balls
ANZ       HRO       KAR             301 running shoes
 .
 .
 .
HRO       PRC       SHM             301 running shoes
KAR       NKL       PRC             301 running shoes
KAR       NKL       SHM             301 running shoes
KAR       PRC       SHM             301 running shoes
NKL       PRC       SHM             301 running shoes
```

If you want to select rows from a payroll table to determine which employees earn more than their manager, you can construct the self-join that Query 3-12a shows.

Query 3-12a

```
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
```

Query 3-12b uses a *correlated subquery* to retrieve and list the 10 highest-priced items ordered.

Query 3-12b

```
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
```

Query 3-12b returns the 10 rows that Query Result 3-12 shows.

Query Result 3-12

```
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
```

You can create a similar query to find and list the 10 employees in the company who have the most seniority.

Correlated and uncorrelated subqueries are described later in "Subqueries in SELECT Statements" on page 3-29.

Using Rowid Values

Important: *OnLine assigns a unique rowid to rows in nonfragmented tables. Rows in fragmented tables do not contain the rowid column. Informix recommends 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, OnLine requires less time to access data in a fragmented table using a primary key than it requires to access the same data using rowid. For additional information about rowids and tables, see "Accessing Data Stored in Fragmented Tables" on page 9-43.*

You can use the hidden *rowid* column in a self-join to locate duplicate values in a table. In the following example, the condition `x.rowid != y.rowid` is equivalent to saying "row x is not the same row as row y."

Query 3-13 selects data twice from the **cust_calls** table, assigning it the table aliases **x** and **y**.

Query 3-13

```
SELECT x.rowid, x.customer_num
    FROM cust_calls x, cust_calls y
    WHERE x.customer_num = y.customer_num
        AND x.rowid != y.rowid
```

Query 3-13 searches for duplicate values in the **customer_num** column, and for their rowids, finding the pair Query Result 3-13 shows.

Query Result 3-13

```
      rowid customer_num

        515          116
        769          116
```

You can write the last condition as Query 3-13 shows.

```
AND x.rowid != y.rowid

AND NOT x.rowid = y.rowid
```

Another way to locate duplicate values is with a correlated subquery, as Query 3-14 shows.

Query 3-14

```
SELECT x.customer_num, x.call_dtime
    FROM cust_calls x
    WHERE 1 <
        (SELECT COUNT (*) FROM cust_calls y
            WHERE x.customer_num = y.customer_num)
```

Query 3-14 locates the same two duplicate **customer_num** values as Query 3-13 and returns the rows Query Result 3-14 shows.

Query Result 3-14

```
customer_num call_dtime

         116 1993-11-28 13:34
         116 1993-12-21 11:24
```

You can use the rowid, shown earlier in a self-join, to locate the internal record number that is associated with a row in a database table. 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. Your rowid might vary from the example shown. The use of rowid is discussed in detail in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

Query 3-15 uses the rowid and the wildcard asterisk symbol (*) in the SELECT clause to retrieve every row in the **manufact** table and their corresponding rowids.

Query 3-15

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

Query Result 3-15

```
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
```

You also can use the rowid when you select a specific column, as Query 3-16 shows.

Query 3-16

```
SELECT rowid, manu_code FROM manufact
```

Query Result 3-16

```
rowid manu_code

  258 ANZ
  261 HRO
  260 HSK
  263 KAR
  264 NKL
  259 NRG
  265 PRC
  262 SHM
  257 SMT
```

You can use the rowid in the WHERE clause to retrieve rows based on their internal record number. This method is handy when no other unique column exists in a table. Query 3-17 uses a rowid from Query 3-16.

Query 3-17

```
SELECT * FROM manufact WHERE rowid = 263
```

Query 3-17 returns the row that Query Result 3-17 shows.

Query Result 3-17

```
manu_code manu_name       lead_time

KAR       Karsten           21
```

Using the USER Function

To obtain additional information about a table, you can combine the rowid with the USER function.

Query 3-18 assigns the label **username** to the USER expression column and returns this information about the **cust_calls** table.

Query 3-18

```
SELECT USER username, rowid FROM cust_calls
```

Query Result 3-18

```
username          rowid

zenda               257
zenda               258
zenda               259
zenda               513
zenda               514
zenda               515
zenda               769
```

You also can use the USER function in a WHERE clause when you select the rowid.

Query 3-19 returns the rowid for only those rows that are inserted or updated by the user who performs the query.

Query 3-19

```
SELECT rowid FROM cust_calls WHERE user_id = USER
```

For example, if the user **richc** used Query 3-19, Query Result 3-19 shows the output.

Query Result 3-19

```
      rowid

        258
        259
```

Using the DBSERVERNAME Function

With INFORMIX-OnLine Dynamic Server, you can add the DBSERVERNAME keyword (or its synonym, SITENAME) to a query to find out where the current database resides.

Query 3-20 finds the database server name and the user name as well as the rowid and the *tabid*, which is the serial-interval table identifier for system catalog tables.

Query 3-20

```
SELECT DBSERVERNAME server, tabid, rowid, USER username
    FROM systables
    WHERE tabid >= 105 OR rowid <= 260
    ORDER BY rowid
```

Query 3-20 assigns display labels to the DBSERVERNAME and USER expressions and returns the 10 rows from the **systables** system catalog table, as Query Result 3-20 shows.

Query Result 3-20

```
server          tabid       rowid username

manatee             1         257 zenda
manatee             2         258 zenda
manatee             3         259 zenda
manatee             4         260 zenda
manatee           105         274 zenda
manatee           106        1025 zenda
manatee           107        1026 zenda
manatee           108        1027 zenda
manatee           109        1028 zenda
manatee           110        1029 zenda
```

Never store a rowid in a *permanent* table or attempt to use it as a foreign key because the rowid can change. For example, if a table is dropped and then reloaded from external data, all the rowids are different.

USER and DBSERVERNAME are discussed in Chapter 2, "Composing Simple SELECT Statements."

Outer Joins

Chapter 2, "Composing Simple SELECT Statements," shows how to create and use some simple joins. Whereas a simple join treats two or more joined tables equally, an *outer join* treats two or more joined tables *unsymmetrically*. A simple join makes one of the tables *dominant* (also called *preserved*) over the other *subservient* tables.

Outer joins occur in four basic types:

- A simple outer join on two tables
- A simple outer join to a third table
- An outer join for a simple join to a third table
- An outer join for an outer join to a third table

This section discusses these types of outer joins. See the discussion of outer joins in Chapter 1 of the *Informix Guide to SQL: Syntax* for full information on their syntax, use, and logic.

In a *simple join*, the result contains only the combinations of rows from the tables 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 from the tables that satisfy the join conditions. *Rows from the dominant table that would otherwise be discarded are preserved, even though no matching row was found in the subservient table.* The dominant-table rows that do not have a matching subservient-table row receive a row of nulls before the selected columns are projected.

An outer join applies conditions to the subservient table while it sequentially applies the join conditions to the rows of the dominant table. The conditions are expressed in a WHERE clause.

An outer join must have a SELECT clause, a FROM clause, and a WHERE clause. To transform a simple join into an outer join, insert the keyword OUTER directly before the name of the subservient tables in the FROM clause. As shown later in this section, you can include the OUTER keyword more than once in your query.

Before you use outer joins heavily, determine whether one or more simple joins can work. You often can get by with a simple join when you do not need supplemental information from other tables.

The examples in this section use table aliases for brevity. Table aliases are discussed in Chapter 2, "Composing Simple SELECT Statements."

Simple Join

Query 3-21 is an example of the type of simple join on the **customer** and **cust_calls** tables that is shown in Chapter 2, "Composing Simple SELECT Statements."

Query 3-21

```
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
```

Query 3-21 returns only those rows in which the customer has made a call to customer service, as Query Result 3-21 shows.

Query Result 3-21

```
customer_num  106
lname         Watson
company       Watson & Son
phone         415-389-8789
call_dtime    1994-06-12 08:20
call_descr    Order was received, but two of the cans of
              ANZ tennis balls within the case were empty

customer_num  110
lname         Jaeger
company       AA Athletics
phone         415-743-3611
call_dtime    1994-07-07 10:24
call_descr    Order placed one month ago (6/7) not received.

customer_num  119
lname         Shorter
company       The Triathletes Club
phone         609-663-6079
call_dtime    1994-07-01 15:00
call_descr    Bill does not reflect credit from previous order

customer_num  121
lname         Wallack
company       City Sports
phone         302-366-7511
call_dtime    1994-07-10 14:05
call_descr    Customer likes our merchandise. Requests that we
              stock more types of infant joggers. Will call back
              to place order.

customer_num  127
lname         Satifer
company       Big Blue Bike Shop
phone         312-944-5691
call_dtime    1994-07-31 14:30
call_descr    Received Hero watches (item # 304) instead of
              ANZ watches

customer_num  116
lname         Parmelee
company       Olympic City
phone         415-534-8822
call_dtime    1993-11-28 13:34
call_descr    Received plain white swim caps (313 ANZ) instead
              of navy with team logo (313 SHM)

customer_num  116
lname         Parmelee
company       Olympic City
phone         415-534-8822
call_dtime    1993-12-21 11:24
call_descr    Second complaint from this customer! Received
              two cases right-handed outfielder gloves (1 HRO)
              instead of one case lefties.
```

Simple Outer Join on Two Tables

Query 3-22 uses the same select list, tables, and comparison condition as the preceding example, but this time it creates a simple outer join.

Query 3-22

```
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
```

The addition of the keyword OUTER in front of 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 corresponding rows from the subservient **cust_calls** table, as Query Result 3-22 shows.

Query Result 3-22

```
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  103
lname         Currie
company       Phil’s Sports
phone         415-328-4543
call_dtime
call_descr

customer_num  104
lname         Higgins
company       Play Ball!
phone         415-368-1100
call_dtime
call_descr

customer_num  105
lname         Vector
company       Los Altos Sports
phone         415-776-3249
call_dtime
call_descr

customer_num  106
lname         Watson
company       Watson & Son
phone         415-389-8789
call_dtime    1994-06-12 08:20
call_descr    Order was received, but two of the cans of
              ANZ tennis balls within the case were empty

customer_num  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
    .
```

Outer Join for a Simple Join to a Third Table

Query 3-23 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*.

Query 3-23

```
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
```

Query 3-23 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 form Query Result 3-23 shows.

Query Result 3-23

```
customer_num lname           order_num stock_num manu_code quantity

         114 Albertson
         118 Baxter
         113 Beatty
         103 Currie
         115 Grant
         123 Hanlon               1020       301 KAR              4
         123 Hanlon               1020       204 KAR              2
         125 Henry
         104 Higgins
         110 Jaeger
         120 Jewell               1017       202 KAR              1
         120 Jewell               1017       301 SHM              2
         111 Keyes
         112 Lawson
         128 Lessor
         109 Miller
         126 Neelie
         122 O'Brian              1019       111 SHM              3
         116 Parmelee
         101 Pauli
         124 Putnum               1021       202 KAR              3
         108 Quinn
         107 Ream
         102 Sadler
         127 Satifer              1023       306 SHM              1
         127 Satifer              1023       105 SHM              1
         127 Satifer              1023       110 SHM              1
         119 Shorter              1016       101 SHM              2
         117 Sipes
         105 Vector
         121 Wallack              1018       302 KAR              3
         106 Watson
```

Outer Join for an Outer Join to a Third Table

Query 3-24 creates an outer join that is the result of an outer join to a third table. This third type is known as a *nested outer join*.

Query 3-24

```
SELECT c.customer_num, 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
```

Query 3-24 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 an outer join, which combines this information with data from the dominant **customer** table. Query 3-24 preserves order numbers that the previous example eliminated, returning rows for orders that do not contain items with either manufacturer code. An optional ORDER BY clause reorganizes the data, as Query Result 3-24 shows.

Query Result 3-24

```
customer_num lname           order_num stock_num manu_code quantity

         114 Albertson
         118 Baxter
         113 Beatty
         103 Currie
         115 Grant                1010
         123 Hanlon               1020       204 KAR              2
         123 Hanlon               1020       301 KAR              4
         125 Henry
         104 Higgins              1011
         104 Higgins              1001
         104 Higgins              1013
         104 Higgins              1003
         110 Jaeger               1008
         110 Jaeger               1015
         120 Jewell               1017       301 SHM              2
         120 Jewell               1017       202 KAR              1
         111 Keyes                1009
         112 Lawson               1006
         128 Lessor
         109 Miller
         126 Neelie               1022
         122 O'Brian              1019       111 SHM              3
         116 Parmelee             1005
         101 Pauli                1002
         124 Putnum               1021       202 KAR              3
         108 Quinn
         107 Ream
         102 Sadler
         127 Satifer              1023       110 SHM              1
         127 Satifer              1023       105 SHM              1
         127 Satifer              1023       306 SHM              1
         119 Shorter              1016       101 SHM              2
         117 Sipes                1012
         117 Sipes                1007
         105 Vector
         121 Wallack              1018       302 KAR              3
         106 Watson               1014
         106 Watson               1004
```

You can state 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.

Outer Join of Two Tables to a Third Table

Query 3-25 shows an outer join that is the result of an outer join of each of two tables to a third table. In this fourth type of outer join, join relationships are possible *only* between the dominant table and the subservient tables.

Query 3-25

```
SELECT c.customer_num, 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
```

Query 3-25 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 Query Result 3-25 shows.

Query Result 3-25

```
customer_num lname            order_num order_date call_dtime

         114 Albertson
         118 Baxter
         113 Beatty
         103 Currie
         115 Grant                 1010 06/17/1994
         123 Hanlon                1020 07/11/1994
         125 Henry
         104 Higgins               1003 05/22/1994
         104 Higgins               1001 05/20/1994
         104 Higgins               1013 06/22/1994
         104 Higgins               1011 06/18/1994
         110 Jaeger                1015 06/27/1994 1994-07-07 10:24
         110 Jaeger                1008 06/07/1994 1994-07-07 10:24
         120 Jewell                1017 07/09/1994
         111 Keyes                 1009 06/14/1994
         112 Lawson                1006 05/30/1994
         109 Miller
         128 Moore
         126 Neelie                1022 07/24/1994
         122 O'Brian               1019 07/11/1994
         116 Parmelee              1005 05/24/1994 1993-12-21 11:24
         116 Parmelee              1005 05/24/1994 1993-11-28 13:34
         101 Pauli                 1002 05/21/1994
         124 Putnum                1021 07/23/1994
         108 Quinn
         107 Ream
         102 Sadler
         127 Satifer               1023 07/24/1994 1994-07-31 14:30
         119 Shorter               1016 06/29/1994 1994-07-01 15:00
         117 Sipes                 1007 05/31/1994
         117 Sipes                 1012 06/18/1994
         105 Vector
         121 Wallack               1018 07/10/1994 1994-07-10 14:05
         106 Watson                1004 05/22/1994 1994-06-12 08:20
         106 Watson                1014 06/25/1994 1994-06-12 08:20
```

If Query 3-25 had tried to create a join condition between the two subservient tables **o** and **x**, as Query 3-26 shows, an error message would have indicated the creation of a two-sided outer join.

Query 3-26

```
WHERE o.customer_num = x.customer_num
```

Subqueries in SELECT Statements

A SELECT statement *nested* in the WHERE clause of another SELECT statement (or in an INSERT, DELETE, or UPDATE statement) is called a *subquery*. Each subquery must contain a SELECT clause and a FROM clause. A subquery must be enclosed in parentheses so that the database server performs that operation first.

Subqueries can be *correlated* or *uncorrelated*. A subquery (or *inner* SELECT statement) is correlated when the value it produces depends on a value produced by the *outer* SELECT statement that contains it. Any other kind of subquery is considered uncorrelated.

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.

You can construct a SELECT statement with a subquery to replace two separate SELECT statements.

Subqueries in SELECT statements allow you to perform the following actions:

- Compare an expression to the result of another SELECT statement
- Determine whether the results of another SELECT statement include an expression
- Determine whether another SELECT statement selects 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:

- 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 represent either one row or one column.

The following keywords introduce a subquery in the WHERE clause of a SELECT statement:

- ALL
- ANY
- IN
- EXISTS

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.

See Chapter 1 in the *Informix Guide to SQL: Syntax* for the complete syntax used to create a condition with a subquery.

Using ALL

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.)

Query 3-27 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.

Query 3-27

```
SELECT order_num, stock_num, manu_code, total_price
    FROM items
    WHERE total_price < ALL
        (SELECT total_price FROM items
            WHERE order_num = 1023)
```

Query Result 3-27

```
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
```

Using ANY

Use the keyword ANY (or its synonym SOME) preceding 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.)

Query 3-28 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.

Query 3-28

```
SELECT DISTINCT order_num
    FROM items
    WHERE total_price > ANY
        (SELECT total_price
            FROM items
            WHERE order_num = 1005)
```

Query Result 3-28

```
order_num

     1001
     1002
     1003
     1004
     1005
     1006
     1007
     1008
     1009
     1010
     1011
     1012
     1013
     1014
     1015
     1016
     1017
     1018
     1019
     1020
     1021
     1022
     1023
```

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

Query 3-29 uses the aggregate function MAX in a subquery to find the **order_num** for orders that include the maximum number of volleyball nets.

Query 3-29

```
SELECT order_num FROM items
    WHERE stock_num = 9
        AND quantity =
            (SELECT MAX (quantity)
                FROM items
                WHERE stock_num = 9)
```

Query Result 3-29

```
order_num

     1012
```

Query 3-30 uses the aggregate function MIN in the subquery to select items for which the total price is higher than 10 times the minimum price.

Query 3-30

```
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)
```

Query Result 3-30

```
order_num stock_num manu_code  total_pr ce

     1003         8 ANZ           $840.00
     1018       307 PRC           $500.00
     1018       110 PRC           $236.00
     1018       304 HRO           $280.00
```

Correlated Subqueries

Query 3-31 is an example of a correlated subquery, which returns a list of the 10 earliest shipping dates in the **orders** table. It includes an ORDER BY clause after the subquery to order the results because you cannot include ORDER BY within a subquery.

Query 3-31

```
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
```

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 executed anew for every row that the outer query considers.

Query 3-31 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 13 rows that have the 10 latest shipping dates, as Query Result 3-31 shows.

Query Result 3-31

```
po_num     ship_date

4745       06/21/1994
278701     06/29/1994
429Q       06/29/1994
8052       07/03/1994
B77897     07/03/1994
LZ230      07/06/1994
B77930     07/10/1994
PC6782     07/12/1994
DM354331   07/13/1994
S22942     07/13/1994
MA003      07/16/1994
W2286      07/16/1994
Z55709     07/16/1994
C3288      07/25/1994
KF2961     07/30/1994
W9925      07/30/1994
```

If you use a correlated subquery, such as Query 3-31, on a very 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. Indexing and performance issues are discussed in the administrator's guide for your database server.

Using EXISTS

The keyword EXISTS is known as an *existential qualifier* because the subquery is true only if the outer SELECT, as Query 3-32a shows, finds at least one row.

Query 3-32a

```
SELECT UNIQUE manu_name, lead_time
    FROM manufact
    WHERE EXISTS
        (SELECT * FROM stock
            WHERE description MATCHES '*shoe*'
                AND manufact.manu_code = stock.manu_code)
```

You often can construct a query with EXISTS that is equivalent to one that uses IN. You can also substitute =ANY for IN, as Query 3-32b shows.

Query 3-32b

```
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
```

Query 3-32a and Query 3-32b return rows for the manufacturers that produce a kind of shoe as well as the lead time for ordering the product. Query Result 3-32 shows the return values.

Query Result 3-32

```
manu_name        lead_time

Anza                 5
Hero                 4
Karsten             21
Nikolus              8
ProCycle             9
Shimara             30
```

You cannot use the predicate IN for a subquery that contains a column with a TEXT or BYTE data type.

Add the keyword NOT to IN or to EXISTS to create a search condition that is the opposite of the one in the preceding queries. You also can substitute !=ALL for NOT IN.

Query 3-33 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 the *INFORMIX-OnLine Dynamic Server Performance Guide* and in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Query 3-33

```
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)
```

Each statement in Query 3-33 returns the rows Query Result 3-33 shows, which identify customers who have not placed orders.

Query Result 3-33

```
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
```

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 3-38.

Query 3-34 performs a subquery on the **items** table to identify all the items in the **stock** table that have not yet been ordered.

Query 3-34

```
SELECT stock.* FROM stock
    WHERE NOT EXISTS
        (SELECT * FROM items
            WHERE stock.stock_num = items.stock_num
                AND stock.manu_code = items.manu_code)
```

Query 3-34 returns the rows that Query Result 3-34 shows.

Query Result 3-34

```
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
      106  PRC       bicycle stem       $23.00  each  each
      107  PRC       bicycle saddle     $70.00  pair  pair
      108  SHM       crankset           $45.00  each  each
      109  SHM       pedal binding     $200.00  case  4 pairs/case
      110  ANZ       helmet            $244.00  case  4/case
      110  HRO       helmet            $260.00  case  4/case
      112  SHM       12-spd, assmbld   $549.00  each  each
      113  SHM       18-spd, assmbld   $685.90  each  each
      201  KAR       golf shoes         $90.00  each  each
      202  NKL       metal woods       $174.00  case  2 sets/case
      203  NKL       irons/wedge       $670.00  case  2 sets/case
      205  NKL       3 golf balls      $312.00  case  24/case
      205  HRO       3 golf balls      $312.00  case  24/case
      301  NKL       running shoes      $97.00  each  each
      301  HRO       running shoes      $42.50  each  each
      301  PRC       running shoes      $75.00  each  each
      301  ANZ       running shoes      $95.00  each  each
      302  HRO       ice pack            $4.50  each  each
      303  KAR       socks              $36.00  box   24 pairs/box
      305  HRO       first-aid kit      $48.00  case  4/case
      306  PRC       tandem adapter    $160.00  each  each
      308  PRC       twin jogger       $280.00  each  each
      309  SHM       ear drops          $40.00  case  20/case
      310  SHM       kick board         $80.00  case  10/case
      310  ANZ       kick board         $84.00  case  12/case
      311  SHM       water gloves       $48.00  box   4 pairs/box
      312  SHM       racer goggles      $96.00  box   12/box
      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
```

No logical limit exists to the number of subqueries a SELECT statement can have, but the size of any statement is physically limited when it is considered as a character string. However, this limit is probably larger than any practical statement that you are likely to compose.

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 Query 3-35 shows.

Query 3-35

```
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)
```

Query 3-35 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.

Query Result 3-35

```
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
```

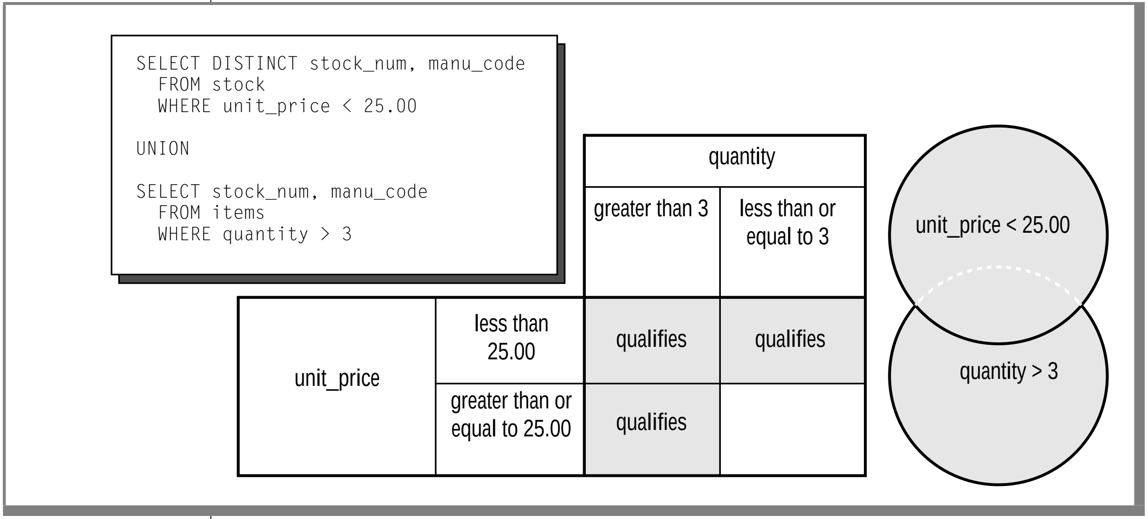
Set Operations

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

The union operation uses the UNION keyword, or *operator*, to combine two queries into a single *compound query*. You can use the UNION keyword between two or more SELECT statements to *unite* them and produce a temporary table that contains rows that exist in any or all of the original tables. (You cannot use a UNION operator inside a subquery or in the definition of a view.) Figure 3-1 illustrates the union set operation.

Figure 3-1
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
```

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 select list in each query must have the same number of columns. Also, the corresponding columns that are selected from each table must contain the same data type (CHARACTER data type columns must be the same length), and these corresponding columns must all allow or all disallow nulls.

Query 3-36 performs a union on the **stock_num** and **manu_code** columns in the **stock** and **items** tables.

Query 3-36

```
SELECT DISTINCT stock_num, manu_code
    FROM stock
    WHERE unit_price < 25.00

UNION

SELECT stock_num, manu_code
    FROM items
    WHERE quantity > 3
```

Query 3-36 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 Query Result 3-36 shows.

Query Result 3-36

```
stock_num manu_code

        5 ANZ
        5 NRG
        5 SMT
        9 ANZ
      103 PRC
      106 PRC
      201 NKL
      301 KAR
      302 HRO
      302 KAR
```

If you include an ORDER BY clause, it must follow Query 3-36 and use an integer, not an identifier, to refer to the ordering column. Ordering takes place after the set operation is complete.

Query 3-37

```
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
```

The compound query in Query 3-37 selects the same rows as Query 3-36 but displays them in order of the manufacturer code, as Query Result 3-37 shows.

Query Result 3-37

```
stock_num manu_code

        5 ANZ
        9 ANZ
      302 HRO
      301 KAR
      302 KAR
      201 NKL
        5 NRG
      103 PRC
      106 PRC
        5 SMT
```

By default, the UNION keyword excludes duplicate rows. Add the optional keyword ALL, as Query 3-38 shows, to retain the duplicate values.

Query 3-38

```
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 stockitem
```

Query 3-38 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 Query 3-37 but also includes duplicate values.

Query Result 3-38

```
stock_num manu_code

        9 ANZ
        5 ANZ
        9 ANZ
        5 ANZ
        9 ANZ
        5 ANZ
        5 ANZ
        5 ANZ
      302 HRO
      302 KAR
      301 KAR
      201 NKL
        5 NRG
        5 NRG
      103 PRC
      106 PRC
        5 SMT
        5 SMT
```

Corresponding columns in the select lists for the combined queries must have identical data types, but the columns do not need to use the same identifier.

Query 3-39 selects the **state** column from the **customer** table and the corresponding **code** column from the **state** table.

Query 3-39

```
SELECT DISTINCT state
    FROM customer
    WHERE customer_num BETWEEN 120 AND 125

UNION

SELECT DISTINCT code
    FROM state
    WHERE sname MATCHES '*a'
```

Query Result 3-39 returns state code abbreviations for customer numbers 120 through 125 and for states whose **sname** ends in `a`.

Query Result 3-39

```
state

AK
AL
AZ
CA
DE
FL
GA
IA
IN
LA
MA
MN
MT
NC
ND
NE
NJ
NV
OK
PA
SC
SD
VA
WV
```

In compound queries, the column names or display labels in the first SELECT statement are the ones that appear in the results. Thus, in Query 3-40, the column name **state** from the first SELECT statement is used instead of the column name **code** from the second.

Query 3-40 performs a union on three tables. The maximum number of unions depends on the practicality of the application and any memory limitations.

Query 3-40

```
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
```

Query 3-40 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**. Query Result 3-40 shows the return values.

Query Result 3-40

```
stock_num manu_code

        5 ANZ
        9 ANZ
        8 ANZ
        4 HSK
        1 HSK
      203 NKL
        5 NRG
      106 PRC
      113 SHM
```

See Chapter 1 of the *Informix Guide to SQL: Syntax* for the complete syntax of the SELECT statement and the UNION operator. See also Chapter 5, "Programming with SQL,"and Chapter 6, "Modifying Data Through SQL Programs,"as well as the product manuals for information specific to the INFORMIX-4GL and INFORMIX-ESQL/C products and any limitations that involve the INTO clause and compound queries.

Query 3-41 uses a combined query to select data into a temporary table and then adds a simple query to order and display it. You must separate the combined and simple queries with a semicolon.

The combined query uses a literal in the select list to tag the output of part of a union so it can be distinguished later. The tag is given the label **sortkey**. The simple query uses that tag as a sort key for ordering the retrieved rows.

Query 3-41

```
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
```

Query 3-41 creates a list in which the most frequently called customers, those from California, appear first, as Query Result 3-41 shows.

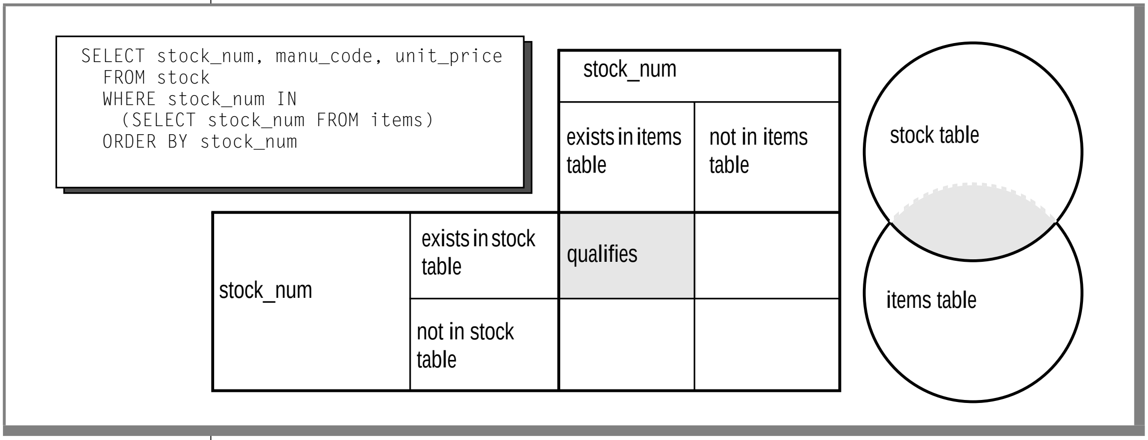
Query Result 3-41

```
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  1
lname    Currie
fname    Philip
company  Phil’s Sports
city     Palo Alto
state    CA
phone    415-328-4543

sortkey  1
lname    Grant
fname    Alfred
company  Gold Medal Sports
city     Menlo Park
state    CA
phone    415-356-1123
.
.
.
sortkey  2
lname    Satifer
fname    Kim
company  Big Blue Bike Shop
city     Blue Island
state    NY
phone    312-944-5691

sortkey  2
lname    Shorter
fname    Bob
company  The Triathletes Club
city     Cherry Hill
state    NJ
phone    609-663-6079

sortkey  2
lname    Wallack
fname    Jason
company  City Sports
city     Wilmington
state    DE
phone    302-366-7511
```

Intersection

The *intersection* of two sets of rows produces a table containing rows that exist in both the original tables. Use the keyword EXISTS or IN to introduce subqueries that show the intersection of two sets. Figure 3-2 illustrates the intersection set operation.

Figure 3-2
The Intersection Set Operation



Query 3-42 is an example of a nested SELECT statement that shows the intersection of the **stock** and **items** tables.

Query 3-42

```
SELECT stock_num, manu_code, unit_price
    FROM stock
    WHERE stock_num IN
        (SELECT stock_num FROM items)
    ORDER BY stock_num
```

Query Result 3-42 contains all the elements from both sets, returning the following 57 rows.

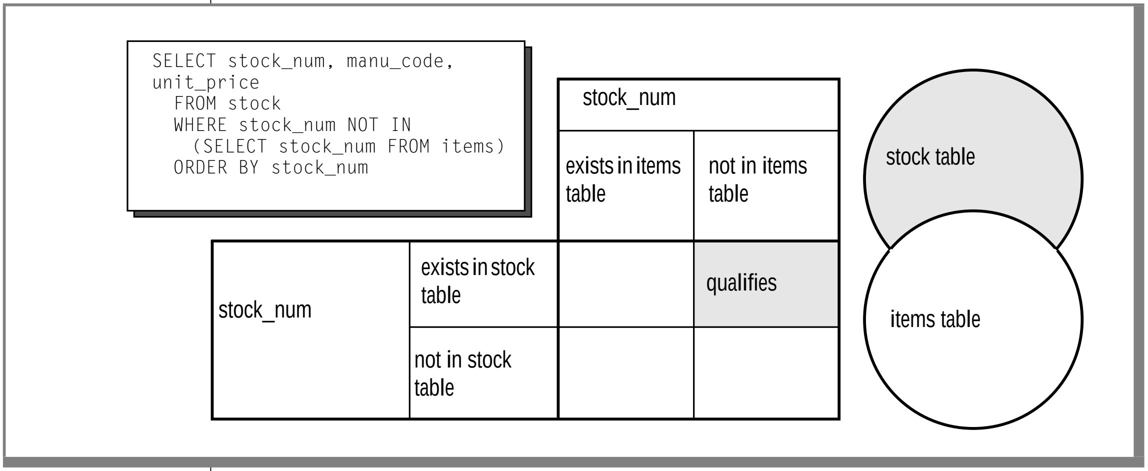
Query Result 3-42

```
stock_num manu_code unit_price

        1 HRO         $250.00z
        1 HSK         $800.00
        1 SMT         $450.00
        2 HRO         $126.00
        3 HSK         $240.00
        3 SHM         $280.00
        4 HRO         $480.00
        4 HSK         $960.00
        5 ANZ          $19.80
        5 NRG          $28.00
        5 SMT          $25.00
        6 ANZ          $48.00
        6 SMT          $36.00
        7 HRO         $600.00
        8 ANZ         $840.00
        9 ANZ          $20.00
      101 PRC          $88.00
      101 SHM          $68.00
      103 PRC          $20.00
      104 PRC          $58.00
      105 PRC          $53.00
      105 SHM          $80.00
      109 PRC          $30.00
      109 SHM         $200.00
      110 ANZ         $244.00
      110 HRO         $260.00
      110 HSK         $308.00
      110 PRC         $236.00
      110 SHM         $228.00
      111 SHM         $499.99
      114 PRC         $120.00
      201 ANZ          $75.00
      201 KAR          $90.00
      201 NKL          $37.50
      202 KAR         $230.00
      202 NKL         $174.00
      204 KAR          $45.00
      205 ANZ         $312.00
      205 HRO         $312.00
      205 NKL         $312.00
      301 ANZ          $95.00
      301 HRO          $42.50
      301 KAR          $87.00
      301 NKL          $97.00
      301 PRC          $75.00
      301 SHM         $102.00
      302 HRO           $4.50
      302 KAR           $5.00
      303 KAR          $36.00
      303 PRC          $48.00
      304 ANZ         $170.00
      304 HRO         $280.00
      306 PRC         $160.00
      306 SHM         $190.00
      307 PRC         $250.00
      309 HRO          $40.00
      309 SHM          $40.00
```

Difference

The *difference* between two sets of rows produces a table containing 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. Figure 3-3 illustrates the difference set operation.

Figure 3-3
The Difference Set Operation



```
SELECT stock_num, manu_code,
unit_price
  FROM stock
  WHERE stock_num NOT IN
    (SELECT stock_num FROM items)
  ORDER BY stock_num
```

Query 3-43 is an example of a nested SELECT statement that shows the difference between the **stock** and **items** tables.

Query 3-43

```
SELECT stock_num, manu_code, unit_price
    FROM stock
    WHERE stock_num NOT IN
        (SELECT stock_num FROM items)
    ORDER BY stock_num
```

Query Result 3-43 contains all the elements from only the first set, which returns 17 rows.

Query Result 3-43

```
stock_num manu_code unit_price

      102 PRC          $480.00
      102 SHM          $220.00
      106 PRC           $23.00
      107 PRC           $70.00
      108 SHM           $45.00
      112 SHM          $549.00
      113 SHM          $685.90
      203 NKL          $670.00
      305 HRO           $48.00
      308 PRC          $280.00
      310 ANZ           $84.00
      310 SHM           $80.00
      311 SHM           $48.00
      312 HRO           $72.00
      312 SHM           $96.00
      313 ANZ           $60.00
      313 SHM           $72.00
```

Summary

This chapter builds on concepts introduced in Chapter 2, "Composing Simple SELECT Statements." It provides sample syntax and results for more advanced kinds of SELECT statements, which are used to perform a query on a relational database. This chapter presents the following material:

- Introduces the GROUP BY and HAVING clauses, which can be used with aggregates to return groups of rows and apply conditions to those groups
- Describes how to use the rowid to retrieve internal record numbers from tables and system-catalog tables and discusses the serial iternal table identifier or tabid
- 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
- Introduces the keyword OUTER, explains how an outer join treats two or more tables asymmetrically, and provides examples of the four kinds of outer join
- Describes how to create correlated and uncorrelated subqueries by nesting a SELECT statement in the WHERE clause of another SELECT statement and shows the use of aggregate functions in subqueries
- Demonstrates the use of the keywords ALL, ANY, EXISTS, IN, and SOME in creating subqueries, and the effect of adding the keyword NOT or a relational operator
- 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

Modifying Data

4

Modifying data is fundamentally different from querying data. Querying data involves examining the contents of tables. Modifying data involves *changing* the contents of tables.

Think about what happens if the system hardware or software fails during a query. In this case, the effect on the application can be severe, but 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 Informix database servers. After an introduction to the statements that modify data, this chapter discusses these solutions. Chapters 8 through 10 cover these topics in greater detail.

Statements That Modify Data

The following statements modify data:

- DELETE
- INSERT
- 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.

Deleting 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 4-27. 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 4-21.

Deleting 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. *Do not execute the following statement*:

```
DELETE FROM customer
```

Because this DELETE statement does not contain a WHERE clause, all rows from the **customer** table are deleted. If you attempt an unconditional delete using the DB-Access or INFORMIX-SQL menu options, the program warns you and asks for confirmation. However, an unconditional delete from within a program can occur without warning.

Deleting a Known Number of 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.

Deleting an Unknown Number of 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 do so
- 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 4-32, and in greater detail in Chapter 7, "Programming for a Multiuser Environment."

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 discussed in "Interrupted Modifications" on page 4-27.

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 reentered. 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.

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.

Inserting 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 an example of adding 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 identifying 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** (of measure)
- **unit_descr** (characterizing 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 this 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* 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 for the current date and time
- The word USER for your user name
- The word DBSERVERNAME (or SITENAME) for the name of the computer where the database server is running

Some columns of a table might not allow null values. If you attempt to insert NULL in such a column, the statement is rejected. Or a column 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. These restrictions are placed on columns using data integrity constraints. For more information on data restrictions, see "Database Privileges" on page 4-16.

Only one column in a table can have the SERIAL data type. The database server generates values for a serial column. To make this happen 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. However, 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.

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.)

Listing 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.

  This means that you must list and supply values for all columns that do not specify a default value or do not permit nulls.

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 setting a default value for a column, see Chapter 9, "Implementing Your Data Model."

After the INSERT statement 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, indicating that null values are in those two columns. Because the **unit** column permits nulls, the number of tire pumps that were purchased for $114 is not known. Of course, if a default value of `box` was 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.

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 select 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. (It is discussed in Chapter 5, "Programming with SQL.") 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.

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 do this. 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, 'HSK' 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 very 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 answer lies in using transactions, as discussed in "Interrupted Modifications" on page 4-27.

Updating Rows

You use the UPDATE statement to change the contents of one or more columns in one or more existing rows of a table. 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 you change must be within the constraints placed on those columns. For more information, refer to "Database Privileges" on page 4-16.

Selecting 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. The WHERE clause can be quite complicated to select the precise set of rows that need changing. The only restriction on the WHERE clause is that the table that you are updating 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 to be updated. In the **stores7** 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.

Updating 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 5 percent, and you must update the **stock** table to reflect this increase. Use a statement such as the following :

```
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 it 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.

Impossible 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 in which the **unit_price** column was incremented by 5 percent. You *can* 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. (Database design is covered in Chapter 8 and Chapter 9.) 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, which is not allowed in an UPDATE statement or DELETE statement. Chapter 6, "Modifying Data Through SQL Programs," discusses how to use an *update cursor* to perform this kind of modification.

Updating 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)
```

The values for multiple columns are produced by a single SELECT statement. 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 NewEra, INFORMIX-4GL, and the SQL API programs, you can use record or host variables to update values. For more information, refer to Chapter 5, "Programming with SQL."*

Database Privileges

Two levels of privileges exist in a database: database-level privileges and table-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. 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 list contains database-level privileges:

Connect privilege	allows you to open a database, issue queries, and create and place indexes on temporary tables.
Resource privilege	allows you to create permanent tables.
DBA privilege	allows you to perform several additional functions as the DBA.

Seven table-level privileges exist. However, only the first four are covered here:

Select privilege	is granted on a table-by-table basis and allows you to select rows from a table (This privilege can be limited by specific columns in a table.)
Delete privilege	allows you to delete rows.
Insert privilege	allows you to insert rows.
Update privilege	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. For more information about **public**, see "The Users and the Public" on page 10-7.

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.

Chapter 10, "Granting and Limiting Access to Your Database," discusses granting privileges from the standpoint of the DBA. A complete list of privileges and a summary of the GRANT and REVOKE statements can be found in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Displaying 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.

```
grantor   grantee     tabid tabauth

tfecit    mutator     101   su-i-x--
tfecit    procrustes  101   s--idx--
tfecit    public      101   s--i-x--
```

The grantor is the user who *grants* the privilege. The grantor is usually the owner of the table but can be another user empowered by the grantor. 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, execute a DELETE statement), it performs a query similar to the preceding one. If you are not the owner of the table, and if it cannot find the necessary privilege on the table for your user name or for **public**, it refuses to perform the operation.

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 data integrity.

Entity Integrity

An entity is any person, place, or thing to be recorded in a database. Each entity represents a table, 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 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, you can 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.

Refer to Chapter 8, "Building Your Data Model," for more information on primary keys and entity integrity.

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.

Semantic integrity is enforced using the following constraints:

- 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 using semantic integrity constraints in database design, refer to "Defining the Domains" on page 9-3.

Referential Integrity

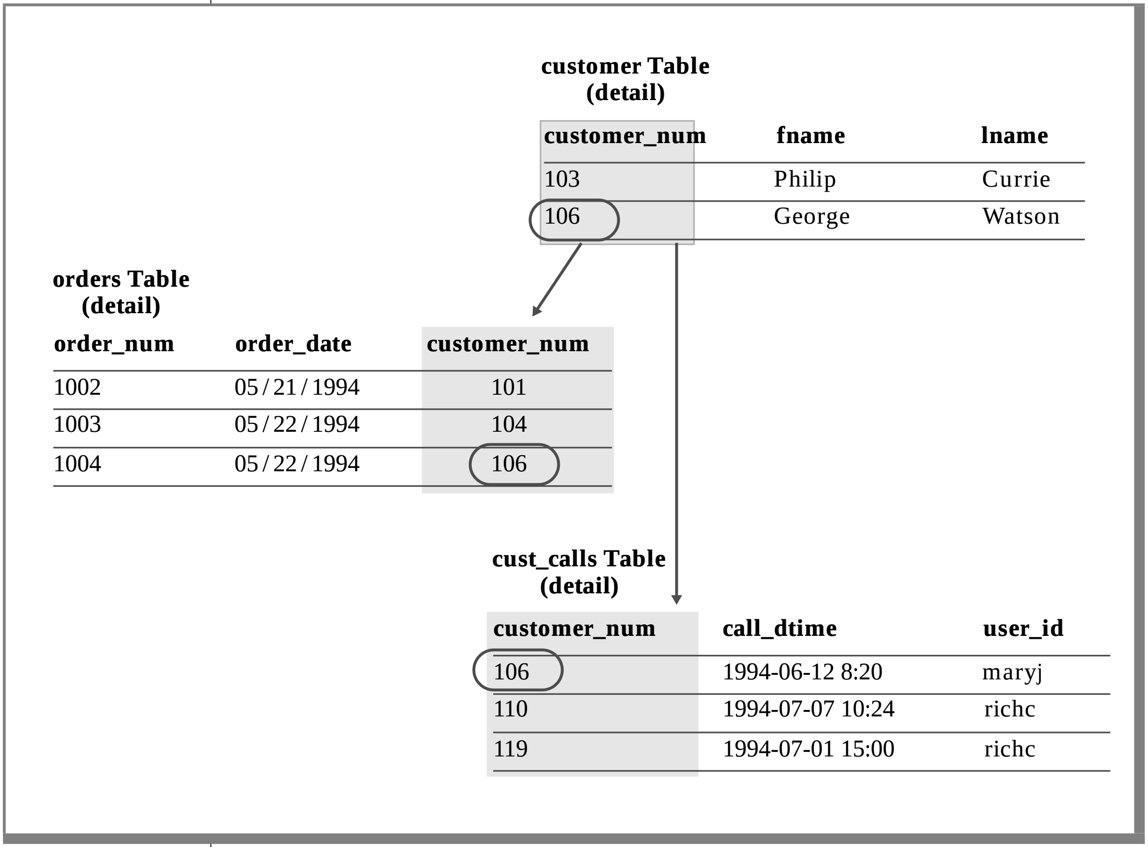
Referential integrity refers to the relationship *between* tables. Because each table in a database must have a primary key, this primary key can appear in other tables because of its relationship to data within those tables. When a primary key from one table appears in another table, it is called a 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, Figure 4-1 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.

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, INFORMIX-OnLine Dynamic 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 "Using the ON DELETE CASCADE Option" on page 4-23.

Figure 4-1
Referential Integrity in the stores7 Database



customer Table (detail)

customer_num	fname	lname
103	Philip	Currie
106	George	Watson

orders Table (detail)

order_num	order_date	customer_num
1002	05/21/1994	101
1003	05/22/1994	104
1004	05/22/1994	106

cust_calls Table (detail)

customer_num	call_dtime	user_id
106	1994-06-12 8:20	maryj
110	1994-07-07 10:24	richc
119	1994-07-01 15:00	richc

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 Chapter 1 of the *Informix Guide to SQL: Syntax*. For information on building data models using primary and foreign keys, refer to Chapter 8, "Building Your Data Model."

Using 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.

Locking 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 logging on in your current database for cascading deletes to work. Logging and cascading deletes are discussed in "Transaction Logging" on page 4-28.

Example

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 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.

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. In correlated subqueries, the subquery (or inner SELECT) is correlated when the value it 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.

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.

You can use the object modes feature to change the modes of database objects. Database objects, within the context of a discussion of the object modes feature, are constraints, indexes, and triggers. 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. The database objects that relate specifically to object modes are constraints, indexes, and triggers and all of them have different modes.

Constraints can be enabled, disabled, or filtering. The database manager does not enforce disabled constraints even though their definitions are still in the system catalogs. Only constraints in the enabled and filtering mode are enforced. However, when a constraint is in filter mode, the database manager ensures the integrity of the base table for that particular constraint. The difference between enabled mode and filtering mode is apparent in the way the database manager handles a query that poses a violation of the constraint. The database manager uses the violation-detection feature when it deals with a constraint violation.

Consider an insert statement that violates a constraint. Depending on the mode of the constraint, the database manager handles the insert statement as follows:

- The constraint is enabled.

  An insert operation that violates an enabled constraint is not inserted into the target table. A constraint violation error is returned to the user, and effects of the statement are rolled back.

- The constraint is disabled.

  An insert operation that violates a disabled constraint is inserted in the target table, and no error is returned to the user.

- The constraint is filtering.

  An insert operation that violates a filtering constraint is not inserted into the target table; instead it is inserted into the violations table. The information about the integrity violation is created and stored in a third table called the diagnostics table. The effects of the insert operation are not rolled back. When you switch the mode of the constraint to filtering, you can determine whether or not an error is returned after a constraint is violated.

  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.

A unique index also has enabled, disabled, and filter modes. A unique index in filter mode operates the same way as a constraint in filter mode. An index that does not avoid duplicate entries, however, only has enabled and disabled modes. When an index is disabled, its contents are not updated following insert, delete, or update modifications to the base table of the index. The optimizer cannot use a disabled index during a query because the index contents are not current.

Unlike constraints and unique indexes, triggers have two modes. Formerly, a trigger either existed and was fired at the appropriate time by the database manager, or nothing happened because the trigger did not exist. Now you can use object modes to disable an existing trigger. The database manager ignores a trigger in disabled mode even though the catalog information of the disabled trigger is kept up to date. The database manager does not ignore a trigger in enabled mode. Triggers do not have a filtering mode since they do not impose any kind of integrity specification on the database.

SQL Statements and Examples

For more detailed information, see the SET, START VIOLATIONS, and STOP VIOLATIONS statements in the *Informix Guide to SQL: Syntax* manual.

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, as you are modifying data, you must assume that some unforeseen event can interrupt the modification.

When a modification is interrupted by an external cause, 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, the job of entering a new order in the **stores7** database requires you to perform the following steps:

- Insert a row in the **orders** table. (This insert generates an order number.)
- 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 right way to build an order-entry application is described in the following list:

- Accept all the data interactively.
- Validate the data, and expand it (by looking 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.

The Transaction

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 crash 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. In INFORMIX-OnLine Dynamic Server, this space is called the *logical log* (because the log records represent logical units of the transactions). In INFORMIX-SE, the space used to store log records is called the transaction-log file.

Databases do not generate transaction records automatically. The database administrator 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 crashes 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. Turn logging on with the CREATE DATABASE statement for OnLine database servers.

Specifying 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 multi-statement 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

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.

Backing Up with INFORMIX-SE

If a database is stored in operating-system files (INFORMIX-SE), backup copies are made using the normal methods for making backup copies in your operating system. Only two special considerations exist for databases.

The first is a practical consideration. A database can grow to great size. It might become the largest file or set of files in the system. It can also be awkward or very time consuming to copy. You might need a special procedure for copying the database, separate from the usual backup procedures, and you might not do the job very frequently.

The second consideration is the special relationship between the database and the transaction-log file. A backup copy is an image of the database at one instant. The log file contains the history of modifications that were made during that instant. It is important that those two instants are identical; in other words, it is important to start a new transaction-log file immediately after you make a backup copy of the database. Then, if you must restore the database from the backup tape, the transaction log contains exactly the history needed to bring it forward in time from that instant to the latest update.

The statement that applies a log to a restored database is ROLLFORWARD DATABASE. To start a new log file, use whatever operating-system commands are needed to delete the file and re-create it empty or simply to set the length of the file to zero.

A transaction-log file can grow to extreme size. If you update a row ten times, just one row exists in the database, but ten update events are recorded in the log file. If the size of the log file is a problem, you can start a fresh log. Choose a time when the database is not being updated (so no transactions are active), and copy the existing log to another medium. That copy represents all modifications for some period of time; preserve it carefully. Then start a new log file. If you ever have to restore the database, you must apply all the log files in their correct sequence.

Backing Up with INFORMIX-OnLine Dynamic Server

The OnLine database server contains elaborate features to support backups and logging. They are described in the *INFORMIX-OnLine Dynamic Server Archive and Backup Guide*.

Conceptually, the facilities of OnLine are similar to those already described for INFORMIX-SE, but they are more elaborate for the following reasons:

- OnLine has very stringent requirements for performance and reliability (for example, it supports making backup copies while databases are in use).
- OnLine manages its own disk space, which is devoted to logging.
- It 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 OnLine administrator usually manages them from a central location.

If you want to make a personal backup copy of a single database or table that is held by OnLine, you can do it with the **onunload** utility. 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 OnLine. As a result, the copy can be made very quickly, and the corresponding **onload** program can restore the file very quickly. However, the data format is not meaningful to any other programs.

If your OnLine administrator is using ON-Archive to create backups and back up logical logs, you might also be able to create your own backup copies using ON-Archive. See your *INFORMIX-OnLine Dynamic Server Archive and Backup Guide* for more information.

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. C*oncurrency* 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.

You use a combination of SQL statements to control the effect that locks have on your data access: 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 5, "Programming with SQL," and Chapter 6, "Modifying Data Through SQL Programs." Also see Chapter 7, "Programming for a Multiuser Environment," for more information about locking and concurrency.

Data Replication

Data replication, in the broadest sense of the term, is when 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 accessing 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 way 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.

INFORMIX-OnLine Dynamic Server Data Replication

Within the broad framework of data replication, OnLine implements nearly transparent data replication of entire database servers. All the data managed by one OnLine database server is replicated and dynamically updated on another OnLine database server, usually at a remote site. OnLine data replication 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 OnLine provides replication transparency, you generally do not need to be concerned with or aware of data replication; the OnLine administrator 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 *INFORMIX-OnLine Dynamic Server Administrator's 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, along with any data constraints, control how and when you can modify 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.

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.

You 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.

You 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.

You 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

Programming with SQL

5

In the examples in the previous chapters, SQL is treated 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 in several ways: through interactive access using DB-Access or INFORMIX-SQL or through application programs written using an SQL API, or through an application language such as NewEra or INFORMIX-4GL.

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 is only an introduction to the 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 slightly different in every language, you must become familiar with the manual for the Informix SQL API specific to that language or with your NewEra or INFORMIX-4GL documentation.

SQL in Programs

You can write a program in any of several languages and mix SQL statements in 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 Informix often abbreviates as ESQL.

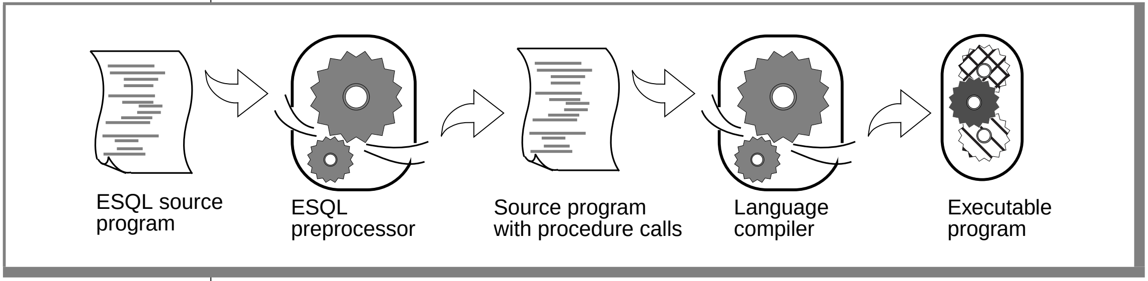
SQL in SQL APIs

ESQL products are Informix SQL APIs. Informix produces SQL APIs for the following programming languages:

- C
- COBOL
- FORTRAN (pre-Version 6.0)
- Ada (Version 4.0 only)

All SQL API products work in a similar way, as Figure 5-1 shows. 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 5-1
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, such as DCE (Distributed Computing Environment package), you can develop 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 multi-threaded ESQL/C application is that each thread can have many active connections to a database server simultaneously. While a nonthreaded ESQL/C application can establish many connections to one or more databases, it can have only one connection active at a time. A multithreaded ESQL/C application can have one active connection per thread and many threads per application.

For more information on connections, see “SQL Connection Statements” on page 11-17. For more information on multithreaded applications, see the *INFORMIX-ESQL/C Programmer’s Manual*.

SQL in Application Languages

Whereas SQL API products allow you to embed SQL in the host language, some languages have SQL as a natural part of their statement set. INFORMIX-4GL incorporates the SQL language as a natural part of the fourth-generation language it supports. The NewEra product provides support for embedded SQL, and it also provides a mechanism called a SuperTable to generate automatically SQL statements that are needed to access a table being displayed. Informix Stored Procedure Language (SPL) also uses SQL as a natural part of its statement set. You use INFORMIX-4GL or an SQL API product to write application programs. You use SPL to write procedures that are stored with a database and called from an application program.

Static Embedding

You can introduce SQL statements into a program in two ways. 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.

Dynamic Statements

Some applications require the ability to compose SQL statements 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. In NewEra, much of the database interaction is done with dynamically executed SQL statements.

Program Variables and Host Variables

Application programs can use program variables within SQL statements. In NewEra, INFORMIX-4GL and 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 sample shows a program variable in INFORMIX-4GL:

```
MAIN
.
.
.
DEFINE drop_number INT
LET drop_number = 108
DELETE FROM items WHERE order_num = drop_number
.
.
.
```

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 being a “guest” in the program.

The following example is a DELETE statement as it might appear when embedded in a COBOL source program:

```
EXEC SQL
    DELETE FROM items
        WHERE order_num = :o-num
END-EXEC.
```

The first and last lines mark off embedded SQL from the normal COBOL statements. Between them, you see an ordinary DELETE statement, as described in Chapter 4, “Modifying Data.” When this part of the COBOL 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 **:o-num**, which is the name of a host variable.

Each SQL API product provides a means of delimiting the names of host variables when they appear in the context of an SQL statement. In COBOL, host-variable names are designated with an initial colon. The example statement asks the database server to delete rows in which the order number equals the current contents of the host variable named **:o-num**. This numeric variable has been declared and assigned a value earlier in the program.

The same DELETE statement embedded in a FORTRAN program looks like the following example:

```
EXEC SQL
    DELETE FROM items
        WHERE order_num = :onum
```

The same statement embedded in an Ada program looks like the following example:

```
EXEC SQL
    DELETE FROM items
        WHERE order_num = $onum;
```

In INFORMIX-ESQL/Ada, a host variable is indicated by a leading dollar sign, and statements end with a semicolon. 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 corresponding DELETE statement is written in INFORMIX-ESQL/C, as the following example shows:

```
EXEC SQL delete FROM items
    WHERE order_num = :onum;
```

In INFORMIX-ESQL/C, an SQL statement can be introduced with either a leading dollar sign ($) or the words EXEC SQL.

These differences of syntax are trivial; the essential points in all languages (an SQL API, NewEra, INFORMIX-4GL, or SPL) are described in the following list:

- You can embed SQL statements in a source program as if they were executable statements of the host language.
- You can 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 all the power of the host language to them. You can hide the SQL statements under a multitude of interfaces, and you can embellish the SQL functions in a multitude of ways.

Calling 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.

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 described in "Retrieving Multiple Rows" on page 5-20.

The 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 stored procedure, the SQLCA of the calling application contains the values triggered by the SQL statement in the procedure.

The principal fields of the SQLCA are listed in Figure 5-2 and Figure 5-3. 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. See your NewEra, INFORMIX-4GL, or SQL API manual for details.

You can also use the SQLSTATE variable of the GET DIAGNOSTICS statement to detect, handle, and diagnose errors. See "The SQLSTATE Value" on page 5-14.

Figure 5-2
The Uses of SQLCODE, SQLERRD, and SQLERRP

integer

SQLCODE

0	Success.
100	No more data / not found.
negative	Error code.

array of 6 integers

SQLERRD

first	Following 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 affected rows. It is not used in INFORMIX-ESQL / Ada.
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 failed CONNECT or DATABASE statement, this field contains the ISAM, operating-system, or network-specific protocol error code.
third	If an application connects to an INFORMIX-Gateway *with DRDA*, this field contains the application-server error code. In this case, sqlca.sqlcode is -29000.
fourth	Following a successful insert operation of a single row, this field contains the value of a generated serial number for that row.
fifth	Following a successful multirow insert, update, or delete operation, this field contains the number of processed rows.
sixth	Following a multirow insert, update, or delete operation that ends with an error, this field contains the number of rows successfully processed before the error was detected.

character (8)

SQLERRP

	Internal use only.

Figure 5-3
The Uses of SQLWARN and SQLERRM

array of 8 characters

SQLWARN

	When Opening or Connecting to a Database:
first	Set to W when any field is set to W. If this field is blank, the others need not be checked.
second	Set to W when the database that is now open uses a transaction log.
third	Set to W when the database that is now open is ANSI compliant.
fourth	Set to W when the database server is INFORMIX-OnLine Dynamic Server.
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).
sixth	Not used.

	All Other Operations:
first	Set to W when any other field is set to W.
second	Set to W when a column value is truncated as it is fetched into a host variable.
third	Set to W when an aggregate function encounters a null value.
fourth	On a SELECT statement or on opening a cursor, set to W when the number of items in the select list is not the same as the number of host variables given in the INTO clause to receive them.
fifth	Set to W if a prepared statement contains a DELETE statement or an UPDATE statement without a WHERE clause.
sixth	Set to W following execution of a statement that does not use ANSI-standard SQL syntax (provided that the **DBANSIWARN** environment variable is set).
seventh	
eighth	

character (71)

SQLERRM

Contains the variable, such as table name, that is placed in the error message. For some networked applications, 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 INFORMIX-ESQL/C, but starting with one in the other languages. In this discussion, the fields are named using specific words such as *third*, and you must translate into the syntax of your programming language.

The 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 Figure 5-2 on page 5-10 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.

In INFORMIX-4GL and NewEra, SQLCODE is also accessible under the name STATUS. NewEra also supports access to SQLCODE through ODBC libraries.

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. (Queries that use cursors are described under "Retrieving Multiple Rows" on page 5-20.) 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 ANSI-compliant databases, SELECT, DELETE, UPDATE, and INSERT statements all set SQLCODE to 100 if no rows are returned. In databases that are not ANSI compliant, only a SELECT statement that returns no rows causes SQLCODE to be set to 100.

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 *Informix Error Messages* manual and in the on-line error message file.

The 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 (referred to as the ISAM error) that reveals the error encountered by the database server I/O routines or by the operating system.

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 INFORMIX-4GL, INFORMIX-ESQL/C, INFORMIX-ESQL/COBOL, and NewEra (Informix CCL only). The fields are used as Figure 5-2 on page 5-10. shows.

These additional details can be very 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 is entered by the user, 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 and INFORMIX-SQL use this feature to position the cursor when you ask to modify a statement after an error.)

The 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.

Important: *NewEra and INFORMIX-4GL call this array SQLWARN.*

Both sets of SQLWARN values are summarized in Figure 5-3 on page 5-11.

The SQLSTATE Value

Certain Informix products, such as INFORMIX-ESQL/COBOL and INFORMIX-ESQL/C, support the SQLSTATE value in compliance with X/Open and ANSI SQL standards. The GET DIAGNOSTICS statement reads the SQLSTATE value in order 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 GET DIAGNOSTICS, the SQLSTATE variable, and the meanings of the SQLSTATE return codes, see "GET DIAGNOSTICS" in Chapter 1 of the *Informix Guide to SQL: Syntax*. If your Informix product supports GET DIAGNOSTICS and SQLSTATE, Informix recommends 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.

Retrieving Single Rows

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 more complicated method to fetch the rows one at a time. Multiple-row select operations are discussed in "Retrieving Multiple Rows" on page 5-20.

To retrieve a single row of data, simply embed a SELECT statement in your program. The following example shows how the embedded SELECT statement can be written using 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('6/1/94'));
```

The INTO clause is the only detail that distinguishes this statement from any example in Chapter 2, “Composing Simple SELECT Statements,” or Chapter 3, “Composing Advanced SELECT Statements.” 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. In the following INFORMIX-4GL example, host variables are used in two ways, as receivers of data and in the WHERE clause:

```
DEFINE cfname, clname, ccompany CHAR(20)
DEFINE cnumbr INTEGER
LET cnumbr = 104
SELECT fname, lname, company
    INTO cfname, clname, ccompany
    FROM customer
    WHERE customer_num = cnumbr
```

Because the **customer_num** column has a unique index (implemented through a constraint), this query returns only one row. 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 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 ESQL/C code is not shown. It 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 used in a statement is noted and passed to the database server along with the statement. The database server does its best to convert column data into the form used by the receiving variables. Almost any conversion is allowed, although some conversions cause a loss of precision. The results of the preceding example differ, depending on the data type of the receiving host variable, as described in the following list:

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`.

Working with Null Data

What if the program retrieves a null value? Null values can be stored in the database, but the data types supported by programming languages do not recognize a null state. A program must have some way of recognizing 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 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 that is the case, this program uses an ESQL/C library function to assign a default value to the host variable. (The function **rstrdate** is part of the INFORMIX-ESQL/C product.)

The syntax that you use to associate an indicator variable differs with the language you are using, but the principle is the same in all languages. However, indicator variables are not used explicitly in INFORMIX-4GL, NewEra, or in SPL. In those languages, null values are supported for variables. In 4GL, the preceding example is written as follows:

```
SELECT paid_date
    INTO op_date
    FROM orders
    WHERE order_num = the_order
IF op_date IS NULL THEN
    LET op_date = date ('01/01/1900')
END IF
```

Dealing with Errors

Although the database server handles conversion between data types automatically, 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 following 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 is supplied by a user or by some other source 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 only following SELECT statements. 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; this topic is covered in Chapter 6, "Modifying Data Through SQL Programs.")

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 `table name 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.

Interpreting 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

Using 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 that it 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.

The following example is an expansion of an earlier INFORMIX-4GL example that displays default values if it cannot find the company that the user requests:

```
DEFINE cfname, clname, ccompany CHAR(20)
DEFINE cnumbr INTEGER
PROMPT 'Enter the customer number: ' FOR cnumbr
LET cfname = 'unknown'
LET clname = 'person'
LET ccompany = 'noplace'
SELECT fname, lname, company
    INTO cfname, clname, ccompany
    WHERE customer_num = cnumbr
DISPLAY cfname,' ', clname,' at ', ccompany
```

This query does not use aggregates, so if no row matches the user-specified customer number, SQLCODE is set to `100` and SQLSTATE is `02000` and the host variables remain unchanged.

Retrieving 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.

Declaring 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 INFORMIX-4GL:

```
DECLARE the_item CURSOR FOR
    SELECT order_num, item_num, stock_num
    INTO o_num, i_num, s_num
    FROM items
```

The declaration gives the cursor a name (**the_item** in this case) and associates it with a SELECT statement. (Chapter 6, "Modifying Data Through SQL Programs," discusses how a cursor also can 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 specify which variables receive data by using the FETCH statement as discussed in "Locating the INTO Clause" on page 5-23.

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 once through the **items** table. Cursors can be declared to read backward and forward (see "Cursor Input Modes" on page 5-24). This cursor, because it lacks a FOR UPDATE clause, is probably used only to read data, not to modify it. (The use of cursors to modify data is covered in Chapter 6, "Modifying Data Through SQL Programs.")

Opening 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 for SQL APIs and in SQLCODE for INFORMIX-4GL and SQL APIs. The following example shows the OPEN statement in INFORMIX-4GL:

```
OPEN the_item
```

Because the database server is seeing the query for the first time, many errors are detected. 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 for use. At this point, however, the program does not know if the cursor can produce any rows.

Fetching 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 to receive the data. The following example shows the completed INFORMIX-4GL code:

```
DECLARE the_item CURSOR FOR
    SELECT order_num, item_num, stock_num
        INTO o_num, i_num, s_num
        FROM items
OPEN the_item
WHILE SQLCA.SQLCODE = 0
    FETCH the_item
    IF SQLCA.SQLCODE = 0 THEN
        DISPLAY o_num, i_num, s_num
    END IF
END WHILE
```

Detecting 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:

```
DECLARE the_item CURSOR FOR
    SELECT order_num, item_num, stock_num
        INTO o_num, i_num, s_num
        FROM items
OPEN the_item
IF SQLCA.SQLCODE = 0 THEN
    FETCH the_item -- fetch first row
END IF
WHILE SQLCA.SQLCODE = 0
    DISPLAY o_num, i_num, s_num
    FETCH the_item
END WHILE
```

In this version, the case of zero returned rows is handled early, so no second test of SQLCA.SQLCODE exists within the loop. These versions have no measurable difference in performance because the time cost of a test of SQLCA.SQLCODE is a tiny fraction of the cost of a fetch.

Locating the INTO Clause

The INTO clause names the host variables that are to receive the data returned by the database server. The INTO clause must appear in either the SELECT or the FETCH statement. However it cannot appear in both. The following example is reworked to specify host variables in the FETCH statement:

```
DECLARE the_item CURSOR FOR
    SELECT order_num, item_num, stock_num
        FROM items
OPEN the_item
WHILE status = 0
    FETCH the_item INTO o_num, i_num, s_num
    IF status = 0 THEN
        DISPLAY o_num, i_num, s_num
    END IF
END WHILE
```

The second form lets you fetch different rows into different variables. For example, you can 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 sequential cursor is opened. A scroll cursor can fetch the next row or any prior row, so it can read rows multiple times. The following example shows a sequential cursor declared in 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 keyword SCROLL, as the following example from INFORMIX-ESQL/FORTRAN 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. The ABSOLUTE option specifies the rank number 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 fetch the first row and then scan through the entire list again. However, these features have a price, as the next section describes.

The 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.

Creating 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 very easy, or it can require a great deal of work and time. Consider the following declaration of a cursor:

```
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:

```
DECLARE hard 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 know 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. Afterward, it can tell the program exactly how many rows the active set contains. This information is not made available, however. 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; but very small changes in the query, in the sizes of the tables, or in the available indexes can change its methods.

The Active Set for a Sequential Cursor

The database server attempts to use as few resources as possible in maintaining 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.

The 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.

The 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 seems 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 in time. 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.

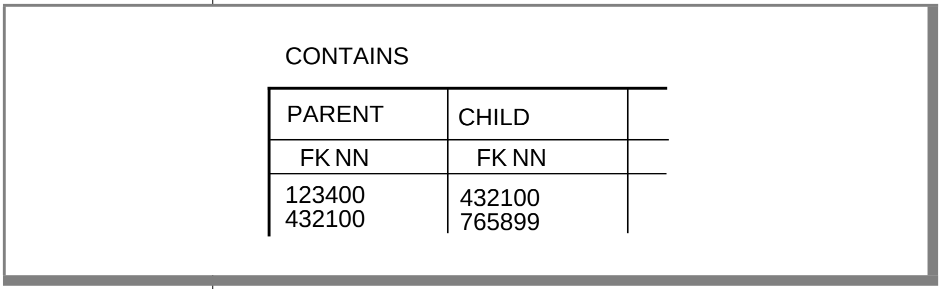
The only time that stale data can cause a problem is when the program intends to use the input data to modify the same database; for example, when a banking application must read an account balance, change it, and write it back. Chapter 6, "Modifying Data Through SQL Programs," discusses programs that modify data.

Using a Cursor: A Parts Explosion

When you use a cursor, supplemented by program logic, you can solve problems that plain SQL cannot solve. One of these 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 #123400 is an assembly of nine parts, nine rows exist with 123400 in the first column and other part numbers in the second. Figure 5-4 shows one of the rows that describe part #123400.



CONTAINS

PARENT	CHILD	
FK NN	FK NN	
123400 432100	432100 765899	

Figure 5-4
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 is a sketch of one solution, as implemented in INFORMIX-4GL:

```
DEFINE part_list ARRAY[200] OF INTEGER
FUNCTION boom (top_part)
    DEFINE this_part, child_part INTEGER
    DEFINE next_to_do, next_free SMALLINT
    DECLARE part_scan CURSOR FOR
        SELECT child INTO child_part FROM contains
            WHERE parent = this_part

    LET next_to_do = 1
    LET part_list[next_to_do] = top_part
    LET next_free = 2

    WHILE next_to_do < next_free
        this_part = part_list[next_to_do]
        FOREACH part_scan
            LET part_list[next_free] = child_part
            LET next_free = next_free + 1
        END FOREACH
        LET next_to_do = next_to_do + 1
    END WHILE
    RETURN next_free - 1
END FUNCTION
```

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 on page 5-28 uses a cursor named **part_scan** to return all the rows with a particular value in the **parent** column. Such a function is easy to implement using the INFORMIX-4GL statement FOREACH, which opens a cursor, iterates once for each row in the selection set, and closes the cursor.

The function on page 5-28 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 earlier 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 extremely 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 the ability 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 the contents of the statement can be determined by user input. 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, the utility that you use to explore SQL interactively, is an INFORMIX-ESQL/C program that constructs, prepares, and executes SQL statements dynamically. For example, it lets users specify the columns of a table using simple, interactive menus. When the user is finished, DB-Access builds the necessary CREATE TABLE or ALTER TABLE statement dynamically and prepares and executes it.

Preparing 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.

This leads to two restrictions. First, if it is a SELECT statement, it cannot include the INTO clause. The INTO clause names host variables into which column data is placed, and host variables are not allowed in a dynamic statement. Second, wherever the name of a host variable normally appears in an expression, a question mark (?) is written as a placeholder.

You can prepare a statement in this form for execution with the PREPARE statement. The following example is written in 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 ones that cannot be prepared 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 "The SQLWARN Array" on page 5-13).

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 example in INFORMIX-ESQL/COBOL:

```
MOVE    'BEGIN WORK;
        UPDATE account
            SET balance = balance + ?
                WHERE acct_number = ?;
        UPDATE teller
            SET balance = balance + ?
                WHERE teller_number = ?;
        UPDATE branch
            SET balance = balance + ?
                WHERE branch_number = ?;
        INSERT INTO history VALUES(timestamp, values);'
```

```
         TO BIG-QUERY.

     EXEC SQL
         PREPARE BIG-Q FROM :BIG-QUERY
     END-EXEC.
```

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, the performance is often better because fewer exchanges take place between the program and the database server.

Executing Prepared SQL

Once a statement is prepared, it can be executed multiple times. Statements other than SELECT statements, and SELECT statements that return only a single row, are executed with the EXECUTE statement.

The following 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 an EXECUTE PROCEDURE) returns only one row, you can use the INTO clause of EXECUTE to specify the host variables that receive the values.

Using Prepared SELECT Statements

A dynamically prepared SELECT statement cannot simply be executed; it might produce more than one row of data, and the database server, not knowing which row to return, produces an error code.

Instead, a dynamic SELECT statement is attached to a cursor. Then, the cursor is opened and used in the usual way. The cursor to be used with a prepared statement is declared for that statement name. The following example is written in INFORMIX-4GL:

```
LET select_2 = 'select order_num, order_date from orders ',
    'where customer_num = ? and order_date > ?'
PREPARE q_orders FROM select_2
DECLARE cu_orders CURSOR FOR q_orders
OPEN cu_orders USING q_c_number, q_o_date
FETCH cu_orders INTO f_o_num, f_o_date
```

The following list identifies the stages of processing in the 4GL example:

1. A character string expressing a SELECT statement is placed in a program variable. It employs two place-holding question marks.
2. The PREPARE statement converts the string into a data structure that can be executed. The data structure is associated with a name, **q_orders**.
3. A cursor named **cu_orders** is declared and associated with the name of the prepared statement.
4. When the cursor is opened, the prepared statement is executed. The USING clause in the OPEN statement provides the names of two host variables whose contents are substituted for the question marks in the original statement.
5. The first row of data is fetched from the open cursor. The INTO clause of the FETCH statement specifies the host variables that are to receive the fetched column values.

Later, the cursor can be closed and reopened. While the cursor is closed, a different SELECT statement can be prepared under the name **q_orders**. In this way, a single cursor can be used to fetch from different SELECT statements.

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 is a predefined data structure that is allocated for this purpose and is known as a system-descriptor area. If you are using 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.

Freeing Prepared Statements

A prepared SQL statement occupies space in memory. With some database servers, it can consume space owned by the database server 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.

Embedding 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 or INFORMIX-SQL. These tools can also be driven from a file of statements, so that the creation of a database can be done with one operating-system command.

Embedding Grant and Revoke Privileges

One task related to data definition is performed repeatedly: the granting and revoking of privileges. The reasons for this are discussed in Chapter 10, "Granting and Limiting Access to Your Database." Because privileges must be granted and revoked frequently, and possibly by users who are not skilled in SQL, it can be useful 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.

The only 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 INFORMIX-4GL function assembles a GRANT statement from the function parameters, and then prepares and executes it:

```
FUNCTION table_grant (priv_to_grant, table_name, user_id)
    DEFINE  priv_to_grant char(100),
            table_name char(20),
            user_id char(20),
            grant_stmt char(200)
    LET grant_stmt =' GRANT ', priv_to_grant,
                    ' ON ', table_name,
                    ' TO ', user_id
    WHENEVER ERROR CONTINUE
    PREPARE the_grant FROM grant_stmt
    IF status = 0 THEN
        EXECUTE the_grant
    END IF
    IF status <> 0 THEN
```

```
         DISPLAY 'Sorry, got error #', status, 'attempting:'
         DISPLAY '     ',grant_stmt
        END IF
        WHENEVER ERROR STOP
        FREE the_grant
    END FUNCTION
```

The following example shows how the opening statement defines the name of the function and the names of its three parameters:

```
    FUNCTION table_grant (priv_to_grant, table_name, user_id)
```

The following example shows how the DEFINE statement defines the parameters and one additional variable local to the function. All four are character strings of various lengths.

```
    DEFINE  priv_to_grant char(100),
            table_name char(20),
            user_id char(20),
            grant_stmt char(200)
```

The following example shows how the variable **grant_stmt** holds the assembled GRANT statement. The assembled GRANT statement is created by concatenating the parameters and some constants.

```
    LET grant_stmt ='GRANT ', priv_to_grant,
                    ' ON ', table_name,
                    ' TO ', user_id
```

This assignment statement uses the comma as a list delimiter to concatenate 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 same feat can be accomplished in other host languages using different syntax, as the following example shows:

```
    WHENEVER ERROR CONTINUE
    PREPARE the_grant FROM grant_stmt
```

If the database server returns an error code in SQLCODE, the default action of an INFORMIX-4GL program is to terminate. However, errors are quite likely when you prepare an SQL statement composed of user-supplied parts, and program termination is a poor way to diagnose the error. In the preceding code, the WHENEVER statement prevents termination. Then the PREPARE statement passes the assembled statement text to the database server for parsing.

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 status = 0 THEN
    EXECUTE the_grant
END IF
```

If the preparation is successful, the next step is to execute the prepared statement. The function in the 4GL example at the beginning of this section displays an error message if anything goes wrong. As written, it makes no distinction between an error from the PREPARE operation and an error from the EXECUTE operation. It does not attempt to interpret the numeric error code but leaves it to the user to interpret.

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

Modifying Data Through SQL Programs

6

The preceding chapter introduced the idea of putting 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 covers the issues that arise when a program needs to modify the database by deleting, inserting, or updating rows. As in Chapter 5, "Programming with SQL," this chapter aims to prepare you for reading the manual for your Informix embedded language, NewEra, or 4GL product.

The general use of the INSERT, UPDATE, and DELETE statements is covered in Chapter 4, "Modifying Data." This chapter examines their use from within a program. You can easily put the statements in a program, but it can be difficult to handle errors and to deal with concurrent modifications from multiple programs.

Using DELETE

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 4, "Modifying Data." 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 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, it is discussed in Chapter 7, “Programming for a Multiuser Environment.”

Other, rarer types of errors can strike after deletions begin, for example, hardware errors that occur while the database is being updated.

Using 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 "Direct Deletions," 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)/* some problem, */
    EXEC SQL rollback work;/* ...put everything back */
else    /* everything worked OK, */
    EXEC SQL commit work;/* ...finish transaction */
```

An important 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. Executing a ROLLBACK WORK statement after an error wipes out the error code; unless it was saved, it cannot be reported to the user.

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.

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 INFORMIX-4GL shows:

```
WHENEVER ERROR CONTINUES{do not terminate on error}
BEGIN WORK {start transaction}
DELETE FROM items
    WHERE order_num = o_num
IF (status >= 0) THEN {no error on first delete}
    DELETE FROM orders
        WHERE order_num = o_num
END IF
IF (status >= 0) THEN {no error on either delete}
    COMMIT WORK
ELSE        {problem on some delete}
    DISPLAY 'Error ', status,' deleting.'
    ROLLBACK WORK
END IF
```

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.

Deleting with a Cursor

You can also write a DELETE statement through 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:

```
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 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);
}
```

Warning: *The design of the ESQL/C function in the previous example is unsafe. It depends on the current isolation level for correct operation. Isolation levels are covered later in the chapter. For more information on isolation levels see Chapter 7, "Programming for a Multiuser Environment." Even when it works as intended, its effects depend on the physical order of rows in the table, which is not generally a good idea.*

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 described in Chapter 7, “Programming for a Multiuser Environment.”)

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.

Clean-up functions of this sort are sometimes needed, but they generally need more sophisticated design. This one deletes all duplicate rows except the last one delivered by the database server. That ordering has nothing to do with the contents 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. A better approach is presented in “An Insert Example” on page 6-12.

Using INSERT

You can embed the INSERT statement in programs. Its form and use in a program are the same as described in Chapter 4, "Modifying Data," with the additional feature that you can use host variables in expressions, both in the VALUES and WHERE clauses. Moreover, a program has the additional ability to insert rows using a cursor.

Using 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 insert rows into a table in bulk efficiently.

Declaring 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 is an example of 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. This 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 minimum size of the insert buffer is set for any implementation of embedded SQL; you have no control over it (it is typically 1 or 2 kilobytes). 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.

Inserting with a Cursor

The code in the previous example 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.

```
WHENEVER ERROR CONTINUE {do not terminate on error}
BEGIN WORK
OPEN new_custs
WHILE status = 0

CALL next_cust() RETURNING the_company, the_fname, the_lname
    IF the_company IS NULL THEN
        EXIT WHILE
    END IF
    PUT new_custs
END WHILE
IF status = 0 THEN         {no problem in a PUT}
    FLUSH new_custs        {write any last rows}
END IF
IF status = 0 THEN         {no problem writing}
    COMMIT WORK            {..make it permanent}
ELSE
    ROLLBACK WORK         {retract any changes}
END IF
```

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.

Examine the INSERT statement on page 6-9 once more. 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 after every PUT statement, to zero if no error occurs and to a negative error code if an error occurs.

The third element of SQLERRD is set to the number of rows actually inserted into the table. It is set to zero if the new row is merely moved to the buffer; to the count of rows that are in the buffer if the buffer load is inserted without error; or to the count of rows inserted before an error occurs, if one does 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, just literal numbers and strings of characters. No matter how many times such an INSERT operation occurs, the rows it produces are identical. In that case, there is no point in copying, buffering, and transmitting each identical row.

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, is passed to the database server. The database server creates and inserts that many rows in one operation.

It is not common to insert a quantity of identical rows. You can do it when you first establish a database, to populate a large table with null data.

An Insert Example

"Deleting with a Cursor" on page 6-7 contains an example of the DELETE statement whose purpose is to look for and delete duplicate rows of a table. A better way to do the same thing is to select the desired rows instead of deleting the undesired ones. The code in the following example shows one way to do this. The example is written in INFORMIX-4GL to take advantage of some features that make SQL programming easy.

```
BEGIN WORK
INSERT INTO new_orders
    SELECT * FROM ORDERS main
        WHERE 1 = (SELECT COUNT(*) FROM ORDERS minor
                    WHERE main.order_num = minor.order_num)
COMMIT WORK

DEFINE ord_row RECORD LIKE orders,
    last_ord LIKE orders.order_num
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
DECLARE ins_row CURSOR FOR
    INSERT INTO new_orders VALUES (ord_row.*)

BEGIN WORK
OPEN ins_row
```

```
    LET last_ord = -1
    FOREACH dup_row
        IF ord_row.order_num <> last_ord THEN
            PUT ins_row
            LET last_ord = ord_row.order_num
        END IF
    END FOREACH
    CLOSE ins_row
    COMMIT WORK
```

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. This example deals with some other database.)

In NewEra and INFORMIX-4GL, you can define a data structure *like* a table; the structure is automatically given one element for each column in the table. The **ord_row** structure is a buffer to hold one row of the table.

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 6-7. 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 is an insert cursor. This cursor is written to take advantage of the asterisk (*) notation of INFORMIX-4GL; you can supply values for all columns simply by naming a record with an asterisk to indicate *all fields*.

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.

This example uses the simplest kind of error handling. Unless it is told otherwise, an INFORMIX-4GL program automatically terminates when an error code is set in SQLCODE. In this event, the active transaction rolls back. This program relies on that behavior; the program assumes that if it reaches the end, no errors exist, and the transaction can be committed. This kind of error handling is acceptable when errors are unlikely, and the program is used by people who do not need to know why the program terminates.

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 do (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.

Using UPDATE

You can embed the UPDATE statement in a program in any of the forms described in Chapter 4, “Modifying Data,” 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 is addressed by a cursor.

Using 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 INFORMIX-ESQL/COBOL) shows the declaration of an update cursor:

```
EXEC SQL
    DECLARE names CURSOR FOR
        SELECT fname, lname, company
        FROM customer
    FOR UPDATE
END-EXEC.
```

The program that uses this cursor can fetch rows in the usual way.

```
EXEC SQL
    FETCH names INTO :FNAME, :LNAME, :COMPANY
END-EXEC.
```

If the program then decides that the row needs to be changed, it can do so.

```
IF COMPANY IS EQUAL TO 'SONY'
    EXEC SQL
        UPDATE customer
            SET fname = 'Midori', lname = 'Tokugawa'
            WHERE CURRENT OF names
    END-EXEC.
```

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. (Levels of locks and concurrent use are discussed in Chapter 7, "Programming for a Multiuser Environment.")

Updating 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 using 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 using any cursor.

Cleaning Up a Table

A final, hypothetical example of using 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, **datcol**, 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 INFORMIX-ESQL/C code needed to accomplish these things:

```
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 described in Chapter 4, “Modifying Data.” A program also can 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 the transaction. Without transaction logging, it is more difficult to write programs that can recover from errors.

Programming for a Multiuser Environment

If your database is contained in a single-user workstation and is not connected on a network to other computers, your programs can modify data freely. But 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 describes *concurrency*: two or more independent uses of the same data at the same time. This chapter addresses concurrency, locking, and isolation levels.

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.

Locking 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.

Locking 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 (which holds multiple rows), a whole table, or an entire database. 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.

This section discusses how a program can achieve the following goals:

- To place all the locks needed to ensure data integrity
- To 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:

```
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:

```
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 possibilities are concerned with what happens next:

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 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 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 very important to the design of some applications. In number 3, the query returns a mix of updated and original data. That result can be a negative thing in some applications. In others, such as one that is taking an average of all prices, it might not matter at all.

In number 4, it 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 *names*.

To control concurrent events such as these, use the locking and *isolation level* features of the database server.

How Locks Work

The INFORMIX-OnLine Dynamic Server database server supports a complex, flexible set of locking features that is described in this section. Some of these locking features work differently on an INFORMIX-SE database server. (See Chapter 1 of the *Informix Guide to SQL: Reference* for a summary of the differences between locking in SE and OnLine database servers.)

Kinds of Locks

INFORMIX-OnLine Dynamic Server supports the following kinds of locks, which it uses in different situations:

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.
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. An exclusive lock cannot be placed where any other kind of lock exists. Once one has been placed, no other lock can be placed on the same object.
promotable	A promotable lock establishes the intent to update. It can only be placed where no other promotable or exclusive lock exists. Promotable locks can be placed on records that already have shared locks. When the program is about to change the locked object, the promotable lock can be promoted 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, the shared lock must be dropped 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.

You can lock an entire database exclusively with the following statement:

```
DATABASE database name EXCLUSIVE
```

This statement succeeds if no other program has opened that database. Once 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 very 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, this action is performed automatically. INFORMIX-OnLine Dynamic Server always locks an entire table while it performs any of the following statements:

- ALTER INDEX
- ALTER TABLE
- CREATE INDEX
- DROP INDEX
- RENAME COLUMN
- RENAME TABLE

The completion of the statement (or end of the transaction) releases the lock. An entire table can also be locked automatically during certain queries.

You can use the LOCK TABLE statement to lock an entire table explicitly. This statement allows you to place either a shared lock or an exclusive lock on an entire table.

A shared table lock prevents any concurrent updating of that table while your program is reading from it. INFORMIX-OnLine Dynamic Server achieves the same degree of protection by setting the isolation level, as described in the next section, which allows greater concurrency than using a shared table lock. However, all Informix database servers support the LOCK TABLE statement.

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. Like an exclusive database lock, an exclusive table lock is often used when massive updates are applied during off-peak hours. For example, some applications do not update tables during the hours of peak use. Instead, they write updates to an *update journal*. During off-peak hours, that journal is read, and all updates are applied in a batch.

Page, Row, and Key Locks

One row of a table is the smallest object that can be locked. A program can lock one row or a selection of rows while other programs continue to work on other rows of the same table.

INFORMIX-OnLine Dynamic Server stores data in units called *disk pages*. (Its disk-storage methods are described in detail in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*. Tips for optimizing tables on disk storage can be found in the *INFORMIX-OnLine Dynamic Server Performance Guide*.) 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.

You choose between locking by rows or locking by pages when you create the table. INFORMIX-OnLine Dynamic Server supports a clause, LOCK MODE, to specify either page or row locking. You can specify lock mode in the CREATE TABLE statement and later change it with the ALTER TABLE statement. (Other Informix database servers do not offer the choice; they lock by row or by page, whichever makes the better implementation.)

Page and row locking are used identically. Whenever INFORMIX-OnLine Dynamic Server needs to lock a row, it locks either the row itself or the page it is on, depending on the lock mode established for the table.

In certain cases, the database server has to lock a row that does not exist. In effect, it locks the place in the table where the row would be if it did exist. The database server does this by placing 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.

The 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 will vary. If the database does not use transactions (that is, if no transaction log exists and you do not use 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 are used and on whether transactions are in use.

When transactions are used, 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. This helps 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 had 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 reads various rows are controlled by the current isolation level, which is discussed in the next section.

Setting the Isolation Level

The *isolation level* is the degree to which your program is isolated from the concurrent actions of other programs. INFORMIX-OnLine Dynamic Server offers a choice of isolation levels. It implements them by setting different rules for how a program uses locks when it is reading. (This description does not apply to reads performed on update cursors.)

To set the isolation level, use either the SET ISOLATION or SET TRANSACTION statement. You can set isolation levels only with the INFORMIX-OnLine Dynamic Server database servers. The SET TRANSACTION statement also lets you set access modes in either INFORMIX-OnLine Dynamic Server or INFORMIX-SE. For more information about access modes, see "Controlling Data Modification with Access Modes" on page 7-16.

Comparing SET TRANSACTION with SET ISOLATION

The SET TRANSACTION statement complies with ANSI SQL-92. This statement is similar to the Informix SET ISOLATION statement; however, the SET ISOLATION statement is not ANSI compliant and does not provide access modes.

The isolation levels that you can set with the SET TRANSACTION statement are comparable to the isolation levels that you can set with the SET ISOLATION statement, as the following table shows.

SET TRANSACTION	Correlates to	SET ISOLATION
Read Uncommitted		Dirty Read
Read Committed		Committed Read
Not Supported		Cursor Stability
(ANSI) Repeatable Read		(Informix) Repeatable Read
Serializable		(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 get 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 show both the SET ISOLATION and SET TRANSACTION statements:

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 more than once in an
active transaction.
```

ANSI Read Uncommitted and Informix Dirty Read Isolation

The simplest isolation level, ANSI Read Uncommitted and 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 for what other programs are doing.

A program always receives complete rows of data; even under ANSI Read Uncommitted or Informix Dirty Read isolation, a program never sees a row in which some columns have been updated and some have not. However, a program that uses ANSI Read Uncommitted or 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 processed data that never really existed (number 4 in the list of concurrency issues on page 7-5).

ANSI Read Uncommitted or 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 database is held in an exclusive lock.
- Only one program is using the database.

ANSI Read Committed and Informix Committed Read Isolation

When a program requests the ANSI Read Committed or Informix Committed Read isolation level, INFORMIX-OnLine Dynamic 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 Informix Committed Read is implemented very 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 are updated but not committed have locks on them, this test ensures that the program does not read uncommitted data.

ANSI Read Committed or Informix Committed Read does not actually place a lock on the fetched row, so it is almost as efficient as ANSI Read Uncommitted or Informix Dirty Read. It is appropriate for use when each row of data is processed as an independent unit, without reference to other rows in the same or other tables.

Informix Cursor Stability Isolation

The next level, Cursor Stability, is available only with the Informix SQL statement SET ISOLATION. When Cursor Stability is in effect, the database server 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).

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 this 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 the point. 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 just inserted by Program A.

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. The 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.

Because Cursor Stability locks only one row at a time, it restricts concurrency less than a table lock or database lock does.

ANSI Serializable, ANSI Repeatable Read, and Informix Repeatable Read Isolation

The definitions for ANSI Serializable, ANSI Repeatable Read, and Informix Repeatable Read isolation levels are all the same.

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. (Scroll cursors are described in Chapter 5, "Programming with SQL.") 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-OnLine Dynamic Server system can monitor the lock table and tell you when it is heavily used.

Serializable is automatically used as the isolation level in an ANSI-compliant database. Serializable is required to ensure operations behave in accordance with the ANSI standard for SQL.

Controlling Data Modification with Access Modes

Both INFORMIX-OnLine Dynamic Server and INFORMIX-SE 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 schemas, tables, temporary tables, indexes, or stored procedures
- Grant or revoke privileges
- Update statistics
- Rename columns or tables

Read-only access mode prohibits updates.

You can execute stored procedures in a read-only transaction as long as the procedure does not try to perform any restricted statements.

Setting 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

If you prefer to wait (this choice is best for many applications), execute the following 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. The delays are usually imperceptible.

Not Waiting for Locks

The disadvantage of waiting for locks is that the wait might become very long (although properly designed applications should hold their locks very 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.

Waiting a Limited Time

When you use INFORMIX-OnLine Dynamic Server, you have an additional choice. You can ask the database server to set an upper limit on a wait. You can issue 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.

Handling a Deadlock

A *deadlock* is a situation in which a pair of programs block 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.

INFORMIX-OnLine Dynamic Server detects deadlocks immediately when they involve only 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, INFORMIX-OnLine Dynamic 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 database administrator 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, and if your application is straightforward, have your program execute the following statements when it starts up (immediately after the first 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.

Locking with Other Database Servers

INFORMIX-OnLine Dynamic Server manages its own locking so that it can provide the different kinds of locks and levels of isolation described in the preceding topics. Other Informix database servers implement locks using the facilities of the host operating system and cannot provide the same conveniences.

Some host operating systems provide locking functions as operating-system services. In these systems, database servers support the SET LOCK MODE statement.

Some host operating systems do not provide *kernel-locking* facilities. In these systems, the database server performs its own locking based on small files that it creates in the database directory. These files have the suffix **.lok**.

To determine the kind of system in which your database server is running, execute the SET LOCK MODE statement and test the error code, as shown in the following fragment of INFORMIX-ESQL/C code:

```
#define LOCK_ONLINE 1
#define LOCK_KERNEL 2
#define LOCK_FILES 3
int which_locks()
{
    int locktype;

    locktype = LOCK_FILES;
    EXEC SQL set lock mode to wait 30;
    if (sqlca.sqlcode == 0)
        locktype = LOCK_ONLINE;
    else
    {
        EXEC SQL set lock mode to wait;
        if (sqlca.sqlcode == 0)
            locktype = LOCK_KERNEL;
    }
    /* restore default condition */
    EXEC SQL set lock mode to not wait;
    return(locktype);
}
```

If the database server does not support the SET LOCK MODE statement, your program is effectively always in NOT WAIT mode; that is, whenever it tries to lock a row that is locked by another program, it receives an error code immediately.

Isolation While Reading

Informix database servers other than INFORMIX-OnLine Dynamic Server do not normally place locks when they fetch rows. Nothing exists that is comparable to the shared locks that OnLine uses to implement the Cursor Stability isolation level.

If your program fetches a row with a singleton SELECT statement or through a cursor that is not declared FOR UPDATE, the row is fetched immediately, regardless of whether it is locked or modified by an unfinished transaction.

This design produces the best performance, especially when locks are implemented by writing notes in disk files, but you must be aware that the program can read rows that are modified by uncommitted transactions.

You can obtain the effect of Cursor Stability isolation by declaring a cursor FOR UPDATE, and then using it for input. Whenever the database server fetches a row through an update cursor, it places a lock on the fetched row. (If the row is already locked, the program waits or receives an error, depending on the lock mode.) When the program fetches another row without updating the current one, the lock on the current row is released, and the new row is locked.

To ensure that the fetched row is locked as long as you use it, you can fetch through an update cursor. (The row cannot become *stale*.) You are also assured of fetching only committed data because locks on rows that are updated are held until the end of the transaction. Depending on the host operating system and the database server, you might experience a performance penalty for using an update cursor in this way.

Locking Updated Rows

When a cursor is declared FOR UPDATE, locks are handled as follows. Before a row is fetched, it is locked. If it cannot be locked, the program waits or returns an error.

The next time a fetch is requested, the database server notes whether the current row is modified (using either the UPDATE or DELETE statement with WHERE CURRENT OF) and whether a transaction is in progress. If both these things are true, the lock on the row is retained. Otherwise, the lock is released.

So if you perform updates within a transaction, all updated rows remain locked until the transaction ends. Rows that are not updated are locked only while they are current. Rows updated outside a transaction, or in a database that does not use transaction logging, are also unlocked as soon as another row is fetched.

Hold Cursors

When transaction logging is used, the database server guarantees that anything done within a transaction can be rolled back at the end of it. To do this reliably, the database server normally applies the following rules:

- All cursors are closed by ending a transaction.
- All locks are released by ending a transaction.

These rules are normal with all 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.

```
DECLARE master CURSOR FOR ...
DECLARE detail CURSOR FOR ... FOR UPDATE
OPEN master
LOOP:
    FETCH master INTO ...
    IF (the fetched data is appropriate) THEN
        BEGIN WORK
        OPEN detail USING data read from master
        FETCH detail ...
        UPDATE ... WHERE CURRENT OF detail
        COMMIT WORK
    END IF
END LOOP
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 ones, 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 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.

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.

Section II

Designing and Managing Databases

Chapter

Building Your Data Model

8

The first step in creating a database is to construct a data model: a precise, complete definition of the data to be stored. This chapter contains a cursory overview of one method of doing this. The following chapters describe how to implement a data model once you design it.

To understand the material in this chapter, you should have a basic understanding of SQL and relational database theory.

Why Build a Data Model

You already have some idea regarding the type of data in your database and how that data needs to be organized. This is the beginning of a data model. By using some type of formal notation to build your data model, you can help your design in two ways:

- It makes you think through the data model completely.

  A mental model often contains unexamined assumptions; formalizing the design reveals these points.
- It is easier to communicate your design to other people.

  A formal statement makes the model explicit, so that others can return comments and suggestions in the same form.

Entity-Relationship Data-Model Overview

Different books present different formal methods of modeling data. Most methods force you to be thorough and precise. If you have already learned a method, by all means use it.

This chapter presents a summary of the entity-relationship (E-R) data model, a modeling method taught in training courses presented by Informix. The E-R modeling method uses the following steps:

1. Identify and define the principal data objects (entities, relationships, and attributes).
2. Diagram the data objects using the entity-relationship approach.
3. Translate your entity-relationship data objects into relational constructs.
4. Resolve the logical data model.
5. Normalize the logical data model.

Steps 1 through 5 are discussed in this chapter. Chapter 9, "Implementing Your Data Model," discusses the final step of converting your logical data model to a physical schema.

The end product of data modeling is a fully defined database design encoded in a diagram similar to Figure 8-16 on page 8-27, which shows the final set of tables for a personal telephone directory. The personal telephone directory is an example developed in this chapter. It is used rather than the **stores7** database because it is small enough to be developed completely in one chapter but large enough to show the entire method.

Identifying and Defining Your Principal Data Objects

The first step in building an entity-relationship data model is to identify and define your principal data objects. The principal data objects are entities, relationships, and attributes.

Discovering Entities

An *entity* is a principal data object that is of significant interest to the user. It is usually a person, place, thing, or event to be recorded in the database. If the data model were a language, entities would be its nouns. The **stores7** database contains the following entities: *customer, orders, items, stock, catalog, cust_calls, call_type, manufact,* and *state.*

The first step in modeling is to choose the entities to record. Most of the entities that you choose will become tables in the model.

Choosing Possible Entities

If you have an idea for your database, you can probably list several entities immediately. However, if other people use the database, you should poll them for their understanding of what fundamental *things* the database should contain. Make a preliminary list of all the entities you can identify. Interview the potential users of the database for their opinions about what must be recorded in the database. Determine basic characteristics for each entity, such as "at least one address must be associated with a name." All the decisions you make in determining your entities become your *business rules.* "The Telephone-Directory Example" on page 8-7 provides some of the business rules for the example in this chapter.

Later, when you *normalize* your data model, some of the entities can expand or become other data objects. See "Normalizing Your Data Model" on page 8-31 for additional information.

Pruning Your List of Entities

When the list of entities seems complete, prune it by making sure that each entity has the following qualities:

- It is significant.

  List only entities that are important to the users of the database and worth the trouble and expense of computer tabulation.

- It is generic.

  List only types of things, not individual instances. For instance, *symphony* might be an entity, but *Beethoven's Fifth* would be an entity instance or entity occurrence.

- It is fundamental.

  List only entities that exist independently, without needing something else to explain them. Anything you could call a trait, a feature, or a description is not an entity. For example, a *part number* is a feature of the fundamental entity called *part*. Also, do not list things that you can derive from other entities; for example, avoid any sum, average, or other quantity that you can calculate in a SELECT expression.

- It is unitary.

  Be sure that each entity you name represents a single class. It cannot be broken down into subcategories, each with its own features. In planning the telephone-directory model (see "The Telephone-Directory Example" on page 8-7), the telephone number, an apparently simple entity, turns out to consist of three categories, each with different features.

These choices are neither simple nor automatic. To discover the best choice of entities, you must think deeply about the nature of the data you want to store. Of course, that is exactly the point of making a formal data model. The following section describes this chapter's example in further detail.

The Telephone-Directory Example

Suppose that you create a database that computerizes a personal telephone directory. The database model must record the names, addresses, and telephone numbers of people and organizations that its user deals with for business and pleasure.

The first step is to define the entities, and the first thing you might do is look carefully at a page from a telephone directory to see what entities are there.

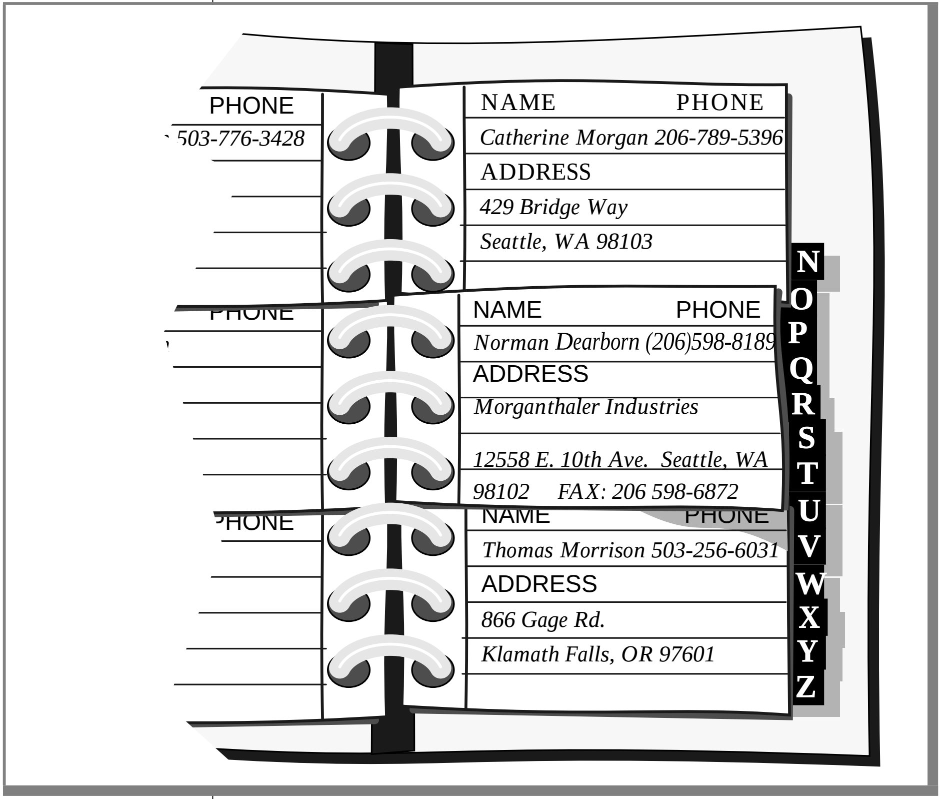


Figure 8-1
Partial Page from a Telephone Directory

The physical form of the existing data can be misleading. Do not let the layout of pages and entries in the telephone directory mislead you into trying to specify an entity that represents one entry in the book—some kind of alphabetized record with fields for name, number, and address. You want to model the data, not the medium.

At first glance, the entities that are recorded in a telephone directory include the following items:

- Names (of persons and organizations)
- Addresses
- Telephone numbers

Do these entities meet the earlier criteria? They are clearly significant to the model and are generic.

Are they fundamental? A good test is to ask if an entity can vary in number independently of any other entity. After you think about it, you realize that a telephone directory sometimes lists people who have no number or current address (people who move or change jobs). A telephone directory also can list both addresses and numbers that are used by more than one person. All three of these entities can vary in number independently; this fact strongly suggests that they are fundamental, not dependent.

Are they unitary? Names can be split into personal names and corporate names. After thinking about it, you decide that all names should have the same features in this model; that is, you do not plan to record different information about a company than you would about a person. Likewise, you decide only one kind of address exists; no need exists to treat home addresses differently from business ones.

However, you also realize that more than one kind of telephone number exists. *Voice* numbers are answered by a person, *fax* numbers connect to a fax machine, and *modem* numbers connect to a computer. You decide that you want to record different information about each kind of number, so these three are different entities.

For the personal telephone-directory example, you decide that you want to keep track of the following entities:

- Name
- Address (mailing)
- Telephone number (voice)
- Telephone number (fax)
- Telephone number (modem)

Diagramming Your Entities

A section in this chapter will teach you how to use the entity-relationship diagrams. For now, create a separate, rectangular box for each entity in the telephone-directory example. You will learn how to put the entities together with relationships in "Diagramming Your Data Objects" on page 8-19.

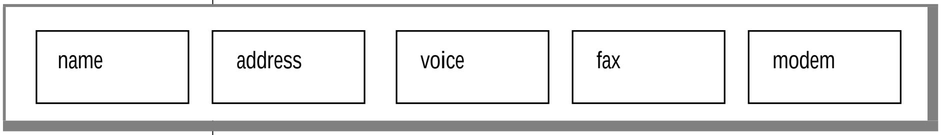


Figure 8-2
Entities in the Personal Telephone-Directory Example

Defining the Relationships

After you choose your entities, you need to consider the relationships between them. Relationships are not always obvious, but all the ones worth recording must be found. The only way to ensure that all the relationships are found is to list all possible relationships exhaustively. Consider every pair of entities *A* and *B* and ask, "What is the relationship between an *A* and a *B*?"

A relationship is an association between two entities. Usually, a verb or preposition that connects two entities implies a relationship. A relationship between entities is described in terms of *connectivity*, *existence dependency*, and *cardinality*.

Connectivity

Connectivity refers to the number of entity instances. An entity instance is a particular occurrence of an entity. The three types of connectivity are one-to-one (written 1:1), one-to-many (written 1:n), and many-to-many (written m:n) as Figure 8-3 shows.

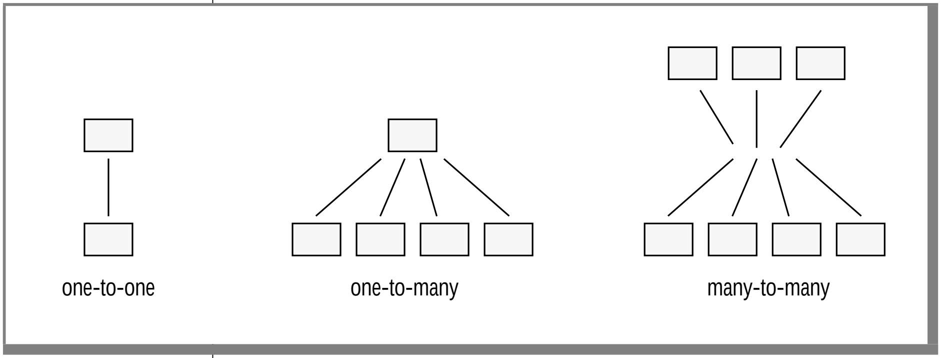


Figure 8-3
Connectivity in Relationships

For example, in the telephone-directory example, an address can be associated with more than one name. The connectivity for the relationship between the name and address entities is one-to-many (1:n).

Existence Dependency

Existence dependency describes whether an entity in a relationship is optional or mandatory. Analyze your business rules to identify whether an entity must exist in a relationship. For example, your business rules might dictate that an address must be associated with a name. Such an association makes the existence dependency for the relationship between the name and address entities mandatory. An example of an optional existence dependency could be a business rule that says a person might or might not have children.

Cardinality

Cardinality places a constraint on the number of times an entity can appear in a relationship. The cardinality of a 1:1 relationship is always one. But the cardinality of a 1:n relationship is open; *n* could be any number. If you need to place an upper limit on *n*, you do it by specifying a cardinality for the relationship. For example, in a store sale example, you could limit the number of sale items that a customer can purchase at one time. You usually place cardinality constraints through your application program or through stored procedures.

For additional information about cardinality, see any entity-relationship data-modeling text. See the "Summary" on page 8-36 for references to two data-modeling books.

Discovering the Relationships

A compact way to discover the relationships is to prepare a matrix that names all the entities on the rows and again on the columns. The matrix in Figure 8-4 reflects the entities for the personal telephone directory.

	name	address	number (voice)	number (fax)	number (modem)
name					
address	▨				
number (voice)	▨	▨			
number (fax)	▨	▨	▨		
number (modem)	▨	▨	▨	▨	

Figure 8-4
A Matrix That Reflects the Entities for a Personal Telephone Directory

You can ignore the lower triangle of the matrix, which is shaded. You must consider the diagonal cells; that is, you must ask the question "What is the relationship between an *A* and another *A*?" In this model, the answer is always none. No relationship exists between a name and a name or an address and another address, at least none that is worth recording in this model. When a relationship exists between an *A* and another *A*, you have found a recursive relationship. (See "Resolving Other Special Relationships" on page 8-30.)

For all cells for which the answer is clearly none, write `none` in the matrix. Figure 8-5 shows the current matrix.

Figure 8-5
A Matrix with Initial Relationships Included

	name	address	number (voice)	number (fax)	number (modem)
name	none				
address	▨	none			
number (voice)	▨	▨	none		
number (fax)	▨	▨	▨	none	
number (modem)	▨	▨	▨	▨	none

Although no entities relate to themselves in this model, this is not always true in other models. A typical example is an employee who is the manager of another employee. Another example occurs in manufacturing, when a part entity is a component of another part.

In the remaining cells, you write the connectivity relationship that exists between the entity on the row and the entity on the column. The following kinds of relationships are possible:

- *One-to-one* (1:1), in which never more than one entity *A* exists for one entity *B* and never more than one *B* for one *A*.
- *One-to-many* (1:n), in which more than one entity *A* never exists, but several entities *B* can be related to *A* (or vice versa).
- *Many-to-many* (m:n), in which several entities *A* can be related to one *B* and several entities *B* can be related to one *A*.

One-to-many relationships are the most common. The telephone-directory model examples shows one-to-many and many-to-many relationships.

As Figure 8-5 shows, the first unfilled cell represents the relationship between names and addresses. What connectivity lies between these entities? You might ask yourself, "How many names can be associated with an address?" You decide that a name can have *zero* or *one* address but no more than one. You write `0-1` opposite **name** and below **address**, as Figure 8-6 shows.

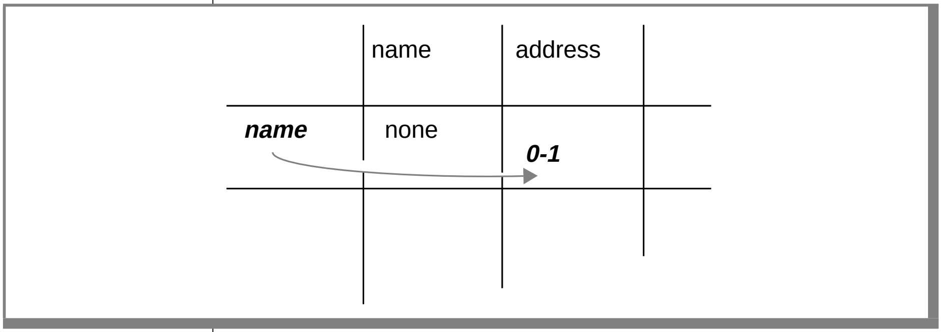


Figure 8-6
Relationship Between Name and Address

Ask yourself how many addresses can be associated with a name. You decide that an address can be associated with more than one name. For example, you can know several people at one company or more than two people who live at the same address.

Can an address be associated with *zero* names? That is, should it be possible for an address to exist when no names use it? You decide that yes, it can. Below **address** and opposite **name**, you write `0-n`, as Figure 8-7 shows.

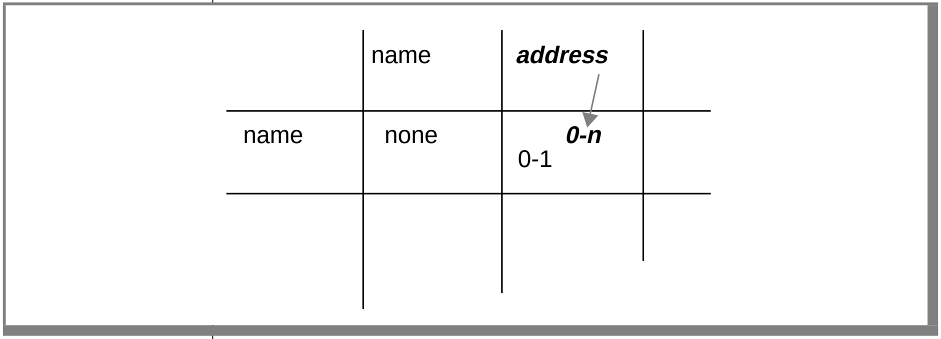


Figure 8-7
Relationship Between Address and Name

If you decide that an address cannot exist unless it is associated with at least one name, you write `1-n` instead of `0-n`.

When the cardinality of a relationship is limited on either side to `1`, it is a 1:n relationship. In this case, the relationship between names and addresses is a 1:n relationship.

Now consider the next cell, the relationship between a name and a voice number. How many voice numbers can a name be associated with, one or more than one? Glancing at your telephone directory, you see that you have often noted more than one telephone number for a person. For a busy salesperson you have a home number, an office number, a paging number, and a car phone number. But you might also have names without associated numbers. You write `0-n` opposite **name** and below **number (voice)**, as Figure 8-8 shows.

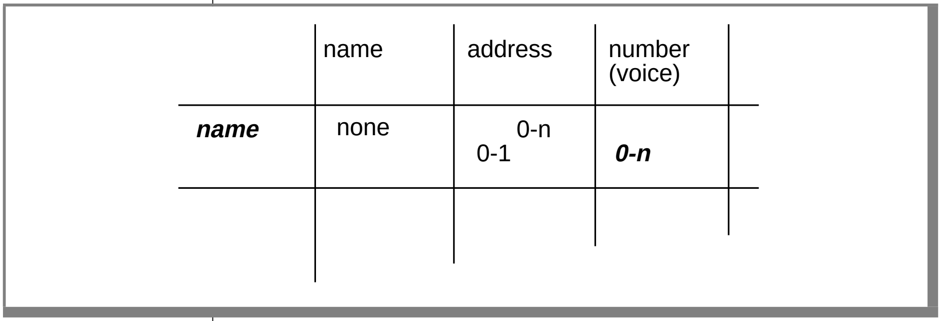


Figure 8-8
Relationship Between Name and Number

What is the other side of this relationship? How many names can be associated with a voice number? You decide that only one name can be associated with a voice number. Can a number be associated with zero names? No, you decide there is no point to recording a number unless someone uses it. You write 1 under **number (voice)** and opposite **name**, as Figure 8-9 shows.

	name	address	***number (voice)***	
name	none	0-n 0-1	***1*** 0-n	

Figure 8-9
Relationship Between Number and Name

Fill out the rest of the matrix in the same fashion, using the following decisions:

- A name can be associated with more than one fax number; for example, a company can have several fax machines. Going the other way, a fax number can be associated with more than one name; for example, several people can use the same fax number.
- A modem number must be associated with exactly one name. (This is an arbitrary decree to complicate the example; pretend it is a requirement of the design.) However, a name can have more than one associated modem number; for example, a company computer can have several dial-up lines.
- Although some relationship exists between a voice number and an address, a modem number and an address, and a fax number and an address in the real world, none needs to be recorded in this model. An indirect relationship already exists through *name*.

Figure 8-10 shows a completed matrix.

	name	address	number (voice)	number (fax)	number (modem)
name	none	0-n 0-1	1 0-n	1-n 0-n	1 0-n
address	▨	none	none	none	none
number (voice)	▨	▨	none	none	none
number (fax)	▨	▨	▨	none	none
number (modem)	▨	▨	▨	▨	none

Figure 8-10
A Completed Matrix for a Telephone Directory

Other decisions reflected in the matrix are that no relationship exists between a fax number and a modem number, between a voice number and a fax number, or between a voice number and a modem number.

You might disagree with some of these decisions (for example, that a relationship between voice numbers and modem numbers is not supported). For the sake of this example, these are our business rules.

Diagramming Your Relationships

For now, save the matrix that you created in this section. You will learn how to create an entity-relationship diagram in "Diagramming Your Data Objects" on page 8-19.

Identifying Attributes

Entities contain *attributes*, which are characteristics or modifiers, qualities, amounts, or features. An attribute is a fact or nondecomposable piece of information about an entity. Later, when you represent an entity as a table, its attributes are added to the model as new columns.

Before you can identify your attributes, you must identify your entities. After you determine your entities, ask yourself, "What characteristics do I need to know about each entity?" For example, in an *address* entity, you probably need information about *street*, *city*, and *zipcode*. Each of these characteristics of the *address* entity becomes an attribute.

Selecting Attributes for Your Entities

In selecting attributes, choose ones that have the following qualities:

- They are significant.

  Include only attributes that are useful to the database users.

- They are direct, not derived.

  An attribute that can be derived from existing attributes (for instance, through an expression in a SELECT statement) should not be made part of the model. The presence of derived data greatly complicates the maintenance of a database.

  At a later stage of the design, you can consider adding derived attributes to improve performance, but at this stage you should exclude them. Performance improvements are discussed in the *INFORMIX-OnLine Dynamic Server Performance Guide*.

- They are nondecomposable.

  An attribute can contain only single values, never lists or repeating groups. Composite values must be broken into separate attributes.

- They contain data of the same type.

  For example, you would want to enter only date values in a birthday attribute, not names or telephone numbers.

The rules for defining attributes are the same as those for defining columns. For more information about defining columns, see "Placing Constraints on Columns" on page 8-24.

The following attributes are added to the telephone-directory example to produce the diagram shown in Figure 8-15 on page 8-21:

- Street, city, state, and zip code are added to the *address* entity.
- Birth date is added to the *name* entity. Also added to the *name* entity are e-mail address, anniversary date, and children's first names.
- Type is added to the *voice* entity to distinguish car phones, home phones, and office phones. A voice number can be associated with only one voice type.
- The hours that a fax machine is attended are added to the *fax* entity.
- Whether a modem supports 9,600-, 14,400-, or 28,800-baud rates is added to the *modem* entity.

Listing Your Attributes

For now, simply list the attributes for the telephone-directory example with the entities with which you think they belong. Your list should look something like Figure 8-11.

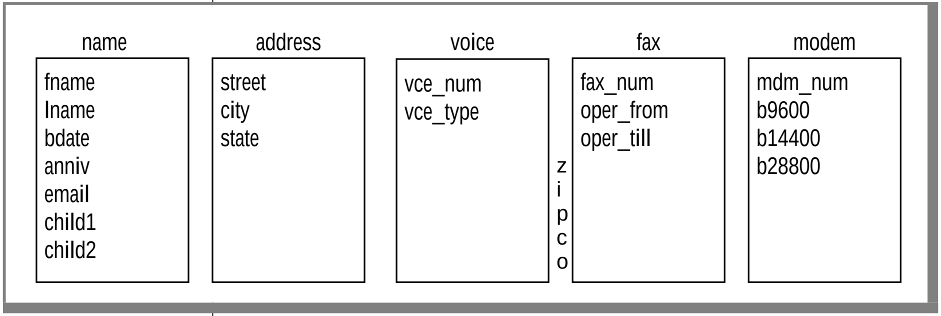


Figure 8-11
Attributes for the Telephone-Directory Example

About Entity Occurrences

An additional data object that you need to know about is the entity occurrence. Each row in a table represents a specific, single occurrence of the entity. For example, if *customer* is an entity, a **customer** table represents the idea of customer; in it, each row represents one specific customer, such as Sue Smith. Keep in mind that entities will become tables, attributes will become columns, and rows will become entity occurrences.

Diagramming Your Data Objects

At this point, you have already discovered and understood the entities and relationships in your database. That is the most important part of the relational database design process. Once you have determined the entities and relationships, you might find it helpful to have a method for displaying your thought process during database design.

Most data-modeling methods provide some form of graphically displaying your entities and relationships. Informix uses the E-R diagram approach originally developed by C. R. Bachman. E-R diagrams serve the following purposes:

- They model the information needs of an organization.
- They identify entities and their relationships.
- They provide a starting point for data definition (data-flow diagrams).
- They provide an excellent source of documentation for application developers as well as database and system administrators.
- They create a logical design of the database that can be translated into a physical schema.

Several different styles of documenting E-R, diagrams exist. If you already have a style that you prefer, use it. Figure 8-12 shows a sample E-R diagram.

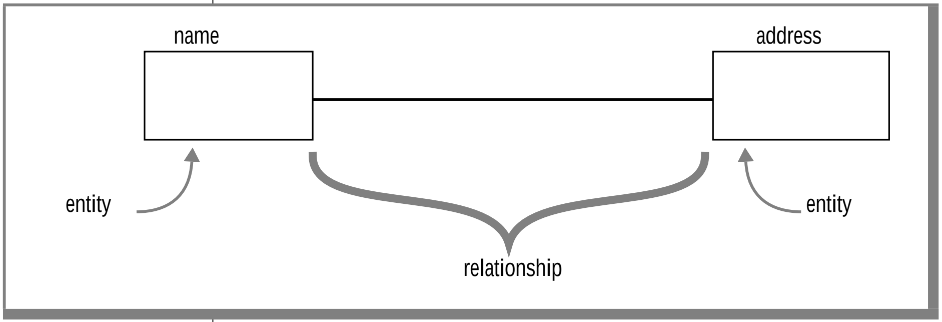


Figure 8-12
Symbols of an Entity-Relationship Diagram

Entities are represented by a box. Relationships are represented by a line that connects the entities. In addition, you use several graphical items to display the following features of relationships, as Figure 8-13 shows:

- A circle across a relationship link indicates *optionality* in the relationship (zero instances can occur).
- A small bar across a relationship link indicates that *exactly one* instance of the entity is associated with another entity (consider the bar to be a "1").
- The "crow's feet" represent *many* in your relationship.

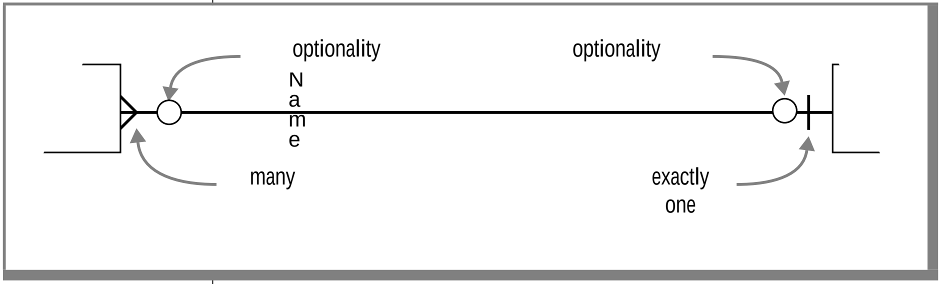


Figure 8-13
The Parts of a Relationship in an Entity-Relationship Diagram

Reading Entity-Relationship Diagrams

You read the diagrams first from left to right and then from right to left. In the case of the *name-address* relationship in Figure 8-14, you read the relationships as follows. Names can be associated with zero or exactly one address; addresses can be associated with zero, one, or many names.

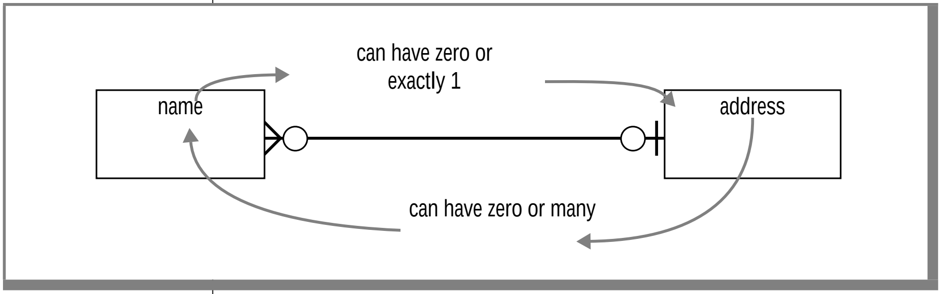


Figure 8-14
Reading an Entity-Relationship Diagram

The Telephone-Directory Example

Figure 8-15 shows the telephone-directory example and includes the entities, relationships, and attributes. This diagram includes the relationships that were established with the matrix. After you study the diagram symbols, compare the E-R diagram in Figure 8-15 with the matrix in Figure 8-10 on page 8-16. Verify for yourself that the relationships are the same in both figures.

A matrix such as Figure 8-10 on page 8-16 is a useful tool when you are first designing your model because, in filling it out, you are forced to think of every possible relationship. However, the same relationships appear in a diagram such as Figure 8-15, and this type of diagram might be easier to read when you are reviewing an existing model.

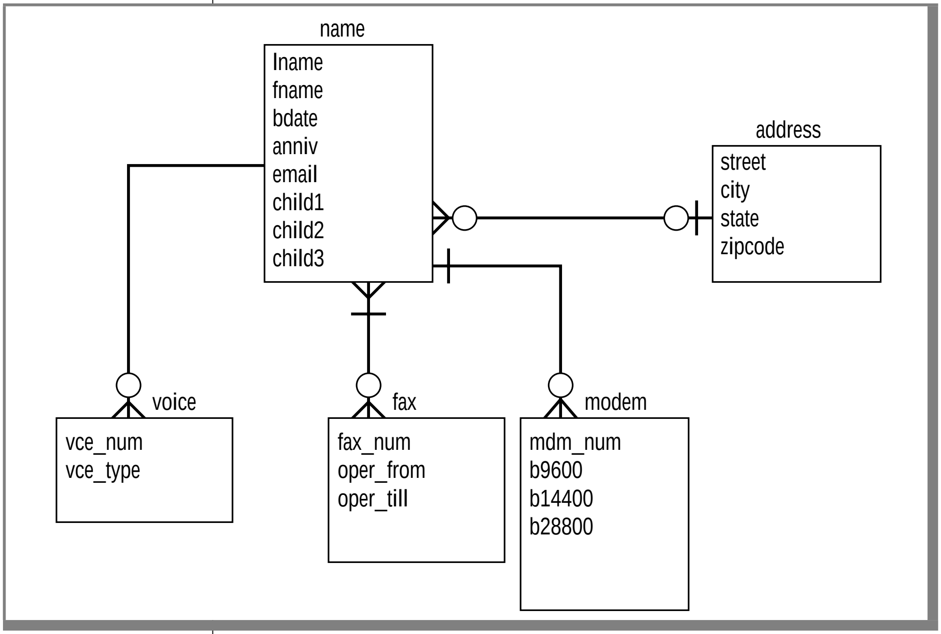


Figure 8-15
Preliminary Entity-Relationship Diagram of the Telephone-Directory Example

After the Diagram Is Complete

The rest of the chapter describes the following tasks:

- How to translate the entities, relationships, and attributes into relational constructs
- How to resolve the E-R data model
- How to normalize the E-R data model

Chapter 9, “Implementing Your Data Model,” shows you how to create a database from the E-R data model.

Translating E-R Data Objects into Relational Constructs

All the data objects you have learned about so far, entities, relationships, attributes, and entity occurrences, will be translated into SQL tables, joins between tables, columns, and rows. The tables, columns, and rows of your database must fit the rules found in “Rules for Defining Tables, Rows, and Columns.”

Your data objects should fit these rules before you normalize your data objects. To normalize your data objects, analyze the dependencies between your entities, relationships, and attributes. Normalization is discussed in “Normalizing Your Data Model” on page 8-31.

After you normalize the data model, you can use SQL statements to create a database that is based on your data model. Chapter 9, “Implementing Your Data Model,” describes how to create your database and provides the database schema for the telephone-directory example.

Each entity that you choose is represented as a table in the model. The table stands for the entity as an abstract concept, and each row represents a specific, individual *occurrence* of the entity. In addition, each attribute of an entity is represented by a column in the table.

The following ideas are fundamental to most relational data-model methods, including the E-R data model. By following these rules while you design your data model, you will save time and effort when you normalize your model.

Rules for Defining Tables, Rows, and Columns

You are already familiar with the idea of a *table* that is composed of *rows* and *columns*. But you must respect the following rules when you define the tables of a formal data model:

- Rows must stand alone.

  Each row of a table is independent and does not depend on any other row of the *same* table. As a consequence, the order of the rows in a table is not significant in the model. The model should still be correct even if all the rows of a table are shuffled into random order.

  After the database is implemented, you can tell the database server to store rows in a certain order for the sake of efficiency, but that order does not affect the model.

- Rows must be unique.

  In every row, some column must contain a unique value. If no single column has this property, the values of some group of columns taken as a whole must be different in every row.

- Columns must stand alone.

  The order of columns within a table has no meaning in the model. The model should still be correct even if the columns are rearranged.

  After the database is implemented, programs and stored queries that use an asterisk to mean *all columns* are dependent on the final order of columns, but that order does not affect the model.

- Column values must be unitary.

  A column can contain only single values, never lists or repeating groups. Composite values must be broken into separate columns. For example, if you decide to treat a person’s first and last names as separate values, as the examples in this chapter show, the names must be in separate columns, not in a single **name** column.

- Each column must have a unique name.

  Two columns within the same table cannot share the same name. However, you can have columns that contain similar information. For example, the name table in the telephone-directory example contains columns for children's names. You can name each column, *child1*, *child2*, and so on.
- Each column must contain data of a single type.

  A column must contain information of the same data type. For example, a column that is identified as an integer must contain only numeric information, not characters from a name.

If your previous experience is only with data organized as arrays or sequential files, these rules might seem unnatural. However, relational database theory shows that you can represent all types of data using only tables, rows, and columns that follow these rules. With a little practice, these rules become automatic.

Placing Constraints on Columns

When you define your table and columns with the CREATE TABLE statement, you constrain each column. These constraints specify whether you want the column to contain characters or numbers, the form that you want dates to use, and other constraints. A *domain* describes the constraints when it identifies the set of valid values that attributes can assume. The domain characteristics of a column can consist of the following items:

- Data type (INTEGER, CHAR, DATE, and so on)
- Format (for example, yy / mm / dd)
- Range (for example, 1,000 to 5,400)
- Meaning (for example, personnel number)
- Allowable values (for example, only grades S or U)
- Uniqueness
- Null support
- Default value
- Referential constraints

You define the domain characteristics when you create your tables. Defining domains and creating your tables and database are discussed in Chapter 9, "Implementing Your Data Model."

Determining Keys for Tables

The columns of a table are either *key* columns or *descriptor* columns. A key column is one that uniquely identifies a particular row in the table. For example, a social-security number is unique for each employee. A descriptor column specifies the nonunique characteristics of a particular row in the table. For example, two employees can have the same first name, Sue. The first name Sue is a nonunique characteristic of an employee. The main types of keys in a table are primary keys and foreign keys.

You designate primary and foreign keys when you create your tables. Primary and foreign keys are used to relate tables physically. Your next task is to specify a primary key for each table. That is, you must identify some quantifiable characteristic of the table that distinguishes each row from every other row.

Primary Keys

The *primary key* of a table is the column whose values are different in every row. Because they are different, they make each row unique. If no one such column exists, the primary key is a *composite* of two or more columns whose values, taken together, are different in every row.

Every table in the model must have a primary key. This rule follows automatically from the rule that all rows must be unique. If necessary, the primary key is composed of all the columns taken together.

The primary key should be a numeric data type (INT or SMALLINT), SERIAL data type, or a short character string (as used for codes). Informix recommends that you avoid using long character strings as primary keys.

Null values are never allowed in a primary-key column. Null values are not comparable; that is, they cannot be said to be alike or different. Hence, they cannot make a row unique from other rows. If a column permits null values, it cannot be part of a primary key.

Some entities have ready-made primary keys such as catalog codes or identity numbers, which are defined outside the model. These are user-assigned keys.

Sometimes more than one column or group of columns can be used as the primary key. All columns or groups that qualify to be primary keys are called *candidate keys*. All candidate keys are worth noting because their property of uniqueness makes them predictable in a SELECT operation. When you select the column of a candidate key, you know the result does not contain any duplicate rows, therefore, the result of a SELECT operation can be a table in its own right, with the selected candidate key as its primary key.

Composite Keys

Some entities lack features that are reliably unique. Different people can have identical names; different books can have identical titles. You can usually find a composite of attributes that work as a primary key. For example, people rarely have identical names and identical addresses, and different books rarely have identical titles, authors, and publication dates.

System-Assigned Keys

A system-assigned primary key is usually preferable to a composite key. A system-assigned key is a number or code that is attached to each instance of an entity when the entity is first entered into the database. The easiest system-assigned keys to implement are serial numbers because the database server can generate them automatically. Informix offers the SERIAL data type for serial numbers. However, the people who use the database might not like a plain numeric code. Other codes can be based on actual data; for example, an employee identification code could be based on a person's initials combined with the digits of the date that they were hired. In the telephone-directory example, a system-assigned primary key is used for the **name** table.

Foreign Keys (Join Columns)

A *foreign key* is simply a column or group of columns in one table that contains values that match the *primary key* in another table. Foreign keys are used to join tables; in fact, most of the *join columns* referred to earlier in this book are foreign-key columns. Figure 8-16 shows the primary and foreign keys of the **customer** and **order** tables from the **stores7** database.

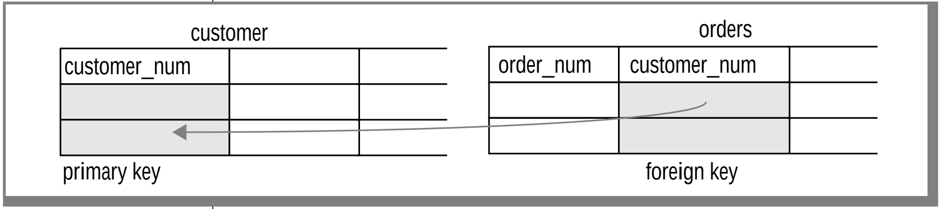


Figure 8-16
Primary and Foreign Keys in the Customer-Order Relationships

Foreign keys are noted wherever they appear in the model because their presence can restrict your ability to delete rows from tables. Before you can delete a row safely, either you must delete all rows that refer to it through foreign keys, or you must define the relationship using special syntax that allows you to delete rows from primary-key and foreign-key columns with a single delete command. The database server disallows deletes that violate referential integrity.

You can always preserve referential integrity by deleting all foreign-key rows before you delete the primary key to which they refer. If you are imposing referential constraints on your database, the database server does not permit you to delete primary keys with matching foreign keys. It also does not permit you to add a foreign-key value that does not reference an existing primary-key value. Referential integrity is discussed in Chapter 4, "Modifying Data."

Adding Keys to the Telephone-Directory Diagram

The initial choices of primary and foreign keys are as Figure 8-17 below shows. This diagram reflects some important decisions.

For the **name** table, the primary key **rec_num** is chosen. Note that the data type for **rec_num** is SERIAL. The values for **rec_num** are system generated. If you look at the other columns (or attributes) in the **name** table, you see that the data types that are associated with the columns are mostly character-based. None of these columns alone is a good candidate for a primary key. If you combine elements of the table into a composite key, you create an exceedingly cumbersome key. The SERIAL data type gives you a key that you can also use to join other tables to the **name** table.

For the **voice**, **fax**, and **modem** tables, the telephone numbers are shown as primary keys. These tables are joined to the **name** table through the **rec_num** key.

The **address** table also uses a system-generated primary key, **id_num**. The **address** table must have a primary key because the business rules state that an address can exist when no names use it. If the business rules prevent an address from existing unless a name is associated with it, then the **address** table could be joined to the **name** table with the foreign key **rec_num** only.

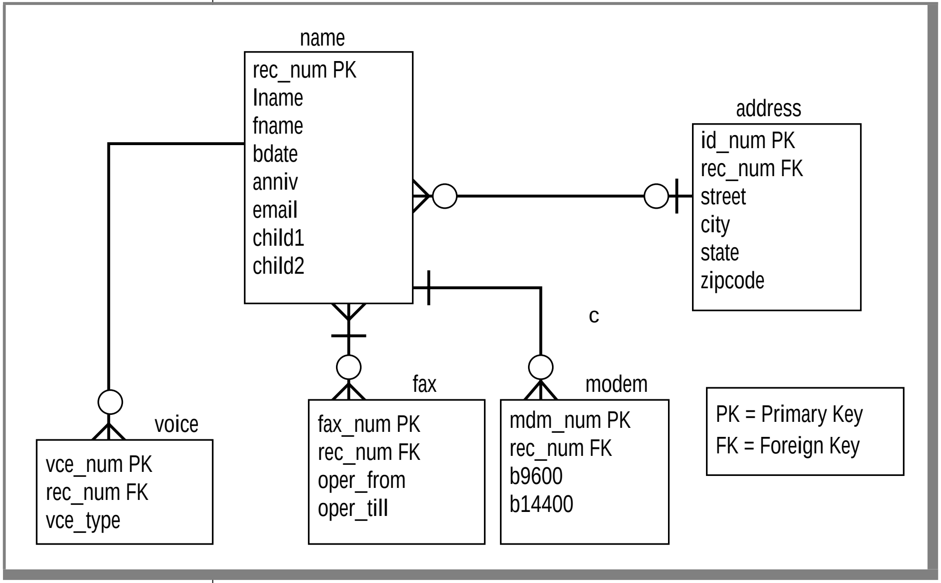


Figure 8-17
Telephone-Directory Diagram with Primary and Foreign Keys Added

Resolving Your Relationships

The aim of a good data model is to create a structure that provides the database server with quick access. To further refine the telephone-directory data model, you can resolve the relationships and normalize the data model. This section addresses the hows and whys of resolving your relationships. Normalizing your data model is discussed in "Normalizing Your Data Model" on page 8-31.

Resolving m:n Relationships

Many-to-many (m:n) relationships add complexity and confusion to your model and to the application development process. The key to resolving m:n relationships is to separate the two entities and create two one-to-many (1:n) relationships between them with a third *intersect* entity. The intersect entity usually contains attributes from both connecting entities.

To resolve a m:n relationship, analyze your business rules again. Have you accurately diagrammed the relationship? In the telephone-directory example, we have a m:n relationship between the *name* and *fax* entities as Figure 8-17 on page 8-28 shows. To resolve the relationship between *name* and *fax*, we carefully reviewed the business rules. The business rules say: "One person can have zero, one, or many fax numbers; *a fax number can be for several people*." Based on what we selected earlier as our primary key for the *voice* entity, a m:n relationship exists.

A problem exists in the *fax* entity because the telephone number, which is designated as the primary key, can appear more than one time in the *fax* entity; this violates the qualification of a primary key. Remember, the primary key must be unique.

To resolve this m:n relationship, you can add an intersect entity between *name* and *fax* entities. The new intersect entity, *faxname*, contains two attributes, **fax_num** and **rec_num**. The primary key for the entity is a composite of both attributes. Individually, each attribute is a foreign key that references the table from which it came. The relationship between the **name** and **faxname** tables is 1:n because one name can be associated with many fax numbers; in the other direction, each **faxname** combination can be associated with one **rec_num**. The relationship between the **fax** and **faxname** tables is 1:n because each number can be associated with many **faxname** combinations.

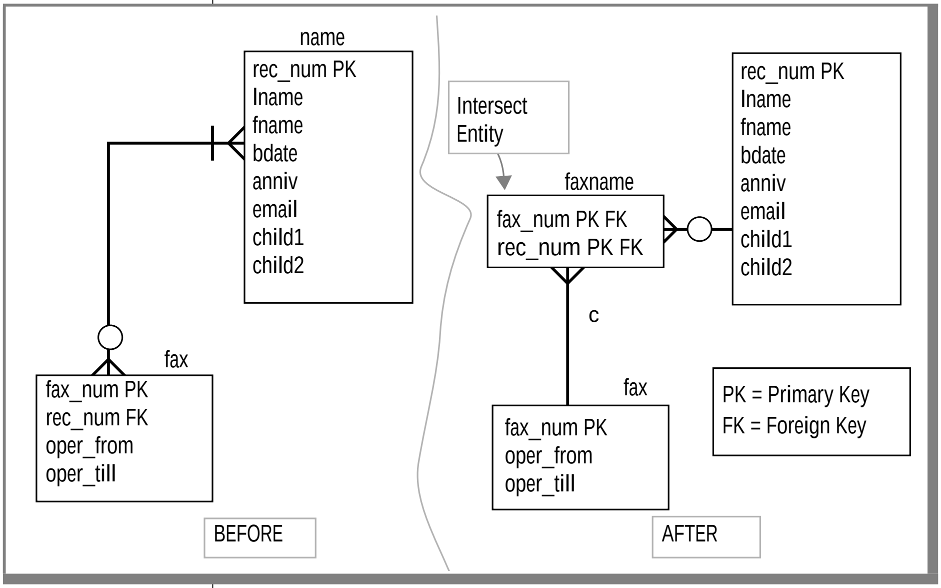


Figure 8-18
Resolving a Many-to-Many (m:n) Relationship

Resolving Other Special Relationships

You might encounter other special relationships that can hamper a smooth-running database. The following list shows these relationships:

- Complex relationships
- Recursive relationships
- Redundant relationships

A *complex* relationship is an association among three or more entities. All the entities must be present for the relationship to exist. To reduce this complexity, reclassify all complex relationships as an entity, related through binary relationships to each of the original entities.

A *recursive* relationship is an association between occurrences of the same entity type. These types of relationships do not occur often. Examples of recursive relationships are bill-of-materials (parts are composed of subparts) and organizational structures (employee manages other employees). See Chapter 5, "Programming with SQL," for an extended example of a recursive relationship. You might choose not to resolve recursive relationships.

A *redundant* relationship exists when two or more relationships are used to represent the same concept. Redundant relationships add complexity to the data model and lead a developer to place attributes in the model incorrectly. Redundant relationships might appear as duplicated entries in your entity-relationship diagram. For example, you might have two entities that contain the same attributes. To resolve a redundant relationship, review your data model. Do you have more than one entity that contains the same attributes? You might need to add an entity to the model to resolve the redundancy. The *INFORMIX-OnLine Dynamic Server Performance Guide* discusses additional topics that are related to redundancy in a data model.

Normalizing Your Data Model

The telephone-directory example in this chapter appears to be a good model. You could implement it at this point into a database, but this example might present problems later on with application development and data-manipulation operations. *Normalization* is a formal approach to applying a set of rules used in associating attributes with entities.

Normalizing your data model can do the following things:

- Produce greater flexibility in your design
- Ensure that attributes are placed in the proper tables
- Reduce data redundancy
- Increase programmer effectiveness
- Lower application maintenance costs
- Maximize stability of the data structure

Normalization consists of several steps to reduce the entities to more desirable physical properties. These steps are called normalization rules, also referred to as *normal forms*. Several normal forms exist; this chapter discusses the first three normal forms. Each normal form constrains the data to be more organized than the last form. Because of this, you must achieve first normal form before you can achieve second normal form, and you must achieve second normal form before you can achieve third normal form.

First Normal Form

An entity is in first normal form if it contains no repeating groups. In relational terms, a table is in first normal form if it contains no repeating columns. Repeating columns make your data less flexible, waste disk space, and make it more difficult to search for data. In the telephone-directory example, it appears that the **name** table contains repeating columns, *child1*, *child2*, and *child3*, as Figure 8-19 shows.

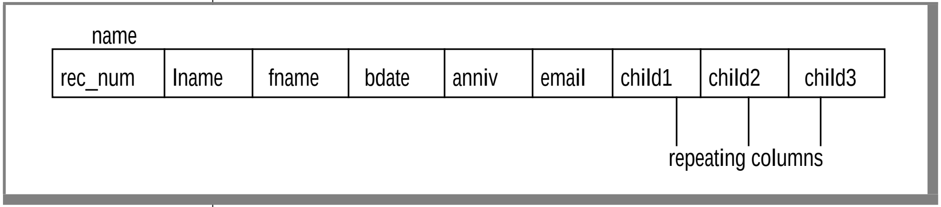


Figure 8-19
Name Entity Before Normalization

You can see some problems in the current table. The table always reserves space on the disk for three child records, whether the person has children or not. The maximum number of children that you can record is three, but some of your acquaintances might have four or more children. To look for a particular child, you would have to search all three columns in every row.

To eliminate the repeating columns and bring the table to first normal form, separate the table into two tables as Figure 8-20 shows. Put the repeating columns into one of the tables. The association between the two tables is established with a primary-key and foreign-key combination. Because a child cannot exist without an association in the **name** table, you can reference the **name** table with a foreign key, **rec_num**.

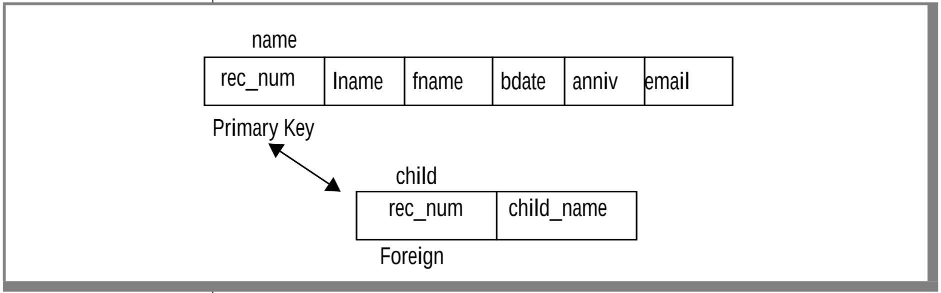


Figure 8-20
First Normal Form Reached for Name Entity

Now check Figure 8-17 on page 8-28 for groups that are not in first normal form. The *name-modem* relationship is not at the first normal form because the columns **b9600**, **b14400**, and **b28800** are considered repeating columns. Add a new attribute called **b_type** to the *modem* table to contain occurrences of **b9600**, **b14400**, and **b28800**. Figure 8-21 shows the data model normalized through first normal form.

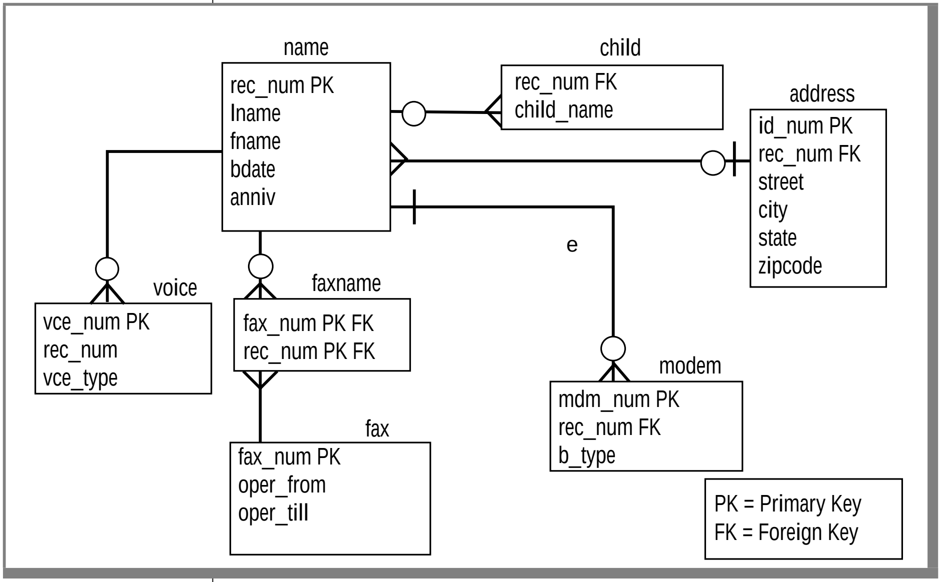


Figure 8-21
The Data Model of a Personal Telephone Directory

Second Normal Form

An entity is in the second normal form if it is in the first normal form, and all its attributes depend on the whole (primary) key. In relational terms, every column in a table must be *functionally dependent* on the whole primary key of that table. Functional dependency indicates that a link exists between the values in two different columns.

If the value of an attribute *depends on* a column, the value of the attribute must change if the value in the column changes. The attribute is a function of the column. The following explanations make this more specific:

- If the table has a one-column primary key, the attribute must depend on that key.
- If the table has a composite primary key, the attribute must depend on the values in all its columns taken as a whole, not on one or some of them.
- If the attribute also depends on other columns, they must be columns of a candidate key; that is, columns that are unique in every row.

If you do not convert your model to the second normal form, you risk data redundancy and difficulty in changing data. To convert first-normal-form tables to second-normal-form tables, remove columns that are not dependent on the primary key.

Third Normal Form

An entity is in the third normal form if it is in the second normal form, and all its attributes are not transitively dependent on the primary key. *Transitive dependence* means that descriptor key attributes depend not only on the whole primary key but also on other descriptor key attributes that, in turn, depend on the primary key. In SQL terms, the third normal form means that no column within a table is dependent on a descriptor column that, in turn, depends on the primary key.

To convert to the third normal form, remove attributes that depend on other descriptor key attributes.

Summary of Normalization Rules

The following normal forms are discussed in this section:

- First normal form: A table is in the first normal form if it contains no repeating columns.
- Second normal form: A table is in the second normal form if it is in the first normal form and contains only columns that are dependent on the whole (primary) key.
- Third normal form: A table is in the third normal form if it is in the second normal form and contains only columns that are nontransitively dependent on the primary key.

When you follow these rules, the tables of the model are in the third normal form, according to E. F. Codd, the inventor of relational databases. When tables are not in the third normal form, either redundant data exists in the model, or problems exist when you attempt to update the tables.

If you cannot find a place for an attribute that observes these rules, you have probably made one of the following errors:

- The attribute is not well defined.
- The attribute is derived, not direct.
- The attribute is really an entity or a relationship.
- Some entity or relationship is missing from the model.

Summary

This chapter summarized and illustrated the following steps of E-R data modeling:

1. *Identify and define* your principal data objects, including the following options:
   - Entities
   - Relationships
   - Attributes
2. *Diagram* your data objects using the E-R diagram approach.
3. *Translate* your E-R data objects into relational constructs.
   - Determine the primary and foreign keys for each entity.
4. *Resolve* your relationships, particularly the following relationships:
   - 1:1 relationships
   - m:n relationships
   - Other special relationships
5. *Normalize* your data model in one of the following forms:
   - First normal form
   - Second normal form
   - Third normal form

When the process is done right, you must examine every aspect of the data not once, but several times.

If you are interested in learning more about database design, you can attend the Informix course, *Relational Database Design*. This thorough course teaches you how to create an E-R data model.

If you are interested in pursuing more about database design on your own, Informix recommends the following excellent books:

- *Database Modeling and Design, The Entity-Relationship Approach* by Toby J. Teorey (Morgan Kauffman Publishers, Inc., 1990)
- *Handbook of Relational Database Design* by Candace C. Fleming and Barbara von Halle (Addison-Wesley Publishing Company, 1989)

Chapter

Implementing Your Data Model

9

Once a data model is prepared, it must be implemented as a database and tables. This chapter covers the decisions that you must make to implement the model.

The first step in implementation is to complete the data model by defining a domain, or set of data values, for every column. The second step is to implement the model using SQL statements.

The first section of this chapter covers defining domains in detail. The second section shows how you create the database (using the CREATE DATABASE and CREATE TABLE statements) and populate it with data.

Defining the Domains

To complete the data model described in Chapter 8, "Building Your Data Model," you must define a domain for each column. The domain of a column describes the constraints on and identifies the set of valid values that attributes (or columns) can assume.

The purpose of a domain is to guard the *semantic integrity* of the data in the model; that is, to ensure that it reflects reality in a sensible way. The integrity of the data model is at risk if you can substitute a name for a telephone number or if you can enter a fraction where only integers are allowed.

To define a domain, first define the *constraints* that a data value must satisfy before it can be part of the domain. Use the following constraints to specify a column domain:

- Data types
- Default values
- Check constraints

You can identify the primary and foreign keys in each table to place referential constraints on columns. Chapter 8, "Building Your Data Model," discusses how these keys are identified.

Data Types

The first constraint on any column is the one that is implicit in the data type for the column. When you choose a data type, you constrain the column so that it contains only values that can be represented by that type.

Each data type represents certain kinds of information and not others. The correct data type for a column is the one that represents all the data values that are proper for that column but as few as possible of the values that are not proper for it.

Choosing a Data Type

Every column in a table must have a data type that is chosen from the types that the database server supports. The choice of data type is important for the following reasons:

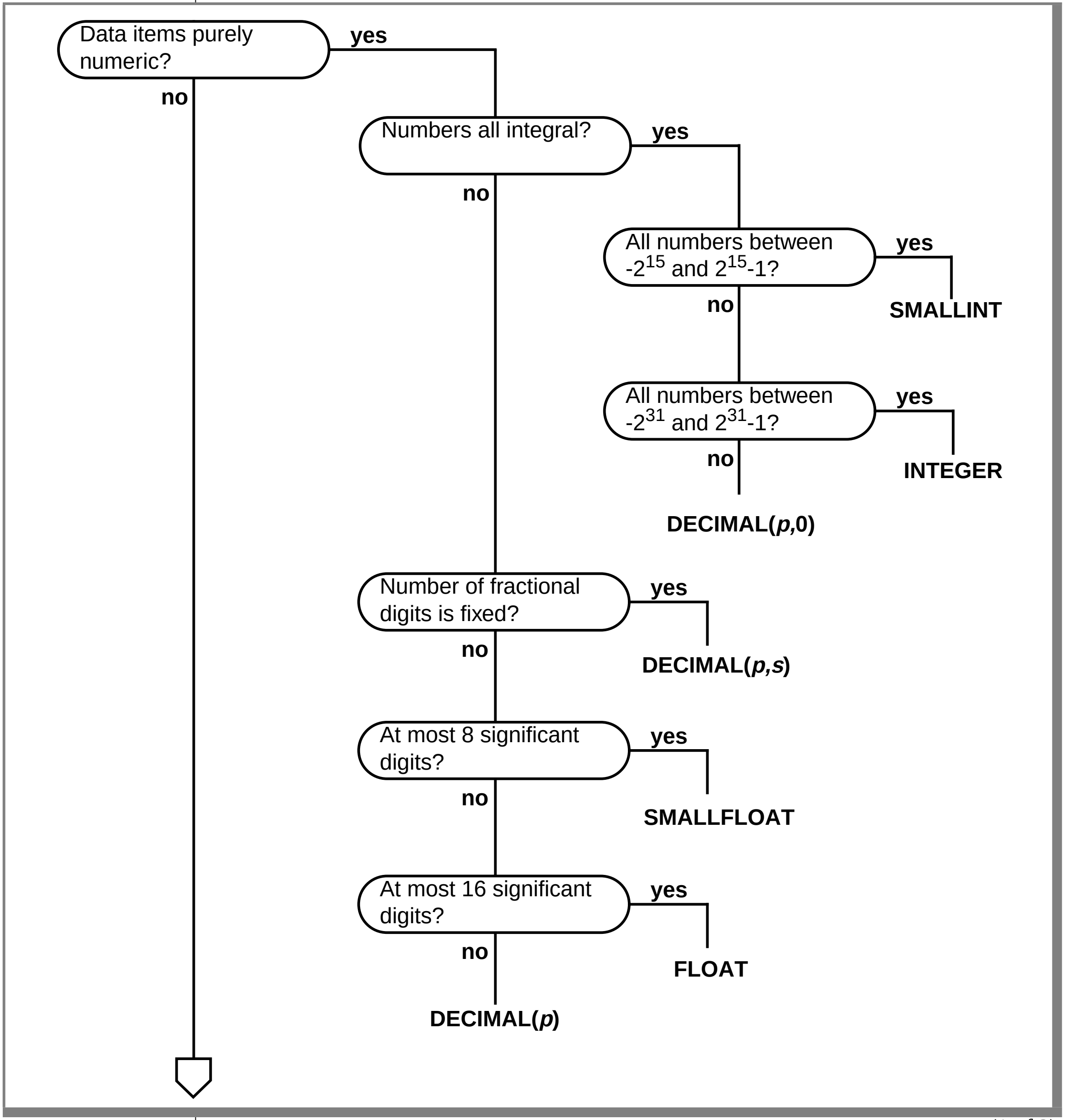
- It establishes the basic domain of the column; that is, the set of valid data items that the column can store.
- It determines the kinds of operations that you can perform on the data. For example, you cannot apply aggregate functions, such as SUM, to columns with a character data type.
- It determines how much space each data item occupies on disk. The space required to accommodate data items is not as important for small tables as it for tables with tens or hundreds of thousands of rows. When a table reaches that many rows, the difference between a 4-byte and an 8-byte type can be crucial.

Using Data Types in Referential Constraints

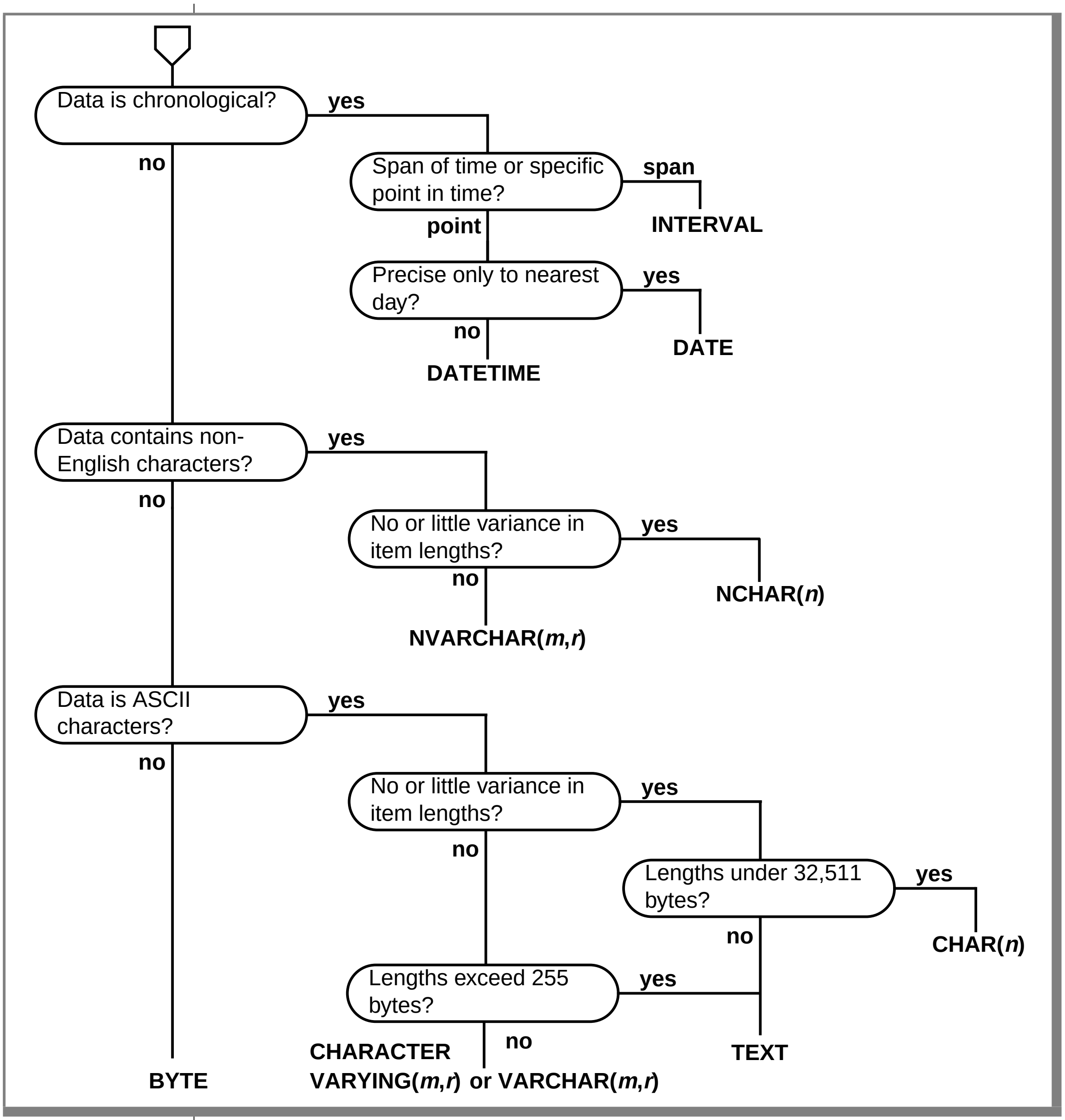
Almost all data type combinations must match when you are trying to pick columns for primary and foreign keys. For example, if you define a primary key as a CHAR data type, you must also define the foreign key as a CHAR data type. However, when you specify a SERIAL data type on a primary key in one table, you specify an INTEGER on the foreign key of the relationship. The SERIAL and INTEGER construction is the only data type combination that you can mix in a relationship.

Figure 9-1 shows the decision tree that summarizes the choices among data types. The choices are explained in the following sections.

Figure 9-1
Choosing a Data Type


Data items purely numeric?
yes
no
Numbers all integral?
yes
no
All numbers between -2^15 and 2^15-1?
yes
SMALLINT
no
All numbers between -2^31 and 2^31-1?
yes
INTEGER
no
DECIMAL(p,0)
Number of fractional digits is fixed?
yes
DECIMAL(p,s)
no
At most 8 significant digits?
yes
SMALLFLOAT
no
At most 16 significant digits?
yes
FLOAT
no
DECIMAL(p)

(1 of 2)


Data is chronological?
yes
no
Span of time or specific point in time?
span
INTERVAL
point
Precise only to nearest day?
yes
DATE
no
DATETIME
Data contains non-English characters?
yes
no
No or little variance in item lengths?
yes
NCHAR(*n*)
no
NVARCHAR(*m*,*r*)
Data is ASCII characters?
yes
no
No or little variance in item lengths?
yes
no
Lengths under 32,511 bytes?
yes
CHAR(*n*)
no
Lengths exceed 255 bytes?
yes
TEXT
no
CHARACTER VARYING(*m*,*r*) or VARCHAR(*m*,*r*)
BYTE

(2 of 2)

Numeric Types

Informix database servers support eight numeric data types. Some are best suited for counters and codes, some for engineering quantities, and some for money.

Counters and Codes: INTEGER and SMALLINT

The INTEGER and SMALLINT data types hold small whole numbers. They are suited for columns that contain counts, sequence numbers, numeric identity codes, or any range of whole numbers when you know in advance the maximum and minimum values to be stored.

Both types are stored as signed binary integers. INTEGER values have 32 bits and can represent whole numbers from -2^{31} through $2^{31}-1$; that is, from –2,147,483,647 through 2,147,483,647. (The maximum negative number, –2,147,483,248, is reserved and cannot be used.)

SMALLINT values have only 16 bits. They can represent whole numbers from –32,767 through 32,767. (The maximum negative number, -32,768, is reserved and cannot be used.)

These data types have the following advantages:

- They take up little space (2 bytes per value for SMALLINT and 4 bytes per value for INTEGER).
- Arithmetic expressions such as SUM and MAX as well as sort comparisons can be done very efficiently on them.

The disadvantage to using INTEGER and SMALLINT is the limited range of values that they can store. The database server does not store a value that exceeds the capacity of an integer. Of course, such excess is not a problem when you know the maximum and minimum values to be stored.

Automatic Sequences: SERIAL

The SERIAL data type is simply INTEGER with a special feature. Whenever a new row is inserted into a table, the database server automatically generates a new value for a SERIAL column. A table can have only one SERIAL column. Because the database server generates them, the serial values in new rows are always different even when multiple users are adding rows at the same time. This service is useful, because it is quite difficult for an ordinary program to coin unique numeric codes under those conditions.

The database server uses all the positive serial numbers by the time it inserts 2^{31} rows in a table. You might not be concerned about the exhaustion of the positive serial numbers because a single application would need to insert a row every second for 68 years, or 68 applications would need to insert a row every second for a year, to use all the positive serial numbers. However, if all the positive serial numbers were used, the database server would continue to generate new numbers. It would treat the next serial quantity as a signed integer. Because the database server uses only positive values, it would simply wrap around and start to generate integer values that begin with a 1.

The sequence of generated numbers always increases. When rows are deleted from the table, their serial numbers are not reused. Rows that are sorted on a SERIAL column are returned in the order in which they were created. That cannot be said of any other data type.

You can specify the initial value in a SERIAL column in the CREATE TABLE statement. This makes it possible to generate different subsequences of system-assigned keys in different tables. The **stores7** database uses this technique. In **stores7**, the customer numbers begin at 101, and the order numbers start at 1001. As long as this small business does not register more than 899 customers, all customer numbers have three digits, and order numbers have four.

A SERIAL column is not automatically a unique column. If you want to be perfectly sure that no duplicate serial numbers occur, you must apply a unique constraint (see “Using CREATE TABLE” on page 9-30). If you define the table using the interactive schema editor in DB-Access or INFORMIX-SQL, it automatically applies a unique constraint to any SERIAL column.

The SERIAL data type has the following advantages:

- It provides a convenient way to generate system-assigned keys.
- It produces unique numeric codes even when multiple users are updating the table.
- Different tables can use different ranges of numbers.

The SERIAL data type has the following disadvantages:

- Only one SERIAL column is permitted in a table.
- It can produce only arbitrary numbers.

Altering the next SERIAL number

The starting value for a SERIAL column is set when the column is created (see "Using CREATE TABLE" on page 9-30). You can use the ALTER TABLE statement later to reset the *next* value, the value that is used for the next-inserted row.

You cannot set the *next* value below the current maximum value in the column because doing so causes the database server to generate duplicate numbers in certain situations. However, you can set the *next* value to any value higher than the current maximum, thus creating gaps in the sequence.

Approximate Numbers: FLOAT and SMALLFLOAT

In scientific, engineering, and statistical applications, numbers are often known to only a few digits of accuracy, and the magnitude of a number is as important as its exact digits.

The floating-point data types are designed for these applications. They can represent any numerical quantity, fractional or whole, over a wide range of magnitudes from the cosmic to the microscopic. For example, they can easily represent both the average distance from the Earth to the Sun (1.5×10^9 meters) or Planck's constant (6.625×10^{-27}). Their only restriction is their limited precision. Floating-point numbers retain only the most significant digits of their value. If a value has no more digits than a floating-point number can store, the value is stored exactly. If it has more digits, it is stored in approximate form, with its least-significant digits treated as zeros.

This lack of exactitude is fine for many uses, but you should never use a floating-point data type to record money or any other quantity whose least significant digits should not be changed to zero.

Two sizes of floating-point data types exist. The FLOAT type is a double-precision, binary floating-point number as implemented in the C language on your computer. A FLOAT data type value usually takes up 8 bytes. The SMALLFLOAT (also known as REAL) data type is a single-precision, binary floating-point number that usually takes up 4 bytes. The main difference between the two data types is their precision. A FLOAT column retains about 16 digits of its values; a SMALLFLOAT column retains only about 8 digits.

Floating-point numbers have the following advantages:

- They store very large and very small numbers, including fractional ones.
- They represent numbers compactly in 4 or 8 bytes.
- Arithmetic functions such as AVG, MIN, and sort comparisons are efficient on these data types.

The main disadvantage of floating-point numbers is that digits outside their range of precision are treated as zeros.

Adjustable-Precision Floating Point: DECIMAL(p)

The DECIMAL(*p*) data type is a floating-point data type similar to FLOAT and SMALLFLOAT. The important difference is that you specify how many significant digits it retains. The precision you write as *p* can range from 1 to 32, from fewer than SMALLFLOAT up to twice the precision of FLOAT.

The magnitude of a DECIMAL(*p*) number ranges from 10^{-130} to 10^{124}.

It is easy to be confused about decimal data types. The one under discussion is DECIMAL(*p*); that is, DECIMAL with only a precision specified. The size of DECIMAL(*p*) numbers depends on their precision; they occupy $1+p/2$ bytes (rounded up to a whole number, if necessary).

DECIMAL(*p*) has the following advantages over FLOAT:

- Precision can be set to suit the application, from highly approximate to highly precise.
- Numbers with as many as 32 digits can be represented exactly.
- Storage is used in proportion to the precision of the number.
- Every Informix database server supports the same precision and range of magnitudes, regardless of the host operating system.

The DECIMAL(*p*) data type has the following disadvantages:

- Performing arithmetic and sorts on DECIMAL(*p*) values is somewhat slower than on FLOAT values.
- Many programming languages do not support the DECIMAL(*p*) data format the way that they support FLOAT and INTEGER. When a program extracts a DECIMAL(*p*) value from the database, it might have to convert the value to another format for processing. (However, INFORMIX-4GL programs can use DECIMAL(*p*) values directly.)

Fixed-Point Numbers: DECIMAL and MONEY

Most commercial applications need to store numbers that have fixed numbers of digits on the right and left of the decimal point. Amounts of money are the most common examples. Amounts in U.S. and other currencies are written with two digits to the right of the decimal point. Normally, you also know the number of digits needed on the left, depending on the kind of transactions that are recorded: perhaps 5 digits for a personal budget, 7 digits for a small business, and 12 or 13 digits for a national budget.

These numbers are *fixed-point* numbers because the decimal point is fixed at a specific place, regardless of the value of the number. The DECIMAL(*p,s*) data type is designed to hold them. When you specify a column of this type, you write its *precision* (*p*) as the total number of digits that it can store, from 1 to 32. You write its *scale* (*s*) as the number of those digits that fall to the right of the decimal point. (Figure 9-2 shows the relation between precision and scale.) Scale can be zero, meaning it stores only whole numbers. When only whole numbers are stored, DECIMAL(*p,s*) provides a way of storing integers of up to 32 digits.

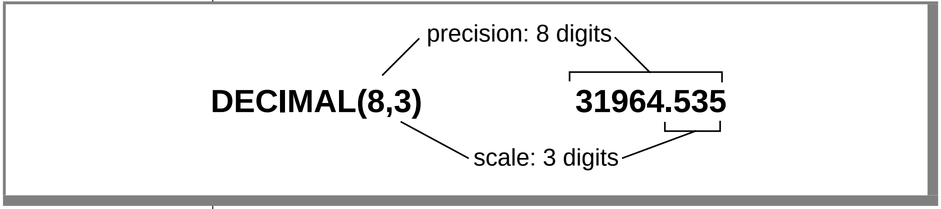


Figure 9-2
The Relation Between Precision and Scale in a Fixed-Point Number

Like the DECIMAL(*p*) data type, DECIMAL(*p,s*) takes up space in proportion to its precision. One value occupies $1+p/2$ bytes, rounded up to a whole number of bytes.

The MONEY type is identical to DECIMAL(*p,s*), but with one extra feature. Whenever the database server converts a MONEY value to characters for display, it automatically includes a currency symbol.

The advantages of DECIMAL(*p,s*) over INTEGER and FLOAT are that much greater precision is available (up to 32 digits as compared with 10 digits for INTEGER and 16 digits for FLOAT), and both the precision and the amount of storage required can be adjusted to suit the application.

The disadvantages are that arithmetic operations are less efficient and that many programming languages do not support numbers in this form. Therefore, when a program extracts a number, it usually must convert the number to another numeric form for processing. (However, INFORMIX-4GL programs can use DECIMAL(*p,s*) and MONEY values directly.)

GLS

Choosing a currency format

Each nation has its own way of displaying money values. When an Informix database server displays a MONEY value, it refers to a currency format that the user specifies. The default locale specifies a U.S. English currency format of the following form:

```
$7,822.45
```

For non-English locales, you can change the current format by means of the MONETARY category of the locale file. For more information on using locales, refer to Chapter 1 of the *Guide to GLS Functionality*. ♦

To customize this currency format, choose your locale appropriately or set the **DBMONEY** environment variable. For more information, see Chapter 4 of the *Informix Guide to SQL: Reference*.

Chronological Types

Informix database servers support three data types for recording time. The DATE data type stores a calendar date. DATETIME records a point in time to any degree of precision from a year to a fraction of a second. The INTERVAL data type stores a span of time; that is, a duration.

Calendar Dates: DATE

The DATE data type stores a calendar date. A DATE value is actually a signed integer whose contents are interpreted as a count of full days since midnight on December 31, 1899. Most often it holds a positive count of days into the current century.

The DATE format has ample precision to carry dates into the far future (58,000 centuries). Negative DATE values are interpreted as counts of days prior to the epoch date; that is, a DATE value of `-1` represents the day December 30, 1899.

Because DATE values are integers, Informix database servers permit them to be used in arithmetic expressions. For example, you can take the average of a DATE column, or you can add 7 or 365 to a DATE column. In addition, a rich set of functions exists specifically for manipulating DATE values. (See Chapter 1 of the *Informix Guide to SQL: Syntax*.)

The DATE data type is compact, at 4 bytes per item. Arithmetic functions and comparisons execute quickly on a DATE column.

GLS

Choosing a date format

You can punctuate and order the components of a date in many ways. When an Informix database server displays a DATE value, it refers to a date format that the user specifies. The default locale specifies a U.S. English date format of the form:

```
10/25/95
```

To customize this date format, choose your locale appropriately or set the **DBDATE** environment variable. For more information, see Chapter 4 of the *Informix Guide to SQL: Reference*.

For languages other than English, you can also change the date format by means of the TIME category of the locale file. For more information on using locales, refer to the *Guide to GLS Functionality*. ♦

Exact Points in Time: DATETIME

The DATETIME data type stores any moment in time in the era that begins 1 A.D. In fact, DATETIME is really a family of 28 data types, each with a different precision. When you define a DATETIME column, you specify its precision. The column can contain any sequence from the list *year*, *month*, *day*, *hour*, *minute*, *second*, and *fraction*. Thus, you can define a DATETIME column that stores only a year, only a month and day, or a date and time that is exact to the hour or even to the millisecond. The size of a DATETIME value ranges from 2 to 11 bytes depending on its precision, as Figure 9-3 shows.

The advantage of DATETIME is that it can store dates more precisely than to the nearest day, and it can store time values. Its sole disadvantage is an inflexible display format, but you can circumvent this advantage. (See "Forcing the format of a DATETIME or INTERVAL value" on page 9-17.)

Figure 9-3
Precisions for the DATETIME Data Type

Precision	Size*	Precision	Size*
year to year	3	day to hour	3
year to month	4	day to minute	4
year to day	5	day to second	5
year to hour	6	day to fraction(*f*)	5+*f*/2
year to minute	7	hour to hour	2
year to second	8	hour to minute	3
year to fraction (*f*)	8+*f*/2	hour to second	4
month to month	2	hour to fraction(*f*)	4+*f*/2
month to day	3	minute to minute	2
month to hour	4	minute to second	3
month to minute	5	minute to fraction(*f*)	3+*f*/2
month to second	6	second to second	2
month to fraction(*f*)	6+*f*/2	second to fraction(*f*)	2+*f*/2
day to day	2	fraction to fraction(*f*)	1+*f*/2

* When *f* is odd, round the size to the next full byte.

Durations: INTERVAL

The INTERVAL data type stores a duration, that is, a length of time. The difference between two DATETIME values is an INTERVAL, which represents the span of time that separates them. The following examples might help to clarify the differences:

- An employee began working on January 21, 1994 (either a DATE or a DATETIME).
- She has worked for 254 days (an INTERVAL value, the difference between the TODAY function and the starting DATE or DATETIME value).
- She begins work each day at 0900 hours (a DATETIME value).
- She works 8 hours (an INTERVAL value) with 45 minutes for lunch (another INTERVAL value).
- Her quitting time is 1745 hours (the sum of the DATETIME when she begins work and the two INTERVALs).

Like DATETIME, INTERVAL is a family of types with different precisions. An INTERVAL value can represent a count of years and months; or it can represent a count of days, hours, minutes, seconds, or fractions of seconds; 18 precisions are possible. The size of an INTERVAL value ranges from 2 to 12 bytes, depending on the formulas that Figure 9-4 shows.

Figure 9-4
Precisions for the INTERVAL Data Type

Precision	**Size***	**Precision**	**Size***
year(p) to year	$1+p/2$	hour(p) to minute	$2+p/2$
year(p) to month	$2+p/2$	hour(p) to second	$3+p/2$
month(p) to month	$1+p/2$	hour(p) to fraction(f)	$4+(p+f)/2$
day(p) to day	$1+p/2$	minute(p) to minute	$1+p/2$
day(p) to hour	$2+p/2$	minute(p) to second	$2+p/2$
day(p) to minute	$3+p/2$	minute(p) to fraction(f)	$3+(p+f)/2$
day(p) to second	$4+p/2$	second(p) to second	$1+p/2$
day(p) to fraction(f)	$5+(p+f)/2$	second(p) to fraction(f)	$2+(p+f)/2$
hour(p) to hour	$1+p/2$	fraction to fraction(f)	$1+f/2$

* Round a fractional size to the next full byte.

INTERVAL values can be negative as well as positive. You can add or subtract them, and you can scale them by multiplying or dividing by a number. This is not true of either DATE or DATETIME. You can reasonably ask, "What is one-half the number of days until April 23?" but not, "What is one-half of April 23?"

Forcing the format of a DATETIME or INTERVAL value

The database server always displays the components of an INTERVAL or DATETIME value in the order *year-month-day hour*:*minute*:*second.fraction*. It does not refer to the date format that is defined to the operating system, as it does when it formats a DATE value.

You can write a SELECT statement that displays the date part of a DATETIME value in the system-defined format. The trick is to isolate the component fields using the EXTEND function and pass them through the MDY() function, which converts them to a DATE. The following code shows a partial example:

```
SELECT ... MDY (
    EXTEND (DATE_RECEIVED, MONTH TO MONTH),
    EXTEND (DATE_RECEIVED, DAY TO DAY),
    EXTEND (DATE_RECEIVED, YEAR TO YEAR))
    FROM RECEIPTS ...
```

When you use INFORMIX-4GL or INFORMIX-SQL to design a report, you have the greater flexibility of the PRINT statement. To select each component of a DATETIME or INTERVAL value as an expression, use the EXTEND function. Give each expression an alias for convenience, as the following partial SELECT statement shows:

```
SELECT ...
    EXTEND (START_TIME, HOUR TO HOUR) H,
    EXTEND (START_TIME, MINUTE TO MINUTE) M, ...
```

Then, in the report, combine the components in a PRINT expression with the desired punctuation, as the following example shows:

```
PRINT 'Start work at ', H USING '&&', M USING '&&', 'hours.'
Start work at 0800 hours.
```

GLS

Choosing a DATETIME Format

When an Informix database server displays a DATETIME value, it refers to a DATETIME format that the user specifies. The default locale specifies a U.S. English DATETIME format of the following form:

```
1995-10-25 18:02:13
```

For languages other than English, you change the DATETIME format by means of the TIME category of the locale file. For more information on using locales, refer to the *Guide to GLS Functionality*.

To customize this DATETIME format, choose your locale appropriately or set the **GL_DATETIME** or **DBTIME** environment variable. For more information see the *Guide to GLS Functionality*.♦

GLS

Character Types

Both the INFORMIX-SE and OnLine database servers support the NCHAR data type. INFORMIX-OnLine Dynamic Server also supports NVARCHAR, the special-use character data type.

Character Data: CHAR(n) and NCHAR(n)

The CHAR(*n*) data type contains a sequence of *n* bytes. These characters can be a mixture of English and non-English characters and can be either single byte or multibyte (Asian). The length *n* ranges from 1 to 32,767. (If you are using the INFORMIX-SE database server, the maximum length is 32,511.) Whenever a CHAR(*n*) value is retrieved or stored, exactly *n* bytes are transferred. If an inserted value is shorter than *n*, the database server extends the value by using single byte ASCII space characters to make up *n* bytes.

Data in CHAR columns is sorted in code-set order. For example, in the ASCII code set, the character *a* has a code-set value of 97, *b* has 98, and so forth. The database server sorts CHAR(*n*) data in this order.

The NCHAR(*n*) data type also contains a sequence of *n* bytes. These characters can be a mixture of English and non-English characters and can be either single byte or multibyte (Asian). The length of *n* has the same limits as the CHAR(*n*) data type. Whenever an NCHAR(*n*) value is retrieved or stored, exactly *n* bytes are transferred. The number of characters transferred can be less than the number of bytes if the data contains multibyte characters. If an inserted value is shorter than *n*, the database server extends the value by using single byte ASCII space characters to make up *n* bytes.

Tip: *The database server accepts values from the user that are extended with either single-byte or multibyte spaces as the locale defines.*

The database server sorts data in NCHAR(*n*) columns according to the order that the locale specifies. For example, the French locale specifies that the character *ê* is sorted after the value *e* but before the value *f*. In other words, the sort order dictated by the French locale is *e*, *ê*, *f*, and so on. For more information on using locales, refer to the *Guide to GLS Functionality*.

Tip: *The only difference between CHAR(n) and NCHAR(n) data is the data sorting and comparison. You can store non-English characters in a CHAR(n) column. However, because the database server uses code-set order to perform any sorting or comparison on CHAR(n) columns, you might not obtain the results in the order that you expected.*

A CHAR(*n*) or NCHAR(*n*) value can include tabs and spaces but normally contains no other nonprinting characters. When rows are inserted using INSERT or UPDATE, or when rows are loaded with a utility program, no means exists for entering nonprintable characters. However, when rows are created by a program using embedded SQL, the program can insert any character except the null (binary zero) character. It is not a good idea to store nonprintable characters in a character column because standard programs and utilities do not expect them.

The advantage of the CHAR(*n*) or NCHAR(*n*) data type is its availability on all database servers. The only disadvantage of CHAR(*n*) or NCHAR(*n*) is its fixed length. When the length of data values varies widely from row to row, space is wasted.

Variable-Length Strings: CHARACTER VARYING(m,r), VARCHAR(m,r), and NVARCHAR(m,r)

For each of the following data types, *m* represents the maximum number of bytes and *r* represents the minimum number of bytes.

Tip: *The data type CHARACTER VARYING (m,r) is ANSI compliant. VARCHAR(m,r) is an Informix data type.*

Often the items in a character column have different lengths; that is, many have an average length, and only a few have the maximum length. The following data types are designed to save disk space when you store such data:

- **CHARACTER VARYING (*m*,*r*).** The CHARACTER VARYING (*m*,*r*) data type contains a sequence of, at most, m bytes or at the least, *r* bytes. This data type is the ANSI-compliant format for character data of varying length. CHARACTER VARYING (*m*,*r*), supports code-set order for comparisons of its character data.
- **VARCHAR (*m*,*r*).** VARCHAR (*m*,*r*) is an Informix-specific data type for storing character data of varying length. In functionality, it is the same as CHARACTER VARYING(*m*,*r*).
- **NVARCHAR (*m*,*r*).** NVARCHAR (*m*,*r*) is also an Informix-specific data type for storing character data of varying length. It compares character data in the order that the locale specifies.

Tip: *This difference in the way data is compared distinguishes NVARCHAR(m,r) data from CHARACTER VARYING(m,r) or VARCHAR(m,r) data. For more information on code set and sort order determined by the locale, see "Character Data: CHAR(n) and NCHAR(n)" on page 9-19.*

When you define columns of these data types, you specify *m* as the *maximum* number of bytes. If an inserted value consists of fewer than *m* bytes, the database server does not extend the value with single-byte spaces (as with CHAR(*n*) and NCHAR(*n*) values.) Instead, it stores only the actual contents on disk, with a 1-byte length field. The limit on *m* is 254 bytes for indexed columns and 255 bytes for non-indexed columns.

The second parameter, *r*, is an optional *reserve* length that sets a lower limit on the number of bytes required by the value that is being stored on disk. Even if a value requires fewer than *r* bytes, *r* bytes are nevertheless allocated to hold it. The purpose is to save time when rows are updated. (See "Variable-Length Execution Time" on page 9-22.)

The advantages of the CHARACTER VARYING(m,r) or VARCHAR(*m*,*r*) data type over the CHAR(*n*) data type are as follows:

- It conserves disk space when the number of bytes that data items require vary widely or when only a few items require more bytes than average.
- Queries on the more compact tables can be faster.

These advantages also apply to the NVARCHAR(*m*,*r*) data type in comparison to the NCHAR(*n*) data type.

The following list describes the disadvantages of using varying length data types:

- They do not allow lengths that exceed 255 bytes.
- Table updates can be slower in some circumstances.
- They are not available with all Informix database servers. ♦

Variable-Length Execution Time

When you use any of the CHARACTER VARYING(m,r), VARCHAR(m,r), or NVARCHAR(m,r) data types, the rows of a table have a varying number of bytes instead of a fixed number of bytes. The speed of database operations is affected when the rows of a table have a varying number of bytes.

Because more rows fit in a disk page, the database server can search the table with fewer disk operations than if the rows were of a fixed number of bytes. As a result, queries can execute more quickly. Insert and delete operations can be a little quicker for the same reason.

When you update a row, the amount of work the database server must do depends on the number of bytes in the new row as compared with the number of bytes in the old row. If the new row uses the same number of bytes or fewer, the execution time is not significantly different than it is with fixed-length rows. However, if the new row requires a greater number of bytes than the old one, the database server might have to perform several times as many disk operations. Thus, updates of a table that use CHARACTER VARYING(m,r), VARCHAR(*m*,*r*), or NVARCHAR(m,r) data can sometimes be slower than updates of a fixed-length field.

To mitigate this effect, specify *r* as a number of bytes that covers a high proportion of the data items. Then most rows use the reserve number of bytes, and padding wastes only a little space. Updates are slow only when a value using the reserve number of bytes is replaced with a value that uses more than the reserve number of bytes.

Large Character Objects: TEXT

The TEXT data type stores a block of text. It is designed to store self-contained documents: business forms, program source or data files, or memos. Although you can store any data in a TEXT item, Informix tools expect a TEXT item to be printable, so restrict this data type to printable ASCII text.

TEXT values are not stored with the rows of which they are a part. They are allocated in whole disk pages, usually areas away from rows. (See the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.)

The advantage of the TEXT data type over CHAR(*n*) and VARCHAR(*m*,*r*) is that the size of a TEXT data item has no limit except the capacity of disk storage to hold it. The disadvantages of the TEXT data type are as follows:

- It is allocated in whole disk pages, so a short item wastes space.
- Restrictions apply on how you can use a TEXT column in an SQL statement. (See "Using Blobs" below.)
- It is not available with all Informix database servers.

You can display TEXT values in reports that you generate with INFORMIX-4GL programs or the ACE report writer. You can display TEXT values on a screen and edit them using screen forms generated with INFORMIX-4GL programs or with the PERFORM screen-form processor.

Using Blobs

Collectively, columns of TEXT and BYTE data type are called *binary large objects* (blobs). The database server simply stores and retrieves them. Normally, blob values are fetched and stored by programs written using INFORMIX-4GL, NewEra, or a language that supports embedded SQL, such as INFORMIX-ESQL/C. In such a program, you can fetch, insert, or update a blob value in a manner similar to the way you read or write a sequential file.

In any SQL statement, interactive or programmed, a blob column *cannot* be used in the following ways:

- In arithmetic or Boolean expressions
- In a GROUP BY or ORDER BY clause
- In a UNIQUE test
- For indexing, either by itself or as part of a composite index

In a SELECT statement entered interactively, or in a form or report, a blob can:

- be selected by name, optionally with a subscript to extract part of it.
- have its length returned by selecting LENGTH(*column*).
- be tested with the IS [NOT] NULL predicate.

In an interactive INSERT statement, you can use the VALUES clause to insert a blob value, but the only value that you can give that column is null. However, you can use the SELECT form of the INSERT statement to copy a blob value from another table.

In an interactive UPDATE statement, you can update a blob column to null or to a subquery that returns a blob column.

Binary Objects: BYTE

The BYTE data type is designed to hold any data a program can generate: graphic images, program object files, and documents saved by any word processor or spreadsheet. The database server permits any kind of data of any length in a BYTE column.

As with TEXT, BYTE data items are stored in whole disk pages in separate disk areas from normal row data.

The advantage of the BYTE data type, as opposed to TEXT or CHAR(*n*), is that it accepts any data. Its disadvantages are the same as those of the TEXT data type.

Changing the Data Type

After the table is built, you can use the ALTER TABLE statement to change the data type that is assigned to a column. Although such alterations are sometimes necessary, you should avoid them for the following reasons:

- To change a data type, the database server must copy and rebuild the table. For large tables, copying and rebuilding can take a lot of time and disk space.
- Some data type changes can cause a loss of information. For example, when you change a column from a longer to a shorter character type, long values are truncated; when you change to a less-precise numeric type, low-order digits are truncated.
- Existing programs, forms, reports, and stored queries might also have to be changed.

Null Values

Columns in a table can be designated as containing null values. A null value means that the value for the column can be unknown or not applicable. For example, in the telephone-directory example in Chapter 8, the *anniv* column of the *name* table can contain null values; if you do not know the person's anniversary, you do not specify it. Do not confuse null value with zero or blank value.

Default Values

A default value is the value that is inserted into a column when an explicit value is not specified in an INSERT statement. A default value can be a literal character string that either you define or one of the following SQL null, constant expressions defines:

- USER
- CURRENT
- TODAY
- DBSERVERNAME

Not all columns need default values, but as you work with your data model, you might discover instances where the use of a default value saves data-entry time or prevents data-entry error. For example, the telephone-directory model has a *State* column. While you are looking at the data for this column, you discover that more than 50 percent of the addresses list California as the state. To save time, you specify the string "CA" as the default value for the *State* column.

Check Constraints

Check constraints specify a condition or requirement on a data value before data can be assigned to a column during an INSERT or UPDATE statement. If a row evaluates to *false* for any of the check constraints that are defined on a table during an insert or update, the database server returns an error. To define a constraint, use the CREATE TABLE or ALTER TABLE statements. For example, the following requirement constrains the values of an integer domain to a certain range:

```
Customer_Number >= 50000 AND Customer_Number <= 99999
```

To express constraints on character-based domains, use the MATCHES predicate and the regular-expression syntax that it supports. For example, the following constraint restricts a Telephone domain to the form of a U.S. local telephone number:

```
vce_num MATCHES '[2-9][2-9][0-9]-[0-9][0-9][0-9][0-9]'
```

For additional information about check constraints, see the CREATE TABLE and ALTER TABLE statements in the *Informix Guide to SQL: Syntax*.

Creating the Database

Now you are ready to create the data model as tables in a database. You do this with the CREATE DATABASE, CREATE TABLE, and CREATE INDEX statements. The *Informix Guide to SQL: Syntax* shows the syntax of these statements in detail. This section discusses the use of CREATE DATABASE and CREATE TABLE in implementing a data model. The use of CREATE INDEX is covered in Chapter 10, "Granting and Limiting Access to Your Database."

Remember that the telephone-directory data model is used for illustrative purposes only. For the sake of the example, it is translated into SQL statements.

You might have to create the same database model more than once. However, the statements that create the model can be stored and executed automatically. See "Using Command Scripts" on page 9-32 for more information.

When the tables exist, you must populate them with rows of data. You can do this manually, with a utility program, or with custom programming.

Using CREATE DATABASE

A database is a container that holds all the parts of a data model. These parts include not only the tables but also views, indexes, synonyms, and other objects that are associated with the database. You must create a database before you can create anything else.

GLS

When the database server creates a database, it stores the locale of the database that is derived from the **DB_LOCALE** environment variable in its system catalog. This locale determines how the database server interprets character data that is stored within the database. By default, the database locale is the U.S. English locale that uses the ISO8859-1 code set. For information on using alternative locales, see the *Guide to GLS Functionality*. ♦

Using CREATE DATABASE with INFORMIX-OnLine Dynamic Server

The OnLine database server differs from other database servers in the way that it creates databases and tables. When the OnLine database server creates a database, it sets up records that show the existence of the database and its mode of logging. It manages disk space directly, so these records are not visible to operating-system commands.

Avoiding Name Conflicts

Normally, only one copy of OnLine is running on a computer, and it manages the databases that belong to all users of that computer. It keeps only one list of database names. The name of your database must be different from that of any other database managed by that database server. (It is possible to run more than one copy of the database server. This is sometimes done, for example, to create a safe environment for testing apart from the operational data. In that case, be sure that you are using the correct database server when you create the database, and again when you access it later.)

Selecting a Dbspace

OnLine offers you the option of creating the database in a particular *dbspace*. A dbspace is a named area of disk storage. Ask your OnLine administrator whether you should use a particular dbspace. The administrator can put a database in a dbspace to isolate it from other databases or to locate it on a particular disk device. (The *INFORMIX-OnLine Dynamic Server Administrator's Guide* discusses dbspaces and their relationship to disk devices.)

Some dbspaces are *mirrored* (duplicated on two disk devices for high reliability); your database can be put in a mirrored dbspace if its contents are of exceptional importance.

Choosing the Type of Logging

OnLine offers the following choices for transaction logging:

- **No logging at all.** Informix does not recommend this choice. If you lose the database due to a hardware failure, you lose all data alterations since the last backup.

  ```
  CREATE DATABASE db_with_no_log
  ```

  When you do not choose logging, BEGIN WORK and other SQL statements that are related to transaction processing are not permitted in the database. This situation affects the logic of programs that use the database.

- **Regular (unbuffered) logging.** This choice is best for most databases. In the event of a failure, you lose only uncommitted transactions.

  ```
  CREATE DATABASE a_logged_db WITH LOG
  ```

- **Buffered logging.** If you lose the database, you lose a few or possibly none of the most recent alterations. In return for this small risk, performance during alterations improves slightly.

  ```
  CREATE DATABASE buf_log_db WITH BUFFERED LOG
  ```

  Buffered logging is best for databases that are updated frequently (so that speed of updating is important), but you can re-create the updates from other data in the event of a crash. Use the SET LOG statement to alternate between buffered and regular logging.

- **ANSI-compliant logging.** This logging is the same as regular logging, but the ANSI rules for transaction processing are also enforced. (See the discussion of ANSI-compliant databases in Chapter 1 of the *Informix Guide to SQL: Reference*.)

  ```
  CREATE DATABASE std_rules_db WITH LOG MODE ANSI
  ```

  The design of ANSI SQL prohibits the use of buffered logging.

The OnLine administrator can turn transaction logging on and off later. For example, the administrator can turn it off before inserting a large number of new rows.

Using CREATE DATABASE with Other Informix Database Servers

Other Informix database servers create a database as a set of one or more files that the operating system manages. For example, under the UNIX operating system, a database is a small group of files in a directory whose name is the database name. (See the manual for your database server for details on how it uses files.) Consequently, the rules for database names are the same as the operating-system rules for filenames.

Choosing the Type of Logging

Other database servers offer the following three choices of logging:

- **No logging at all.** Informix does not recommend this choice. If you lose the database due to a hardware failure, you lose all data alterations since the last backup.

  ```
  CREATE DATABASE not_logged_db
  ```

  When you do not choose logging, BEGIN WORK and other SQL statements related to transaction processing are not permitted in the database. This affects the logic of programs that use the database.

- **Regular logging.** This choice is best for most databases. If the database is lost, only the alteration in progress at the time of failure is lost.

  ```
  CREATE DATABASE a_logged_db WITH LOG IN '/logs/a_log_file'
  ```

  You must specify a file to contain the transaction log. (The form of the filename depends on the rules of your operating system.) This file grows whenever the database is altered. Whenever the database files are backed up, set the log file back to an empty condition so that it reflects only transactions that have occurred since the latest backup.
- **ANSI-compliant logging.** This choice is the same as regular logging, but the ANSI rules for transaction processing are also enforced. (See the discussion of ANSI-compliant databases in Chapter 1 of the *Informix Guide to SQL: Reference*.)

  ```
  CREATE DATABASE std_rules_db WITH LOG IN '/logs/a_log_file' MODE ANSI
  ```

To add a transaction log to a nonlogged database later, use the START DATABASE statement.

Using CREATE TABLE

Use the CREATE TABLE statement to create each table that you designed in the data model. This statement has a complicated form, but it is basically a list of the columns of the table. For each column, you supply the following information:

- The name of the column
- The data type (from the domain list you made)
- If the column (or columns) is a primary key, the primary-key constraint
- If the column (or columns) is a foreign key, the foreign-key constraint
- If the column is not a primary key and should not allow nulls, the not null constraint
- If the column is not a primary key and should not allow duplicates, the unique constraint
- If the column has a default value, the default constraint
- If the column has a check constraint, the check constraint

In short, the CREATE TABLE statement is an image in words of the table as you drew it in the data-model diagram. The following example shows the statements for the telephone-directory model:

```
CREATE TABLE name
        (
        rec_num SERIAL PRIMARY KEY,
        lname CHAR(20),
        fname CHAR(20),
        bdate DATE,
        anniv DATE,
        email VARCHAR(25)
        );

CREATE TABLE child
        (
        child CHAR(20),
        rec_num INT,
        FOREIGN KEY (rec_num) REFERENCES NAME (rec_num)
        );

CREATE TABLE address
        (
        id_num SERIAL PRIMARY KEY,
        rec_num INT,
        street VARCHAR (50,20),
        city VARCHAR (40,10),
        state CHAR(5) DEFAULT 'CA',
        zipcode CHAR(10),
        FOREIGN KEY (rec_num) REFERENCES name (rec_num)
        );

CREATE TABLE voice
        (
        vce_num CHAR(13) PRIMARY KEY,
        vce_type CHAR(10),
        rec_num INT,
        FOREIGN KEY (rec_num) REFERENCES name (rec_num)
        );

CREATE TABLE fax
        (
        fax_num CHAR(13),
        oper_from DATETIME HOUR TO MINUTE,
        oper_till DATETIME HOUR TO MINUTE,
        PRIMARY KEY (fax_num)
        );

CREATE TABLE faxname
        (
        fax_num CHAR(13),
        rec_num INT,
        PRIMARY KEY (fax_num, rec_num),
          FOREIGN KEY (fax_num) REFERENCES fax (fax_num),
          FOREIGN KEY (rec_num) REFERENCES name (rec_num)
          );

  CREATE TABLE modem
          (
          mdm_num CHAR(13) PRIMARY KEY,
          rec_num INT,
          b_type CHAR(5),
          FOREIGN KEY (rec_num) REFERENCES name (rec_num)
          );
```

Using Command Scripts

You can create the database and tables by entering the statements interactively. But, in some cases you might have to do it again or several more times.

You might have to do it again to make a production version after a test version is satisfactory. You might have to implement the same data model on several computers. To save time and reduce the chance of errors, you can put all the commands to create a database in a file and execute them automatically.

Capturing the Schema

You can write the statements to implement your model into a file. However, you can also have a program do it for you. See the *Informix Migration Guide*. It documents the **dbschema** utility, a program that examines the contents of a database and generates all the SQL statements required to re-create it. You can build the first version of your database interactively, making changes until it is exactly as you want it. Then you can use **dbschema** to generate the SQL statements necessary to duplicate it.

Executing the File

Programs that you use to enter SQL statements interactively, such as DB-Access or INFORMIX-SQL, can be driven from a file of commands. The use of these products is covered in the *DB-Access User Manual* or the *INFORMIX-SQL User Guide*. You can start DB-Access or INFORMIX-SQL to read and execute a file of commands that you or **dbschema** prepared.

An Example

Most Informix database server products come with a demonstration database called **stores7** (the database used for most of the examples in this book). The **stores7** database is delivered as an operating-system command script that calls Informix products to build the database. You can copy this command script and use it as the basis for automating your own data model.

Populating the Tables

For your initial tests, the easiest way to populate the tables interactively is by typing INSERT statements in DB-Access or INFORMIX-SQL. To insert a row into the **manufact** table of the **stores7** database in DB-Access, enter the following command:

```
INSERT INTO manufact VALUES ('MKL', 'Martin', 15)
```

If you are preparing an application program in NewEra, INFORMIX-4GL, or another language, you can use the program to enter rows.

Often, the initial rows of a large table can be derived from data that is stored in tables in another database or in operating-system files. You can move the data into your new database in a bulk operation. If the data is in another Informix database, you can retrieve it in several ways.

If you are using INFORMIX-OnLine Dynamic Server, you can simply select the data you want from the other database on another database server as part of an INSERT statement in your database. As the following example shows, you could select information from the **items** table in the **stores7** database to insert into a new table:

```
INSERT INTO newtable
    SELECT item_num, order_num, quantity, stock_num,
        manu_code, total_price
    FROM stores7@otherserver:items
```

If you are using INFORMIX-SE, you can select the data you want from one database and insert it into another database as long as the databases are on the same database server. As the following example shows, you could select information from the **catalog** table in the **stores7** database to insert into a new table by using a temporary table:

```
CONNECT TO 'sharky/db1';

SELECT item_num, stock_num, manu_code
    FROM items
    INTO TEMP temptable;

DISCONNECT;

CONNECT TO 'sharky/db2';

SELECT * from temptable
    INTO TEMP newsetable;
```

If you want to select data from another database server in INFORMIX-SE, you must export the data to a file. You can use the UNLOAD statement in DB-Access, INFORMIX-SQL, NewEra, or INFORMIX-4GL; or you can write a report in ACE or INFORMIX-4GL and direct the output to a file.

When the source is another kind of file or database, you must find a way to convert it into a flat ASCII file; that is, a file of printable data in which each line represents the contents of one table row.

After you have the data in a file, you can use the **dbload** utility to load it into a table. For more information on **dbload**, see the *Informix Migration Guide*. The LOAD statement in DB-Access, INFORMIX-SQL, INFORMIX-4GL, or NewEra can also load rows from a flat ASCII file. See Chapter 1 of the *Informix Guide to SQL: Syntax* for information about the LOAD and UNLOAD statements.

Inserting hundreds or thousands of rows goes much faster if you turn off transaction logging. No point exists in logging these insertions because, in the event of a failure, you can easily re-create the lost work. The following list contains the steps of a large bulk-load operation:

- If any chance exists that other users are using the database, exclude them with the DATABASE EXCLUSIVE statement.
- If you are using INFORMIX-OnLine Dynamic Server, ask the administrator to turn off logging for the database.

  The existing logs can be used to recover the database in its present state, and you can run the bulk insertion again to recover those rows if they are lost.
- Perform the statements or run the utilities that load the tables with data.
- Back up the newly loaded database.

  If you are using INFORMIX-OnLine Dynamic Server, either ask the administrator to perform a full or incremental backup, or use the **onunload** utility to make a binary copy of your database only.

  If you are using other database servers, use operating-system commands to back up the files that represent the database.
- Restore transaction logging, and release the exclusive lock on the database.

You can enclose the steps of populating a database in a script of operating-system commands. You can automate the INFORMIX-OnLine Dynamic Server administrator commands by invoking the command-line equivalents to ON-Monitor.

Fragmenting Tables and Indexes

This section on fragmentation explains how to create and manage fragmented tables using SQL statements. It covers the following topics:

- How to create and maintain fragmented tables and indexes
- How to access data that is stored in fragmented tables

Before you read this section, familiarize yourself with the terms and concepts related to fragmentation and parallel database queries (PDQ) that are contained in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*.

Creating a Fragmented Table

You can fragment a table at the same time that you create it, or you can fragment existing nonfragmented tables. An overview of both alternatives is given in the following sections. For the complete syntax of the SQL statements that you use to create fragmented tables, see Chapter 1 of the *Informix Guide to SQL: Syntax*.

Before you create a fragmented table, you must decide on an appropriate distribution scheme for your tables. See the *INFORMIX-OnLine Dynamic Server Administrator's Guide* for advice on choosing a distribution scheme that meets your needs.

Fragmenting a New Table

To create a fragmented table, use the FRAGMENT BY clause of the CREATE TABLE statement. Suppose that you wish to create a fragmented table similar to the **stores7** table, **orders**. You decide on a round-robin distribution scheme with three fragments. Consult with the OnLine administrator to set up three dbspaces, one for each of the fragments: **dbspace1**, **dbspace2**, and **dbspace3**. To create the fragmented table, execute the following SQL statement:

```
CREATE TABLE my_orders (
    order_num SERIAL(1001),
    order_date DATE,
    customer_num INT,
    ship_instruct CHAR(40),
    backlog CHAR(1),
    po_num CHAR(10),
    ship_date DATE,
    ship_weight DECIMAL(8,2),
    ship_charge MONEY(6),
    paid_date DATE,
    PRIMARY KEY (order_num),
    FOREIGN KEY (customer_num) REFERENCES customer(customer_num))
    FRAGMENT BY ROUND ROBIN IN dbspace1,dbspace2,dbspace3
```

If you decide instead to create the table using an expression-based distribution scheme, you can use the FRAGMENT BY EXPRESSION clause of CREATE TABLE. Suppose that your **my_orders** table has 30,000 rows, and you wish to distribute rows evenly across three fragments stored in **dbspace1**, **dbspace2**, and **dbspace3**. You decide to use the column **order_num** to define the expression fragments.

You can define the expression the following example shows:

```
CREATE TABLE my_orders (order_num serial, ...)
    FRAGMENT BY EXPRESSION
          order_num <  10000 IN dbspace1,
          order_num <  20000 IN dbspace2,
          order_num >= 20000 IN dbspace3
```

Creating a Fragmented Table from Nonfragmented Tables

You might need to convert nonfragmented tables into fragmented tables in the following circumstances:

- You have an application-implemented version of table fragmentation.

  In this case, you will probably want to convert several small tables into one large fragmented table. The following section tells you how to proceed when this is the case.
- You have an existing large table that you want to fragment.

  Follow the instructions in the section "Creating a Fragmented Table from a Single Nonfragmented Table" on page 9-39.

Remember that before you perform the conversion, you must set up an appropriate number of dbspaces to contain the newly created fragmented tables.

Creating a Table from More Than One Nonfragmented Table

You can combine two or more nonfragmented tables into a single fragmented table. The nonfragmented tables must have identical table structures and must be stored in separate dbspaces. To combine the nonfragmented tables, use the ATTACH clause of the ALTER FRAGMENT statement.

For example, suppose that you have three nonfragmented tables, **account1**, **account2**, and **account3**, and that you store the tables in the dbspaces **dbspace1**, **dbspace2**, and **dbspace3**, respectively. All three tables have identical structures, and you want to combine the three tables into one table that is fragmented by expression on the common column **acc_num**.

You want rows with **acc_num** less than or equal to 1120 to be stored in the fragment that is stored in **dbspace1**. Rows with **acc_num** greater than 1120 but less than or equal to 2000 are to be stored in **dbspace2.** Finally, rows with **acc_num** greater than 2000 are to be stored **dbspace3**.

To fragment the tables with this fragmentation strategy, execute the following SQL statement:

```
ALTER FRAGMENT ON TABLE tab1 ATTACH
    tab1 AS acc_num <= 1120,
    tab2 AS acc_num >  1120 and acc_num <= 2000,
    tab3 AS acc_num > 2000
```

The result is a single table, **tabl**. The other tables, **tab2** and **tab3,** were consumed and no longer exist. For more information on the ATTACH clause of the ALTER FRAGMENT statement, see Chapter 1 of the *Informix Guide to SQL: Syntax*.

Creating a Fragmented Table from a Single Nonfragmented Table

To create a fragmented table from a nonfragmented table, use the INIT clause of the ALTER FRAGMENT statement. For example, suppose you want to convert the table **orders** to a table fragmented by round-robin. The following SQL statement performs the conversion:

```
ALTER FRAGMENT ON TABLE orders INIT FRAGMENT BY ROUND ROBIN
```

Any existing indexes on the nonfragmented table will become fragmented with the same fragmentation strategy as the table.

Modifying a Fragmented Table

You can make two general types of modifications to a fragmented table. The first type consists of the modifications that you can make to a nonfragmented table. Such modifications include adding a column, dropping a column, changing a column data type, and so on. For these modifications, use the same SQL statements that you would normally use on a nonfragmented table.

The second type of modification consists of changes to a fragmentation strategy. This section explains how to modify a fragmentation strategy using SQL statements.

Modifying Fragmentation Strategies

The need to alter a fragmentation strategy after you implement fragmentation sometimes occurs. Most frequently, you will need to modify your fragmentation strategy when you use fragmentation with intraquery parallelization or interquery parallelization. Modifying your fragmentation strategy in these circumstances is one of several ways you can tune the performance of your OnLine system.

Using the MODIFY Clause to Change a Fragmentation Strategy

To modify an existing fragmentation strategy, use the ALTER FRAGMENT statement. Use the MODIFY clause of the ALTER FRAGMENT statement to modify one or more of the expressions in a fragmentation strategy.

For example, suppose that you initially created the fragmented table with the following CREATE TABLE statement:

```
CREATE TABLE account (acc_num INTEGER, ............)
    FRAGMENT BY EXPRESSION
        acc_num <= 1120 in dbspace1,
        acc_num > 1120 and acc_num < 2000 in dbspace2,
        REMAINDER IN dbspace3
```

Executing the following ALTER FRAGMENT statement ensures that no account numbers with a value less than or equal to zero are stored in the fragment that is contained in **dbspace1**:

```
ALTER FRAGMENT ON TABLE account
    MODIFY dbspace1 to acc_num > 0 and acc_num <=1120
```

You cannot use the MODIFY clause to alter the number of fragments contained in your distribution scheme. Use the INIT or ADD clause of ALTER FRAGMENT described in the next section instead.

Adding a New Fragment

If the modifications that you want to make require adding a new fragment to your table, use the ADD clause of the ALTER FRAGMENT statement.

For example, suppose that you want to add a fragment to a table that you created using the following SQL statement:

```
CREATE TABLE frag_table ...
    FRAGMENT BY ROUND ROBIN IN dbspace1,dbspace2,dbspace3
```

To add a fourth dbspace, **dbspace4**, execute the following SQL statement:

```
ALTER FRAGMENT ON TABLE frag_table ADD dbspace4
```

The ADD clause of ALTER FRAGMENT contains options for adding a dbspace before or after an existing dbspace, provided the fragmentation strategy is expression based. See the ALTER FRAGMENT statement in Chapter 1 of the *Informix Guide to SQL: Syntax* for more information.

Using the INIT Clause to Reinitialize a Fragmentation Scheme Completely

Consider using the INIT clause when you want to reinitialize a fragmentation strategy completely. For example, suppose that you initially created the fragmented table with the following CREATE TABLE statement:

```
CREATE TABLE account (acc_num INTEGER, ............)
    FRAGMENT BY EXPRESSION
        acc_num <= 1120 in dbspace1,
        acc_num > 1120 and acc_num < 2000 in dbspace2,
        REMAINDER IN dbspace3
```

However, after several months of operation with this distribution scheme, you find that the number of rows in the fragment contained in **dbspace2** is twice the number of rows contained in the other two fragments. This imbalance causes the disk containing **dbspace2** to become an I/O bottleneck.

To remedy this situation, you decide to modify the distribution so that the number of rows in each fragment is approximately even. You want to modify the distribution scheme so that it contains four fragments instead of three fragments. A new dbspace, **dbspace2a,** is to contain the new fragment that will store the first half of the rows previously that were contained in **dbspace2**. The fragment in **dbspace2** will contain the second half of the rows that it previously stored.

To implement the new distribution scheme, first create the dbspace **dbspace2a**. Then execute the following statement:

```
ALTER FRAGMENT ON TABLE account INIT
    FRAGMENT BY EXPRESSION
        acc_num <= 1120 in dbspace1,
        acc_num >  1120 and acc_num <= 1500 in dbspace2a,
        acc_num >  1500 and acc_num < 2000 in dbspace2,
        REMAINDER IN dbspace3
```

As soon as you execute this statement, OnLine discards the old fragmentation strategy, and the rows contained in the table are redistributed according to the new fragmentation strategy.

You can also use the INIT clause of ALTER FRAGMENT to perform the following actions:

- Convert a single nonfragmented table into a fragmented table
- Convert a fragmented table into a nonfragmented table
- Convert a table fragmented by round-robin to an expression-based fragmentation strategy
- Convert a table fragmented by expression to a round-robin fragmentation strategy

See the ALTER FRAGMENT statement in Chapter 1 of the *Informix Guide to SQL: Syntax* for more information.

Dropping a Fragment

In the process of defining a fragmentation strategy, you might find it necessary to drop one or more fragments. Suppose you wish to drop a fragment that was defined by this SQL statement:

```
CREATE TABLE frag_table (col_a int, col_b int)
    FRAGMENT BY ROUND ROBIN IN dbspace1,dbspace2,dbspace3
```

To drop the second fragment, issue the following SQL statement:

```
ALTER FRAGMENT ON TABLE frag_table DROP dbspace2
```

When you issue this statement, all the rows in **dbspace2** are moved to the remaining dbspaces, **dbspace1** and **dbspace3**. For more information on dropping fragments, see the ALTER FRAGMENT statement in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Accessing Data Stored in Fragmented Tables

Rows that are stored in nonfragmented tables can be accessed by several methods. One method is to reference the rowid of the row that you are seeking. The term *rowid* refers to an integer that defines the physical location of a row. OnLine assigns rows in a nonfragmented table a unique rowid, which allows applications access to a particular row in a table.

Rows in fragmented tables, in contrast, are *not* assigned a rowid. If you wish to access data by rowid, you must explicitly create a rowid column as described in "Creating a Rowid Column" on page 9-44. If user applications attempt to reference a rowid in a fragmented table that does not contain a rowid that you explicitly created, OnLine displays an appropriate error message, and execution of the application is halted.

Using Primary Keys Instead of Rowids

Informix recommends that you use primary keys rather than rowids as a method of access in your applications. Because primary keys are defined in the ANSI specification of SQL, using them to access data makes your applications more portable.

Refer to the *Informix Guide to SQL: Reference* and the *Informix Guide to SQL: Syntax* for a complete description of how to define and use primary keys to access data.

Rowid in a Fragmented Table

From the viewpoint of an application, the functionality of a rowid column in a fragmented table is identical to that of a rowid of a nonfragmented table. However, unlike the rowid of a nonfragmented table, OnLine uses an index to map the rowid to a physical location. Accessing data in a fragmented table by rowid is significantly slower than accessing data in a nonfragmented table by rowid. Accessing data in a fragmented table by rowid is no faster than accessing data using a primary key. In addition, primary-key access can lead to significantly improved performance in many situations, particularly when access is in parallel.

When OnLine accesses a row in a fragmented table using the rowid column, it uses an index to look up the physical address of the row before it attempts to access the row. For a nonfragmented table, OnLine uses direct physical access without having to do an index lookup. Consequently, accessing a row in a fragmented table using rowid takes slightly longer than accessing a row using rowid in a nonfragmented table. You should also expect a small performance impact on the processing of inserts and deletes due to the cost of maintaining the rowid index for fragmented tables.

The section that follows explains how to create a rowid in a fragmented table.

Creating a Rowid Column

If, for some reason, you find that your applications must access data in a fragmented table using a rowid column, you must create a rowid column for the fragmented table.

You can create the column at the same time that you create the table by using the WITH ROWIDS clause of the CREATE TABLE statement. When you issue the CREATE TABLE...WITH ROWIDS statement, OnLine creates a rowid column that adds 4 bytes to each row in the fragmented table. In addition, OnLine creates an internal index that it uses to access the data in the table by rowid. After the rowid column is created, OnLine inserts a row in the **sysfragments** catalog table, which indicates the existence and attributes of the rowid column.

If you decide that you need a rowid column after you build the fragmented table, use the ADD ROWIDS clause of the ALTER TABLE statement or the INIT clause of the ALTER FRAGMENT statement.

You can drop the rowid column from a fragmented table with the DROP ROWIDS clause of the ALTER TABLE statement. See the ALTER TABLE statement in Chapter 1 of the *Informix Guide to SQL: Syntax* for more information.

You cannot create or add a rowid column by naming it as one of the columns in a table that you create or alter. For example, you will receive an error if you execute the following statement:

```
CREATE TABLE test_table (rowid INTEGER, ....)
```

You will get the following error:

```
-227 DDL options on rowid are prohibited. error.
```

Granting and Revoking Privileges from Fragments

You need to have a strategy for controlling data distribution if you want to grant useful fragment privileges. Fragmenting data records by expression is such a strategy. The round-robin data-record distribution strategy, on the other hand, is not a useful strategy because each new data record is added to the next fragment. This distribution nullifies any clean method of tracking data distribution and therefore eliminates any real use of fragment authority. Because of this difference between expression-based distribution and round-robin distribution, the GRANT FRAGMENT and REVOKE FRAGMENT statements apply only to tables that are fragmented by an expression strategy.

Important: *If you issue a* GRANT FRAGMENT *statement or a* REVOKE FRAGMENT *statement against a table that is fragmented with a round-robin strategy, the command fails, and an error message is returned.*

When you create a fragmented table, no default fragment authority exists. Use the GRANT FRAGMENT statement to grant insert, update, or delete authority on one or more of the fragments. If you want to grant all three privileges at once, use the ALL keyword of the GRANT FRAGMENT statement. However, you cannot grant fragment privileges by merely naming the table that contains the fragments. You must name the specific fragments.

When the time comes to revoke insert, update, or delete privileges, use the REVOKE FRAGMENT statement. This statement revokes privileges on one or more fragments of a fragmented table from one or more users. If you want to revoke all privileges that currently exist for a table, you can use the ALL keyword. If no fragments are specified in the command, the permissions being revoked apply to all fragments in the table that currently have permissions.

For more information, see the GRANT FRAGMENT, REVOKE FRAGMENT and SET statements in the *Informix Guide to SQL: Syntax* reference.

Summary

This chapter covered the following work, which you must do to implement a data model:

- Specify the domains, or constraints, that are used in the model, and complete the model diagram by assigning constraints to each column.
- Use interactive SQL to create the database and the tables in it.
- If you must create the database again, write the SQL statements to do so into a script of commands for the operating system.
- Populate the tables of the model, first using interactive SQL and then by bulk operations.
- Possibly write the bulk-load operation into a command script so you can repeat it easily.
- Possibly use the fragmentation SQL statements to create, alter, and modify fragmented tables.

You can now use and test your data model. If it contains very large tables, or if you must protect parts of it from certain users, more work remains to be done. That work is one of the subjects in the *INFORMIX-OnLine Dynamic Server Performance Guide*.

Chapter

10

Granting and Limiting Access to Your Database

In some databases, all data is accessible to every user. In others, this is not the case; some users are denied access to some or all of the data. You can restrict access to data at the following levels, which are the subject of this chapter:

- When the database is stored in operating-system files, you can sometimes use the file-permission features of the operating system.

  This level is not available when INFORMIX-OnLine Dynamic Server holds the database. It manages its own disk space, and the operating-system rules do not apply.
- You can use the GRANT and REVOKE statements to give or deny access to the database or to specific tables, and you can control the kinds of uses that people can make of the database.
- You can use the CREATE PROCEDURE statement to write and compile a stored procedure, which controls and monitors the users who can read, modify, or create database tables.
- You can use the CREATE VIEW statement to prepare a restricted or modified view of the data. The restriction can be vertical, which excludes certain columns, or horizontal, which excludes certain rows, or both.
- You can combine GRANT and CREATE VIEW statements to achieve precise control over the parts of a table that a user can modify and with what data.

In addition to these points, INFORMIX-OnLine / Secure offers a type of automatic security that is called mandatory access control (MAC). With MAC, all users and all data are assigned a security label, and OnLine / Secure compares the labels before it allows access. For example, a user with the TOP SECRET label could view an UNCLASSIFIED row, but an UNCLASSIFIED user could not view a TOP SECRET row. This topic and other topics related to security in OnLine / Secure are addressed in the *INFORMIX-OnLine/Secure Security Features User's Guide*.

Controlling Access to Databases

The normal database-privilege mechanisms are based on the GRANT and REVOKE statements. They are covered in "Granting Privileges" on page 10-5. However, you can sometimes use the facilities of the operating system as an additional way to control access to a database.

Securing Database Files

Database servers other than INFORMIX-OnLine Dynamic Server store databases in operating-system files. Typically, a database is represented as a number of files: one for each table, one for the indexes on each table, and possibly others. The files are collected in a directory. The directory represents the database as a whole.

Multiuser Systems

To deny access to the database, you can deny access to the database directory. Your operating system and your computer hardware determine the means by which you can do this. Multiuser operating systems provide software facilities such as UNIX file permissions.

Important: *In UNIX, the database directory is created with group identity* ***informix****, and the database server always runs under group identity* ***informix****. Thus, you cannot use group permissions to restrict access to a particular group of users. You can, however, remove all group permissions (file mode 700) and deny access to anyone except the owner of the directory.*

You can also deny access to individual tables in this way; for example, by making the files that represent those tables unavailable to certain users, while leaving the rest of the files accessible. However, the database servers are not designed for tricks of this kind. When an unauthorized user tries to query one of the tables, the database server probably returns an error message about not being able to locate a file. This message can confuse users.

Single-User Systems

Typical single-user systems have few software controls on file access; you can make a database inaccessible to others only by writing it on a disk that you can detach from the computer and keep locked.

None of these techniques apply when you use the OnLine database server. It controls its own disk space at the device level, bypassing the file-access mechanisms of the operating system.

Securing Confidential Data

No matter what access controls the operating system gives you, when the contents of an entire database are highly sensitive, you might not want to leave it on a public disk that is fixed to the computer. You can circumvent normal software controls when the data must be secure.

When you or another authorized person is not using the database, it does not have to be available on-line. You can make it inaccessible in one of the following ways, which have varying degrees of inconvenience:

- Detach the physical medium from the computer, and take it away. If the disk itself is not removable, the disk drive might be removable.
- Copy the database directory to tape, and take possession of the tape.
- Use an encryption utility to copy the database files. Keep only the encrypted version.

In the latter two cases, after making the copies, you must remember to erase the original database files using a program that overwrites an erased file with null data.

Instead of removing the entire database directory, you can copy and then erase the files that represent individual tables. Do not overlook the fact that index files contain copies of the data from the indexed column or columns. Remove and erase the index files as well as the table files.

Granting Privileges

The authorization to use a database is called a *privilege*. For example, the authorization to use a database is called the Connect privilege, and the authorization to insert a row into a table is called the Insert privilege. You control the use of a database by granting these privileges to other users or by revoking them.

Two groups of privileges control the actions a user can perform on data. These include database-level privileges, which affect the entire database, and table-level privileges, which relate to individual tables. In addition to these two groups, procedure-level priviliges determine who can execute a procedure.

Database-Level Privileges

The three levels of database privilege provide an overall means of controlling who accesses a database.

Connect Privilege

The least of the privilege levels is Connect, which gives a user the basic ability to query and modify tables. Users with the Connect privilege can perform the following functions:

- Execute the SELECT, INSERT, UPDATE, and DELETE statements, provided that they have the necessary table-level privileges
- Execute a stored procedure, provided that they have the necessary table-level privileges
- Create views, provided that they are permitted to query the tables on which the views are based
- Create temporary tables and create indexes on the temporary tables

Before users can access a database, they must have the Connect privilege. Ordinarily, in a database that does not contain highly sensitive or private data, you give the GRANT CONNECT TO PUBLIC privilege shortly after you create the database.

If you do not grant the Connect privilege to **public**, the only users who can access the database through the database server are those to whom you specifically grant the Connect privilege. If limited users should have access, this privilege lets you provide it to them and deny it to all others.

The Users and the Public

Privileges are granted to single users by name or to all users under the name of **public**. Any privileges granted to **public** serve as default privileges.

Prior to executing a statement, the database server determines whether a user has the necessary privileges. (The information is in the system catalog; see "Privileges in the System Catalog" on page 10-10.)

The database server looks first for privileges that are granted specifically to the requesting user. If it finds such a grant, it uses that information. It then checks to see if less restrictive privileges have been granted to **public**. If so, the database server uses the less-restrictive privileges. If no grant has been made to that user, the database server looks for privileges granted to **public**. If it finds a relevant privilege, it uses that one.

Thus, to set a minimum level of privilege for all users, grant privileges to **public**. You can override that, in specific cases, by granting higher individual privileges to users.

Resource Privilege

The Resource privilege carries the same authorization as the Connect privilege. In addition, users with the Resource privilege can create new, permanent tables, indexes, and stored procedures, thus permanently allocating disk space.

Database Administrator Privilege

The highest level of database privilege is *Database Administrator*, or DBA. When you create a database, you are automatically the DBA. Holders of the DBA privilege can perform the following functions:

- Execute the DROP DATABASE, START DATABASE, and ROLLFORWARD DATABASE statements
- Drop or alter any object regardless of who owns it
- Create tables, views, and indexes to be owned by other users
- Grant database privileges, including the DBA privilege, to another user
- Alter the NEXT SIZE (but no other attribute) of the system catalog tables, and insert, delete, or update rows of any system catalog table except **systables**

Warning: *Although users with the DBA privilege can modify most system catalog tables, Informix strongly recommends that you do not update, delete, or insert any rows in them. Modifying the system catalog tables can destroy the integrity of the database. Informix does support using the ALTER TABLE statement to modify the size of the next extent of system catalog tables.*

Ownership Rights

The database, and every table, view, index, procedure, and synonym in it, has an owner. The owner of an object is usually the person who created it, although a user with the DBA privilege can create objects to be owned by others.

The owner of an object has all rights to that object and can alter or drop it without additional privileges.

Table-Level Privileges

You can apply seven privileges, table by table, to allow nonowners the privileges of owners. Four of them, the Select, Insert, Delete, and Update privileges, control access to the contents of the table. The Index privilege controls index creation. The Alter privilege controls the authorization to change the table definition. The References privilege controls the authorization to specify referential constraints on a table.

In an ANSI-compliant database, only the table owner has any privileges. In other databases, the database server, as part of creating a table, automatically grants all table privileges except Alter and References to **public**. Automatically granting all table privileges to **public** means that a newly created table is accessible to any user with the Connect privilege. If this is not what you want (if users exist with the Connect privilege who should not be able to access this table), you must revoke all privileges on the table from **public** after you create the table.

Access Privileges

Four privileges govern how users can access a table. As the owner of the table, you can grant or withhold the following privileges independently:

- The Select privilege allows selection, including selecting into temporary tables.
- The Insert privilege allows a user to add new rows.
- The Update privilege allows a user to modify existing rows.
- The Delete privilege allows a user to delete rows.

The Select privilege is necessary for a user to retrieve the contents of a table. However, the Select privilege is not a precondition for the other privileges. A user can have Insert or Update privileges without having the Select privilege.

For example, your application might have a usage table. Every time a certain program is started, it inserts a row into the usage table to document that it was used. Before the program terminates, it updates that row to show how long it ran and perhaps to record counts of work its user performed.

If you want any user of the program to be able to insert and update rows in this usage table, grant Insert and Update privileges on it to **public**. However, you might grant the Select privilege to only a few users.

Privileges in the System Catalog

Privileges are recorded in the system catalog tables. Any user with the Connect privilege can query the system catalog tables to determine what privileges have been granted and to whom.

Database privileges are recorded in the **sysusers** table, in which the primary key is user ID, and the only other column contains a single character `C`, `R`, or `D` for the privilege level. A grant to the keyword of PUBLIC is reflected as a user name of **public** (lowercase).

Table-level privileges are recorded in **systabauth**, which uses a composite primary key of the table number, grantor, and grantee. In the **tabauth** column, the privileges are encoded in the list that the following diagram shows.

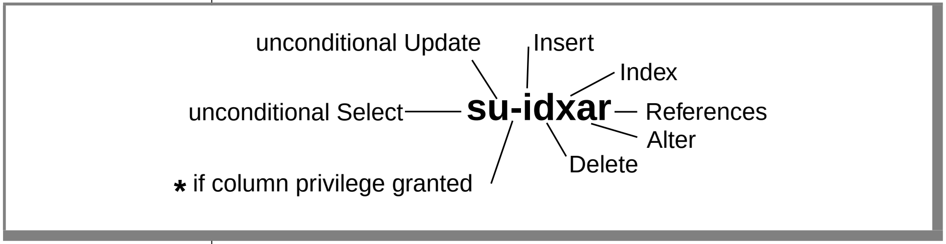


Figure 10-1
List of Encoded Priviliges

A hyphen means an ungranted privilege, so that a grant of all privileges is shown as `su-idxar`, and `-u------` shows a grant of only Update. The code letters are normally lowercase, but they are uppercase when the keywords WITH GRANT OPTION are used in the GRANT statement.

When an asterisk (*) appears in the third position, some column-level privilege exists for that table and grantee. The specific privilege is recorded in **syscolauth**. Its primary key is a composite of the table number, the grantor, the grantee, and the column number. The only attribute is a three-letter list that shows the type of privilege: `s`, `u`, or `r`.

Index, Alter, and References Privileges

The Index privilege permits its holder to create and alter indexes on the table. The Index privilege, similar to the Select, Insert, Update, and Delete privileges, is granted automatically to **public** when a table is created.

You can grant the Index privilege to anyone, but to exercise the ability, the user must also hold the Resource database privilege. So, although the Index privilege is granted automatically (except in ANSI-compliant databases), users who have only the Connect privilege to the database cannot exercise their Index privilege. Such a limitation is reasonable because an index can fill a large amount of disk space.

The Alter privilege permits its holder to use the ALTER TABLE statement on the table, including the power to add and drop columns, reset the starting point for SERIAL columns, and so on. You should grant the Alter privilege only to users who understand the data model very well and whom you trust to exercise their power very carefully.

The References privilege allows you to impose referential constraints on a table. As with the Alter privilege, you should grant the References privilege only to users who understand the data model very well.

Column-Level Privileges

You can qualify the Select, Update, and References privileges with the names of specific columns. Naming specific columns allows you to grant very specific access to a table. You can permit a user to see only certain columns, to update only certain columns, or to impose referential constraints on certain columns.

Using INFORMIX-OnLine Dynamic Server (so that table data can be inspected only through a call to the database server), this feature solves the problem that only certain users should know the salary, performance review or other sensitive attributes of an employee. To make the example specific, suppose a table of employee data is defined as the following example shows:

```
CREATE TABLE hr_data
    (
    emp_key INTEGER,
    emp_name CHAR(40),
    hire_date DATE,
    dept_num SMALLINT,
    user-id CHAR(18),
    salary DECIMAL(8,2)
    performance_level CHAR(1),
    performance_notes TEXT
    )
```

Because this table contains sensitive data, you execute the following statement immediately after you create it:

```
REVOKE ALL ON hr_data FROM PUBLIC
```

For selected persons in the Human Resources department and for all managers, you execute the following statement:

```
GRANT SELECT ON hr_data TO harold_r
```

In this way, you permit certain users to view all columns. (The final section of this chapter discusses a way to limit the view of managers to their employees only.) For the first-line managers who carry out performance reviews, you could execute a statement such as the following one:

```
GRANT UPDATE (performance_level, performance_notes)
    ON hr_data TO wallace_s, margot_t
```

This statement permits the managers to enter their evaluations of their employees. You would execute a statement such as the following one only for the manager of the Human Resources department or whoever is trusted to alter salary levels:

```
GRANT UPDATE (salary) ON hr_data to willard_b
```

For the clerks in the Human Resources department, you could execute a statement such as the following one:

```
GRANT UPDATE (emp_key, emp_name, hire_date, dept_num)
    ON hr_data TO marvin_t
```

This statement gives certain users the ability to maintain the nonsensitive columns but denies them authorization to change performance ratings or salaries. The person in the MIS department who assigns computer user IDs is the beneficiary of a statement such as the following one:

```
GRANT UPDATE (user_id) ON hr_data TO eudora_b
```

On behalf of all users who are allowed to connect to the database, but who are not authorized to see salaries or performance reviews, execute statements such as the following one to permit them to see the nonsensitive data:

```
GRANT SELECT (emp_key, emp_name, hire_date, dept_num, user-id)
   ON hr_data TO george_b, john_s
```

These users can perform queries such as the following one:

```
SELECT COUNT(*) FROM hr_data WHERE dept_num IN (32,33,34)
```

However, any attempt to execute a query such as the following one produces an error message and no data:

```
SELECT performance_level FROM hr_data
    WHERE emp_name LIKE '*Smythe'
```

Procedure-Level Privileges

You can apply the Execute privilege on a procedure to authorize nonowners to run a procedure. If you create a procedure in a database that is not ANSI compliant, the default procedure-level privilege is PUBLIC; you do not need to grant the Execute privilege to specific users unless you have first revoked it. If you create a procedure in an ANSI-compliant database, no other users have the Execute privilege by default; you must grant specific users the Execute privilege. The following example grants the Execute privilege to the user **orion** so that **orion** can use the stored procedure that is named **read-address**:

```
GRANT EXECUTE ON read_address TO orion;
```

Procedure-level privileges are recorded in the **sysprocauth** system catalog table. The **sysprocauth** table uses a primary key of the procedure number, grantor, and grantee. In the **procauth** column, the execute privilege is indicated by a lowercase letter *e*. If the execute privilege was granted with the WITH GRANT option, the privilege is represented by an uppercase letter *E*.

For more information on procedure-level privileges, see "Privileges on Stored Procedures" on page 12-15.

Automating Privileges

This design might seem to force you to execute a tedious number of GRANT statements when you first set up the database. Furthermore, privileges require constant maintenance as people change jobs. For example, if a clerk in Human Resources is terminated, you want to revoke the Update privilege as soon as possible; otherwise the unhappy employee might execute a statement such as the following one:

```
UPDATE hr_data
    SET (emp_name, hire_date, dept_num) = (NULL, NULL, 0)
```

Less dramatic, but equally necessary, changes of privilege are required daily, or even hourly, in any model that contains sensitive data. If you anticipate this need, you can prepare some automated tools to help maintain privileges.

Your first step should be to specify privilege classes that are based on the jobs of the users, not on the structure of the tables. For example, a first-line manager needs the following privileges:

- The Select and limited Update privilege on the hypothetical **hr_data** table
- The Connect privilege to this and other databases
- Some degree of privilege on several tables in those databases

When the manager is promoted to a staff position or sent to a field office, you must revoke all those privileges and grant a new set of privileges.

Define the privilege classes you support, and for each class specify the databases, tables, and columns to which you must give access. Then devise two automated procedures for each class, one to grant the class to a user and one to revoke it.

Automating with INFORMIX-4GL

The mechanism you use depends on your operating system and other tools. If you are a programmer, one of the tools you can use is INFORMIX-4GL. 4GL makes it easy to program a simple user interaction, as the following example shows:

```
DEFINE mgr_id char(20)
PROMPT 'What is the user-id of the new manager? ' FOR mgr_id
CALL table_grant ('SELECT', 'hr_data', mgr_id)
```

Unfortunately, although INFORMIX-4GL allows you to mix GRANT and REVOKE statements freely with other program statements, it does not let you create parameters from them from program variables. To customize a GRANT statement with a user ID that is taken from user input, the program must build the statement as a string, prepare it with a PREPARE statement, and execute it with an EXECUTE statement. (These statements are discussed in detail in Chapter 5, “Programming with SQL,” where the following example is analyzed in detail.)

The following example shows one possible definition of the 4GL function **table_grant()**, which is invoked by the CALL statement in the preceding example:

```
FUNCTION table_grant (priv_to_grant, table_name, user_id)
    DEFINE  priv_to_grant char(100),{may include column-
list}
            table_name CHAR(20),
            user_id CHAR(20),
            grant_stmt CHAR(200)
    LET grant_stmt =' GRANT ', priv_to_grant,
                    ' ON ', table_name,
                    ' TO ', user_id
    WHENEVER ERROR CONTINUE
    PREPARE the_grant FROM grant_stmt
    IF status = 0 THEN
        EXECUTE the_grant
    END IF
    IF status <> 0 THEN
        DISPLAY 'Sorry, got error #', status, 'attempting:'
        DISPLAY '      ', grant_stmt
    END IF
    WHENEVER ERROR STOP
END FUNCTION
```

Automating with a Command Script

Your operating system probably supports automatic execution of command scripts. In most operating environments, interactive SQL tools such as DB-Access and INFORMIX-SQL accept commands and SQL statements to execute from the command line. You can combine these two features to automate privilege maintenance.

The details depend on your operating system and the version of DB-Access or INFORMIX-SQL that you are using. In essence, you want to create a command script that performs the following functions:

- Takes a user ID whose privileges are to be changed as its parameter
- Prepares a file of GRANT or REVOKE statements customized to contain that user ID
- Invokes DB-Access or INFORMIX-SQL with parameters that tell it to select the database and execute the prepared file of GRANT or REVOKE statements

In this way, you can reduce the change of the privilege class of a user to one or two commands.

Using Roles

Another way to avoid the difficulty of changing user privileges on a case by case basis is to use roles. The concept of a role in the database environment is similar to the group concept in an operating system. A role is a database feature that lets the DBA standardize and change the privileges of many users by treating them as members of a class.

For example, you can create a role called *news_mes* that grants connect, insert, and delete privileges for the databases that handle company news and messages. When a new employee arrives, you need only add that person to the role *news_mes*. The new employee acquires the privileges of the role *news_mes*. This process also works in reverse. To change the privileges of all the members of *news_mes*, change the privileges of the role.

Creating a Role

To start the role creation process, determine the name of the role along with the connections and privileges you want to grant. Although the connections and privileges are strictly in your domain, you need to consider some factors when you name a role. Do not use any of the following words as role names.

alter	default	index	null	resource
connect	delete	insert	public	select
DBA	execute	none	references	update

A role name must be different from existing role names in the database. A role name must also be different from user names that are known to the operating system, including network users known to the server machine. To make sure your role name is unique, check the names of the users in the shared memory structure who are currently using the database as well as the following system catalog tables:

- **sysusers**
- **systabauth**
- **syscolauth**
- **sysprocauth**
- **sysfragauth**
- **sysroleauth**

When the situation is reversed, and you are adding a user to the database, check that the user name is not the same as any of the existing role names.

After you have approved the role name, use the CREATE ROLE statement to create a new role. After the role is created, all privileges for role administration are, by default, given to the DBA.

Manipulating User Privileges and Granting Roles to Other Roles

As DBA, you can use the GRANT statement to grant role privileges to users. You can also give a user the option to grant privileges to other users. Use the WITH GRANT OPTION clause of the GRANT statement to do this. You can use the WITH GRANT OPTION clause only when you are granting privileges to a user.

For example, the following query returns an error because you are granting privileges to a role with the grantable option:

```
GRANT SELECT on tab1 to rol1
    WITH GRANT OPTION
```

Important: *Do not use the WITH GRANT OPTION clause of the GRANT statement when you grant privileges to a role. Only a user can grant privileges to other users.*

When you grant role privileges, you can substitute a role name for the user name in the GRANT statement. You can grant a role to another role. For example, say that role A is granted to role B. When a user enables role B, the user gets privileges from both role A and role B.

However, a cycle of role-grant cannot be transitive. If role A is granted role B, and role B is granted role C, then granting C to A returns an error.

If you need to change privileges, use the REVOKE statement to delete the existing privileges, and then use the GRANT statement to add the new privileges.

Users Need to Enable Roles

After the DBA grants privileges and adds users to a role, you must use the SET ROLE statement in a database session to enable the role. Unless you enable the role, you are limited to the privileges that are associated with PUBLIC or the privileges that are directly granted to you because you are the owner of the object.

Confirming Membership In Roles and Dropping Roles

You can find yourself in a situation where you are uncertain which user is included in a role. Perhaps you did not create the role or the person who created the role is not available. Issue queries against the **sysroleauth** and **sysusers** tables to find who is authorized for which table and how many roles are in existence.

After you determine which users are members of which roles, you might discover that some roles are no longer useful. To remove a role, use the DROP ROLE statement. Before you remove a role, the following conditions must be met:

- Only roles that are listed in the **sysusers** catalog table as a role can be destroyed.
- You must have DBA privileges, or you must be given the grantable option in the role to drop a role.

Controlling Access to Data Using Stored Procedures

You can use a stored procedure to control access to individual tables and columns in the database. You can accomplish various degrees of access control through a procedure. (Stored procedures are fully described in Chapter 12, "Creating and Using Stored Procedures.") A powerful feature of Stored Procedure Language (SPL) is the ability to designate a stored procedure as a DBA-privileged procedure. When you write a DBA-privileged procedure, you can allow users who have few or no table privileges to have DBA privileges when they execute the procedure. In the procedure, users can carry out very specific tasks with their temporary DBA privilege. The DBA-privileged feature lets you accomplish the following tasks:

- You can restrict how much information individual users can read from a table.
- You can restrict all the changes that are made to the database and ensure that entire tables are not emptied or changed accidentally.
- You can monitor an entire class of changes made to a table, such as deletions or insertions.
- You can restrict all object creation (data definition) to occur within a stored procedure so that you have complete control over how tables, indexes, and views are built.

Restricting Reads of Data

The procedure in the following example hides the SQL syntax from users, but it requires that users have the Select privilege on the **customer** table. If you want to restrict what users can select, write your procedure to work in the following environment:

- You are the DBA of the database.
- The users have the Connect privilege to the database. They do not have the Select privilege on the table.
- Your stored procedure (or set of stored procedures) is created using the DBA keyword.
- Your stored procedure (or set of stored procedures) reads from the table for users.

If you want users to read only the name, address, and telephone number of a customer, you can modify the procedure as the following example shows:

```
CREATE DBA PROCEDURE read_customer(cnum INT)
RETURNING CHAR(15), CHAR(15), CHAR(18);

DEFINE p_lname,p_fname CHAR(15);
DEFINE p_phone CHAR(18);

SELECT fname, lname, phone
    INTO p_fname, p_lname, p_phone
    FROM customer
    WHERE customer_num = cnum;

RETURN p_fname, p_lname, p_phone;

END PROCEDURE;
```

Restricting Changes to Data

Using stored procedures, you can restrict changes made to a table. Simply channel all changes through a stored procedure. The stored procedure makes the changes, rather than users making the changes directly. If you want to limit users to deleting one row at a time to ensure that they do not accidentally remove all the rows in the table, set up the database with the following privileges:

- You are the DBA of the database.
- All the users have the Connect privilege to the database. They might have the Resource privilege. They do not have the Delete privilege (for this example) on the table being protected.
- Your stored procedure is created using the DBA keyword.
- Your stored procedure performs the deletion.

Write a stored procedure similar to the following one, which deletes rows from the **customer** table using a WHERE clause with the **customer_num** that the user provides:

```
CREATE DBA PROCEDURE delete_customer(cnum INT)

DELETE FROM customer
    WHERE customer_num = cnum;

END PROCEDURE;
```

Monitoring Changes to Data

Using stored procedures, you can create a record of changes made to a database. You can record changes made by a particular user, or you can make a record of each time a change is made.

You can monitor all the changes made to the database by a single user. Simply channel all changes through stored procedures that keep track of changes that each user makes. If you want to record each time the user **acctclrk** modifies the database, set up the database with the following privileges:

- You are the DBA of the database.
- All other users have the Connect privilege to the database. They might have the Resource privilege. They do not have the Delete privilege (for this example) on the table being protected.
- Your stored procedure is created using the DBA keyword.
- Your stored procedure performs the deletion and records that a certain user has made a change.

Write a stored procedure similar to the following one, which uses a customer number the user provides to update a table. If the user happens to be **acctclrk**, a record of the deletion is put in the file **updates**.

```
CREATE DBA PROCEDURE delete_customer(cnum INT)

DEFINE username CHAR(8);

DELETE FROM customer
    WHERE customer_num = cnum;

IF username = 'acctclrk' THEN
    SYSTEM 'echo Delete from customer by acctclrk >>
/mis/records/updates' ;
ENF IF
END PROCEDURE;
```

To monitor all the deletions made through the procedure, remove the IF statement and make the SYSTEM statement more general. If you change the previous procedure to record all deletions, it looks like the procedure shown next.

```
CREATE DBA PROCEDURE delete_customer(cnum INT)

DEFINE username CHAR(8);
LET username = USER ;
DELETE FROM tbname WHERE customer_num = cnum;

SYSTEM
 'echo Deletion made from customer table, by '||username
||'>>/hr/records/deletes';

END PROCEDURE;
```

Restricting Object Creation

To put restraints on what objects are built and how they are built, use stored procedures within the following setting:

- You are the DBA of the database.
- All the other users have the Connect privilege to the database. They do not have the Resource privilege.
- Your stored procedure (or set of stored procedures) is created using the DBA keyword.
- Your stored procedure (or set of stored procedures) creates tables, indexes, and views in the way you defined them. You might use such a procedure to set up a training database environment.

Your procedure might include the creation of one or more tables and associated indexes, as the following example shows:

```
CREATE DBA PROCEDURE all_objects()

CREATE TABLE learn1 (intone SERIAL, inttwo INT NOT NULL,
charcol CHAR(10) );
CREATE INDEX learn_ix ON learn1 (inttwo);
CREATE TABLE toys (name CHAR(15) NOT NULL UNIQUE,
            description CHAR(30), on_hand INT);
END PROCEDURE;
```

To use the **all_objects** procedure to control additions of columns to tables, revoke the Resource privilege on the database from all users. When users try to create a table, index, or view using an SQL statement outside your procedure, they cannot do so. When users execute the procedure, they have a temporary DBA privilege so the CREATE TABLE statement, for example, succeeds, and you are guaranteed that every column that is added has a constraint that is placed on it. In addition, objects that users create are owned by that user. For the **all_objects** procedure, whoever executes the procedure owns the two tables and the index.

Using Views

A *view* is a synthetic table. You can query it as if it were a table, and in some cases, you can update it as if it were a table. However, it is not a table. It is a synthesis of the data that exists in real tables and other views.

The basis of a view is a SELECT statement. When you create a view, you define a SELECT statement that generates the contents of the view at the time the view is accessed. A user also queries a view using a SELECT statement. The database server merges the SELECT statement of the user with the one defined for the view and then actually performs the combined statements.

The result has the appearance of a table; it is similar enough to a table that a view even can be based on other views, or on joins of tables and other views.

Because you write a SELECT statement that determines the contents of the view, you can use views for any of the following purposes:

- To restrict users to particular columns of tables

  You name only permitted columns in the select list in the view.
- To restrict users to particular rows of tables

  You specify a WHERE clause that returns only permitted rows.
- To constrain inserted and updated values to certain ranges

  You can use the WITH CHECK OPTION (discussed on page 10-30) to enforce constraints.
- To provide access to derived data without having to store redundant data in the database

  You write the expressions that derive the data into the select list in the view. Each time you query the view, the data is derived anew. The derived data is always up to date, yet no redundancies are introduced into the data model.
- To hide the details of a complicated SELECT statement

  You hide complexities of a multitable join in the view so that neither users nor application programmers need to repeat them.

Creating Views

The following example creates a view based on a table in the **stores7** database:

```
CREATE VIEW name_only AS
SELECT customer_num, fname, lname FROM customer
```

The view exposes only three columns of the table. Because it contains no WHERE clause, the view does not restrict the rows that can appear.

GLS

The following example creates a view based on a table that is available when a locale other than the default U.S. English locale using the ISO8859-1 code set has been enabled. In the example, the view, column, and table names contain non-English characters.

```
CREATE VIEW çà_va AS
SELECT numéro, nom FROM abonnés; ♦
```

The following example is based on the join of two tables:

```
CREATE VIEW full_addr AS
SELECT address1, address2, city, state.sname, zipcode
    FROM customer, state
    WHERE customer.state = state.code
```

The table of state names reduces the redundancy of the database; it lets you store the full state names only once, which can be useful for long state names such as Minnesota. This **full_addr** view lets users retrieve the address as if the full state name were stored in every row. The following two queries are equivalent:

```
SELECT * FROM full_addr WHERE customer_num = 105

SELECT address1, address2, city, state.sname, zipcode
    FROM customer, state
    WHERE customer.state = state.code
        AND customer_num = 105
```

However, be careful when you define views that are based on joins. Such views are not *modifiable*; that is, you cannot use them with UPDATE, DELETE, or INSERT statements. (Modifying through views is covered beginning on page 10-28.)

The following example restricts the rows that can be seen in the view:

```
CREATE VIEW no_cal_cust AS
    SELECT * FROM customer WHERE NOT state = 'CA'
```

This view exposes all columns of the **customer** table, but only certain rows. The following example is a view that restricts users to rows that are relevant to them:

```
CREATE VIEW my_calls AS
    SELECT * FROM cust_calls WHERE user_id = USER
```

All the columns of the **cust_calls** table are available but only in those rows that contain the user IDs of the users who can execute the query.

Duplicate Rows from Views

A view might produce duplicate rows, even when the underlying table has only unique rows. If the view SELECT statement can return duplicate rows, the view itself can appear to contain duplicate rows.

You can prevent this problem in two ways. One way is to specify DISTINCT in the select list in the view. However, specifying DISTINCT makes it impossible to modify through the view. The alternative is to always select a column or group of columns that is constrained to be unique. (You can be sure that only unique rows are returned if you select the columns of a primary key or of a candidate key. Primary and candidate keys are discussed in Chapter 8, "Building Your Data Model.")

Restrictions on Views

Because a view is not really a table, it cannot be indexed, and it cannot be the object of such statements as ALTER TABLE and RENAME TABLE. The columns of a view cannot be renamed with RENAME COLUMN. To change anything about the definition of a view, you must drop the view and re-create it.

Because it must be merged with the user's query, the SELECT statement on which a view is based cannot contain any of the following clauses:

INTO TEMP	The user's query might contain INTO TEMP; if the view also contains it, the data would not know where to go.
UNION	The user's query might contain UNION. No meaning has been defined for nested UNION clauses.
ORDER BY	The user's query might contain ORDER BY. If the view also contains it, the choice of columns or sort directions could be in conflict.

When the Basis Changes

The tables and views on which a view is based can change in several ways. The view automatically reflects most of the changes.

When a table or view is dropped, any views in the same database that depend on it are automatically dropped.

The only way to alter the definition of a view is to drop and re-create it. Therefore, if you change the definition of a view on which other views depend, you must also re-create the other views (because they all have been dropped).

When a table is renamed, any views in the same database that depend on it are modified to use the new name. When a column is renamed, views in the same database that depend on that table are updated to select the proper column. However, the names of columns in the views themselves are not changed. For an example of this, recall the following view on the **customer** table:

```
CREATE VIEW name_only AS
    SELECT customer_num, fname, lname FROM customer
```

Now suppose that the **customer** table is changed in the following way:

```
RENAME COLUMN customer.lname TO surname
```

To select last names of customers directly, you must now select the new column name. However, the name of the column as seen through the view is unchanged. The following two queries are equivalent:

```
SELECT fname, surname FROM customer
```

```
SELECT fname, lname FROM name_only
```

When you alter a table by dropping a column, views are not modified. If they are used, error -217 (`Column not found in any table in the query`) occurs. The reason views are not dropped is that you can change the order of columns in a table by dropping a column and then adding a new column of the same name. If you do this, views based on that table continue to work. They retain their original sequence of columns.

INFORMIX-OnLine Dynamic Server permits you to base a view on tables and views in external databases. Changes to tables and views in other databases are not reflected in views. Such changes might not be apparent until someone queries the view and gets an error because an external table changed.

Modifying Through a View

You can modify views as if they were tables. Some views can be modified and others not, depending on their SELECT statements. The restrictions are different, depending on whether you use DELETE, UPDATE, or INSERT statements.

No modification is possible on a view when its SELECT statement contains any of the following features:

- A join of two or more tables

  Many anomalies arise if the database server tries to distribute modified data correctly across the joined tables.
- An aggregate function or the GROUP BY clause

  The rows of the view represent many combined rows of data; the database server cannot distribute modified data into them.
- The DISTINCT keyword or its synonym UNIQUE

  The rows of the view represent a selection from among possibly many duplicate rows; the database server cannot tell which of the original rows should receive the modification.

When a view avoids all these things, each row of the view corresponds to exactly one row of one table. Such a view is *modifiable*. (Of course, particular users can modify a view only if they have suitable privileges. Privileges on views are discussed beginning on page 10-31.)

Deleting Through a View

A modifiable view can be used with a DELETE statement as if it were a table. The database server deletes the proper row of the underlying table.

Updating a View

You can use a modifiable view with an UPDATE statement as if it were a table. However, a modifiable view can still contain derived columns; that is, columns that are produced by expressions in the select list of the CREATE VIEW statement. You cannot update derived columns (sometimes called *virtual* columns).

When a column is derived from a simple arithmetic combination of a column with a constant value (for example, `order_date+30`), the database server can, in principle, figure out how to invert the expression (in this case, by subtracting 30 from the update value) and perform the update. However, much more complicated expressions are possible, most of which cannot easily be inverted. Therefore, the database server does not support updating any derived column.

The following example shows a modifiable view that contains a derived column and an UPDATE statement that can be accepted against it:

```
CREATE VIEW call_response(user_id,received,resolved,duration
        )AS
    SELECT user_id,call_dtime,res_dtime, res_dtime
        call_dtime
        FROM cust_calls
        WHERE user_id = USER

UPDATE call_response SET resolved = TODAY
    WHERE resolved IS NULL
```

The duration column of the view cannot be updated because it represents an expression (the database server cannot, even in principle, decide how to distribute an update value between the two columns named in the expression). But as long as no derived columns are named in the SET clause, the update can be performed as if the view were a table.

A view can return duplicate rows even though the rows of the underlying table are unique. You cannot distinguish one duplicate row from another. If you update one of a set of duplicate rows (for example, by using a cursor to update WHERE CURRENT), you cannot be sure which row in the underlying table receives the update.

Inserting into a View

You can insert rows into a view provided that the view is modifiable *and* contains no derived columns. The reason for the second restriction is that an inserted row must provide values for all columns, and the database server cannot tell how to distribute an inserted value through an expression. An attempt to insert into the **call_response** view, as the previous example shows, would fail.

When a modifiable view contains no derived columns, you can insert into it as if it were a table. However, the database server uses null as the value for any column that is not exposed by the view. If such a column does not allow nulls, an error occurs, and the insert fails.

Using WITH CHECK OPTION

You can insert into a view a row that does not satisfy the conditions of the view; that is, a row that is not visible through the view. You can also update a row of a view so that it no longer satisfies the conditions of the view.

To avoid updating a row of a view so that it no longer satisfies the conditions of the view, you can add the clause WITH CHECK OPTION when you create the view. This clause asks the database server to test every inserted or updated row to ensure that it meets the conditions set by the WHERE clause of the view. The database server rejects the operation with an error if the conditions are not met.

In the previous example, the view named **call_response** is defined as the following example shows:

```
CREATE VIEW call_response(user_id,received,resolved,duration)AS
    SELECT user_id,call_dtime,res_dtime,res_dtime-call_dtime
        FROM cust_calls
        WHERE user_id = USER
```

You can update the **user_id** column of the view, as the following example shows:

```
UPDATE call_response SET user_id = 'lenora'
    WHERE received BETWEEN TODAY AND TODAY-7
```

The view requires rows in which **user_id** equals USER. If a user named **tony** performs this update, the updated rows vanish from the view. However, you can create the view as the following example shows:

```
CREATE VIEW call_response(user_id,received,resolved,duration) AS
    SELECT user_id,call_dtime,res_dtime,res_dtime-call_dtime
        FROM cust_calls
        WHERE user_id = USER
WITH CHECK OPTION
```

The preceding update by **tony** is rejected as an error.

You can use the WITH CHECK OPTION feature to enforce any kind of data constraint that can be stated as a Boolean expression. In the following example, you can create a view of a table in which all the logical constraints on data are expressed as conditions of the WHERE clause. Then you can require all modifications to the table to be made through the view.

```
CREATE VIEW order_insert AS
    SELECT * FROM orders O
        WHERE order_date = TODAY -- no back-dated entries
            AND EXISTS -- ensure valid foreign key
                (SELECT * FROM customer C
                    WHERE O.customer_num = C.customer_num)
            AND ship_weight < 1000 -- reasonableness checks
            AND ship_charge < 1000
WITH CHECK OPTION
```

Because of EXISTS and other tests, which are expected to be successful when retrieving existing rows, this view displays data from **orders** inefficiently. However, if insertions to **orders** are made only through this view (and you are not already using integrity constraints to constrain data), users cannot insert a back-dated order, an invalid customer number, or an excessive shipping weight and shipping charge.

Privileges and Views

When you *create* a view, the database server tests your privileges on the underlying tables and views. When you *use* a view, only your privileges with regard to the view are tested.

Privileges When Creating a View

Therefore, the database server tests to make sure that you have all the privileges that you need to execute the SELECT statement in the view definition. If you do not, the view is not created.

This test ensures that users cannot gain unauthorized access to a table by creating a view on the table and querying the view.

After you create the view, the database server grants you, the creator and owner of the view, at least the Select privilege on it. No automatic grant is made to **public**, as is the case with a newly created table.

The database server tests the view definition to see if the view is modifiable. If it is, the database server grants you the Insert, Delete, and Update privileges on the view, provided that you also have those privileges on the underlying table or view. In other words, if the new view is modifiable, the database server copies your Insert, Delete, and Update privileges from the underlying table or view, and grants them on the new view. If you have only the Insert privilege on the underlying table, you receive only the Insert privilege on the view.

This test ensures that users cannot use a view to gain access to any privileges that they did not already have.

Because you cannot alter or index a view, the Alter and Index privileges are never granted on a view.

Privileges When Using a View

When you attempt to use a view, the database server tests only the privileges that you are granted on the view. It does *not* test your right to access the underlying tables.

If you created the view, your privileges are the ones noted in the preceding paragraph. If you are not the creator, you have the privileges that were granted to you by the creator or someone who had the WITH GRANT OPTION privilege.

Therefore you can create a table and revoke public access to it; then you can grant limited access privileges to the table through views. The process of creating such a table can be demonstrated through the previous examples using the **hr_data** table. The following table shows its definition:

```
CREATE TABLE hr_data
    (
    emp_key INTEGER,
    emp_name CHAR(40),
    hire_date DATE,
    dept_num SMALLINT,
    user-id CHAR(18),
    salary DECIMAL(8,2),
    performance_level CHAR(1),
    performance_notes TEXT
    )
```

The previous example centers on granting privileges directly on this table. The following examples take a different approach. Assume that when the table was created, the following statement was executed:

```
REVOKE ALL ON hr_data FROM PUBLIC
```

(Such a statement is not necessary in an ANSI-compliant database.) Now you create a series of views for different classes of users. For those who should have read-only access to the nonsensitive columns, you create the following view:

```
CREATE VIEW hr_public AS
    SELECT emp_key, emp_name, hire_date, dept_num, user_id
        FROM hr_data
```

Users who are given the Select privilege for this view can see nonsensitive data and update nothing. For Human Resources personnel who must enter new rows, you create a different view, as the following example shows:

```
CREATE VIEW hr_enter AS
    SELECT emp_key, emp_name, hire_date, dept_num
        FROM hr_data
```

You grant these users both Select and Insert privileges on this view. Because you, the creator of both the table and the view, have the Insert privilege on the table and the view, you can grant the Insert privilege on the view to others who have no privileges on the table.

On behalf of the person in the MIS department who enters or updates new user IDs, you create still another view, as the following example shows:

```
CREATE VIEW hr_MIS AS
    SELECT emp_key, emp_name, user_id
        FROM hr_data
```

This view differs from the previous view in that it does not expose the department number and date of hire.

Finally, the managers need access to all columns and they need the ability to update the performance-review data for their own employees only. These requirements can be met by creating a table, **hr_data**, that contains a department number and a computer user IDs for each employee. Let it be a rule that the managers are members of the departments that they manage. Then the following view restricts managers to rows that reflect only their employees:

```
CREATE VIEW hr_mgr_data AS
    SELECT * FROM hr_data
        WHERE dept_num =
            (SELECT dept_num FROM hr_data
                WHERE user_id = USER)
        AND NOT user_id = USER
```

The final condition is required so that the managers do not have update access to their own row of the table. Therefore, you can safely grant the Update privilege to managers for this view, but only on selected columns, as the following statement shows:

```
GRANT SELECT, UPDATE (performance_level, performance_notes)
    ON hr_mgr_data TO peter_m
```

Summary

When a database contains public material, or when only you and trusted associates use the database, security is not an important consideration, and few of the ideas in this chapter are needed. But as more people are allowed to use and modify the data, and as the data becomes increasingly confidential, you must spend more time and be ever more ingenious at controlling the way users can approach the data.

The techniques discussed here can be divided into the following groups:

- Keeping data confidential

  When the database resides in operating-system files, you can use features of the operating system to deny access to the database. In any case, you control the granting of the Connect privilege to keep people out of the database.

  When different classes of users have different degrees of authorization, you must give them all the Connect privilege. You can use table-level privileges to deny access to confidential tables or columns. Or, you can use a stored procedure to provide limited access to confidential tables or columns. In addition, you can deny all access to tables and allow it only through views that do not expose confidential rows or columns.

- Controlling changes to data and database structure

  To safeguard the integrity of the data model, restrict grants of the Resource, Alter, References, and DBA privileges. To ensure that only authorized persons modify the data, control the grants of the Delete and Update privileges and grant the Update privilege on as few columns as possible. To ensure that consistent, reasonable data is entered, grant the Insert privilege only on views that express logical constraints on the data. Alternatively, to control the insertion and modification of data, or the modification of the database itself, limit access to constrictive stored procedures.

Chapter

Understanding Informix Networking

11

This chapter gives an overview of the use of databases on a computer network. It introduces some commonly used terminology and illustrates various network configurations. The chapter also presents an overview of how the components of either a local or network connection fit together so that a client application can find data on a database server.

This chapter discusses the following networking configurations that you can use with Informix databases and points out some of their effects on performance and usability:

- All on one computer
- A simple network connection
- Multiple connections on a network
- Data managed by non-Informix database servers (INFORMIX-TP/XA)

You cannot simply build a computer network; you have to re-examine how your applications and database servers share data. This chapter also covers the following topics concerned with managing data that is shared over a network:

- Distributed data
- Connecting to data
- Protecting your data
- Synonym chains
- Network transparency

The final sections of the chapter discuss protecting your data in a networked environment.

What Is a Network?

A *computer network* is a group of computers, workstations, and other devices connected together over a communications system to share resources and data. A network *site* is simply the location of one of the computers on the network. Sometimes the network sites are widely separated, but they might also be in the same room or building. Two network *sites* can even coexist on the same computer.

To make a practical computer network work, you must master a multitude of technical details regarding hardware and software. Far too many details exist, and they change too rapidly to cover them in this book. This chapter provides a conceptual discussion of some of the issues that you might encounter when you use a computer network. For more information, refer to the manual that accompanies the Informix client / server product that you use and to the manuals provided by the vendor of your operating system.

Database Management System Configurations

A *relational database management system* (RDBMS) includes all the components necessary to create and maintain a relational database. An Informix RDBMS has several pieces: the user interface, the database server, and the data itself. It is easiest to think of these pieces as all being located in the same computer, but many other arrangements are possible. In some arrangements, the application and the database server are on different computers, and the data is distributed across several others.

The client applications of an RDBMS do not need to be modified to run on a network. The communications tools that are part of all Informix products handle the tasks of locating and attaching to the database servers. To the application, a database on a networked computer appears no different than a database on the computer where the application resides.

A Single-User Configuration

Figure 11-1 shows a diagram of a simple database management system on a single computer. The organization in Figure 11-1 is one you would typically find on a personal computer that runs DOS. It is unusual to have a single-user situation on a UNIX system, but you certainly can. One example of a single-user UNIX system would be a desktop workstation in a development environment.

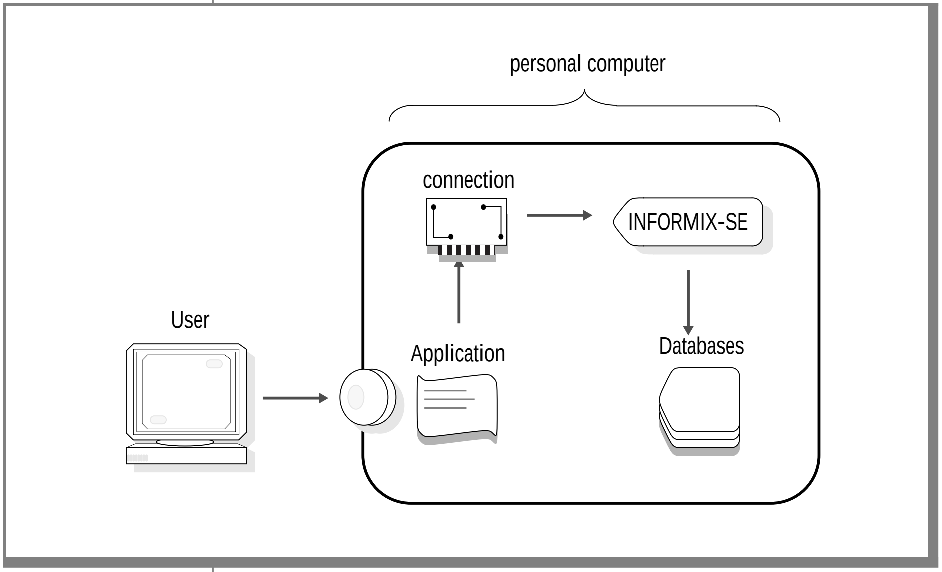


Figure 11-1
A Database Management System on a Personal Computer

The components of the system in Figure 11-1 are described in the following list:

- **An application program.** Any program that issues a query can be the application. It could, for example, be a program written in INFORMIX-4GL, a C language program with embedded SQL, or compiled screen forms and reports.
- **A connection.** On a simple system such as this one, the communication component is frequently so well integrated with the system that it is omitted from diagrams and not discussed. However, it does exist.
- **A database server.** The database server receives queries from the application, searches the database, and returns information to the application. The database server manages or administers the databases that it controls.

  The database server in Figure 11-1 is a *local* server because it resides on the same host computer as the client application.
- **A database.** Databases are usually stored on a magnetic disk. If this system were a UNIX system with INFORMIX-OnLine Dynamic Server, the database might be located on some other medium, such as a WORM (write-once read-many-times) drive controlled by INFORMIX-OnLine/Optical.

Advantages and Disadvantages of a Single-User System

A configuration that involves only one computer is the easiest configuration to set up and maintain, and it gives the fastest access to data. However, the data is not available to users on other computers, and the size of the databases or the amount of processing that is needed might outgrow the capacity of the computer.

A Local Multiuser Configuration

Figure 11-2 shows another database management system configuration, a multiuser system with a local database server such as one you might find on a computer with a UNIX operating system.

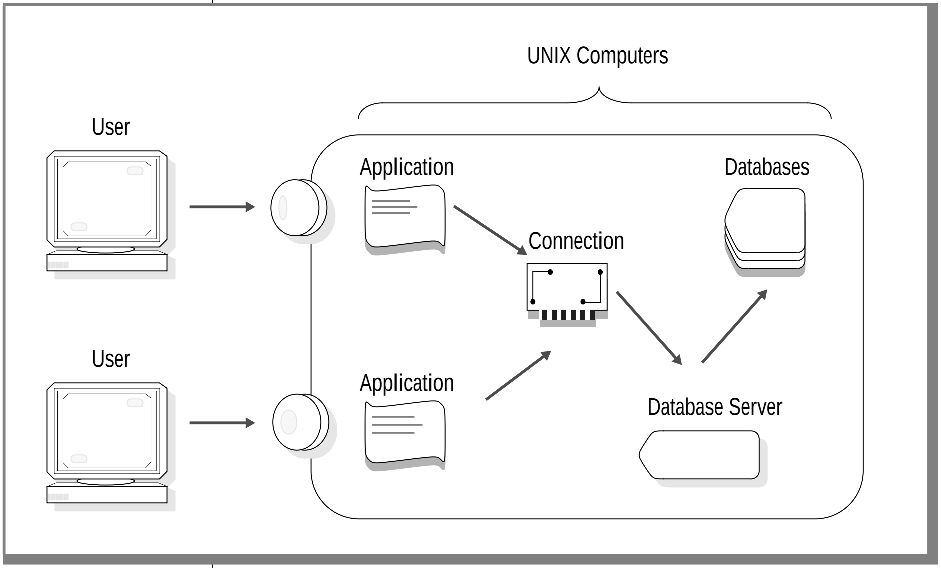


Figure 11-2
A Database Management System on a UNIX Computer

The components of the systems in Figure 11-2 are similar to the components in Figure 11-1 on page 11-5, as the following list describes:

- **Application programs.** Two or more applications use the same database server to access information in the databases. You might have two users at individual terminals, as shown, or you might have multiple windows on a single workstation.

- **A connection.** On a local UNIX system, the following types of connection are possible:
  - Network connection
  - Interprocess communication (IPC)

    IPC is a UNIX feature that transfers information very quickly between the application and the database server. It is available only when the application and the database server reside on the same computer. INFORMIX-SE databases use a type of IPC connection that is called *unnamed pipes* and INFORMIX-OnLine Dynamic Server databases use an IPC connection technique that is called *shared memory*.
- **A database server.** This database server will be either INFORMIX-OnLine Dynamic Server or INFORMIX-SE.
- **Databases.**

Advantages and Disadvantages of Local Multiuser Systems

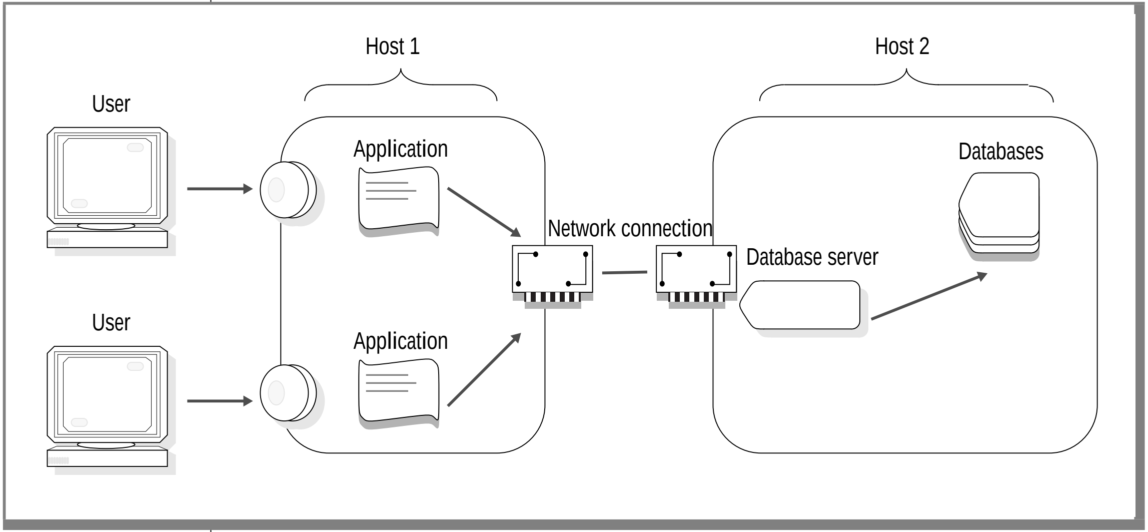
A configuration that allows multiple users gives better access to the data than does a single-user system. With a local database, a multiuser configuration is still easy to set up and maintain. However, as with the single-user system, the data is not available to users on other computers, and the size of the databases or the amount of processing needed might outgrow the capacity of the computer.

IPC shared memory provides very fast communication between the client application and the database server. However, IPC shared memory communication is vulnerable to programming errors if the client application does explicit memory addressing or overindexes data arrays. Such errors do not affect the application if you use IPC unnamed pipes or network communication. (See "Single-Computer Configuration That Uses Network Communication" on page 11-10.)

A Remote Configuration

Figure 11-3 shows a *remote* or *network* configuration, where the application resides on one computer and the database server and its associated databases reside on another computer on the network. In contrast, the database servers in Figure 11-1 and Figure 11-2 are local database servers.

Figure 11-3
A Simple Network Connection



In Figure 11-3, the applications might be INFORMIX-ESQL / COBOL or INFORMIX-ESQL / C applications. The database server might be INFORMIX-OnLine Dynamic Server (UNIX) or INFORMIX-SE *for Windows NT*.

Different computers are referred to as sites or *host computers*. The database server in Figure 11-3 is a *remote* database server because it is on a different host computer from the application that uses its services. A database server can be local with respect to one application and remote with respect to another application, as illustrated in Figure 11-6 on page 11-15.

Advantages and Disadvantages of Remote Network Connections

The configuration shown in Figure 11-3 is an example of *distributed processing*. In distributed processing, multiple computers contribute to a single computing task. In this example, `host1` handles the computing requirements of the application, such as screen display, generation of reports, and printing; `host2` handles the computing required to manipulate information in the databases. Using a network also gives the client application the opportunity to access data from several computers.

Response from a database server using network communication is not as fast as response from a database server using IPC because of the extra computing required to prepare the data for network communication and because of the transmit time. A network is somewhat more difficult to configure and maintain than a local system that uses IPC communication.

Single-Computer Configuration That Uses Network Communication

Figure 11-4 shows a configuration that behaves as if multiple sites were residing on one computer. In this configuration, which is known as *local loopback*, all the components are on the same computer, but the connections are made as if they were connected through a network.

Because the connections use network software, the database server appears to the application as a remote site. The dashed line indicates the division between the two sites. The database administrator configures the system to provide local or local loopback connections (or both).

The software for the client application and the software for the database server can be stored in the same directory, or the software can be stored in two separate directories.

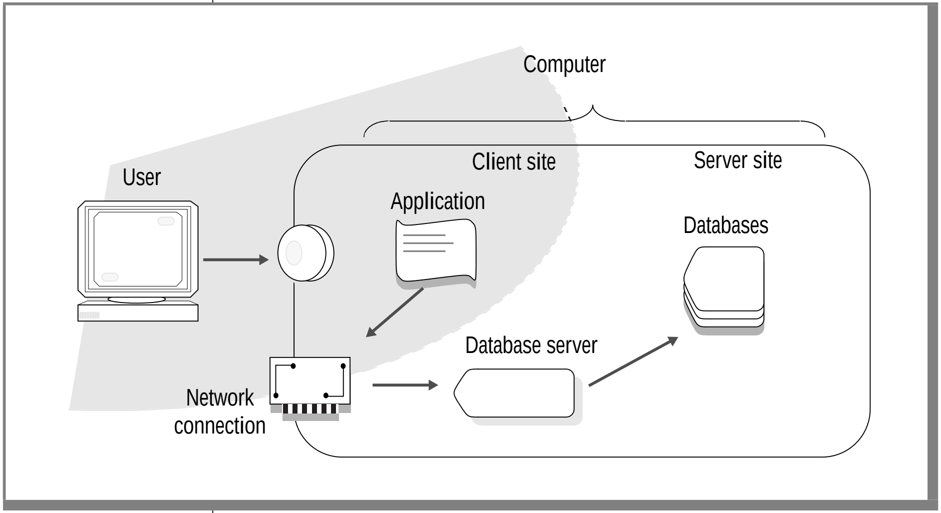


Figure 11-4
An Example of Local Loopback

Advantages and Disadvantages of Local Loopback

Local loopback allows you to test network operations without requiring an actual remote computer, but it is not as fast as a IPC. However, unlike IPC shared-memory communication, local loopback is not vulnerable to corruption due to memory-addressing errors or overindexed data arrays. (See "Advantages and Disadvantages of Local Multiuser Systems" on page 11-8.)

Distributed Databases

Although a network lets you separate the application from the data, the application still is limited to the contents of a single database. With most database servers, you can query or modify tables only in the current database.

A *distributed database* has information on multiple databases that are organized to appear as a single database to the user. The data can be maintained by a variety of database servers and located on computers supported by different operating systems and communication networks.

The OnLine database server allows you to query data in multiple databases anywhere on the network. When the INFORMIX-TP/XA feature is added to INFORMIX-OnLine Dynamic Server, you can create global transactions that span multiple computer systems and even multiple XA-compliant database systems from different vendors. INFORMIX-SE does not provide distributed database processing capabilities.

INFORMIX-Gateway *with DRDA* allows you to perform distributed queries that include non-Informix databases that conform to the distributed relational database architecture (DRDA) protocols defined by IBM.

Advantages and Disadvantages of Distributed Databases

Distributed databases are useful because operations that use databases are often naturally distributed into separate pieces, either organizationally, geographically, or both. A distributed database system provides the following advantages:

- Local data can be kept locally where it is most easily maintained and most frequently used.
- Data from remote sites is available to all users.
- Duplicate copies can be maintained for safety of the data.

A distributed database system has the following disadvantages:

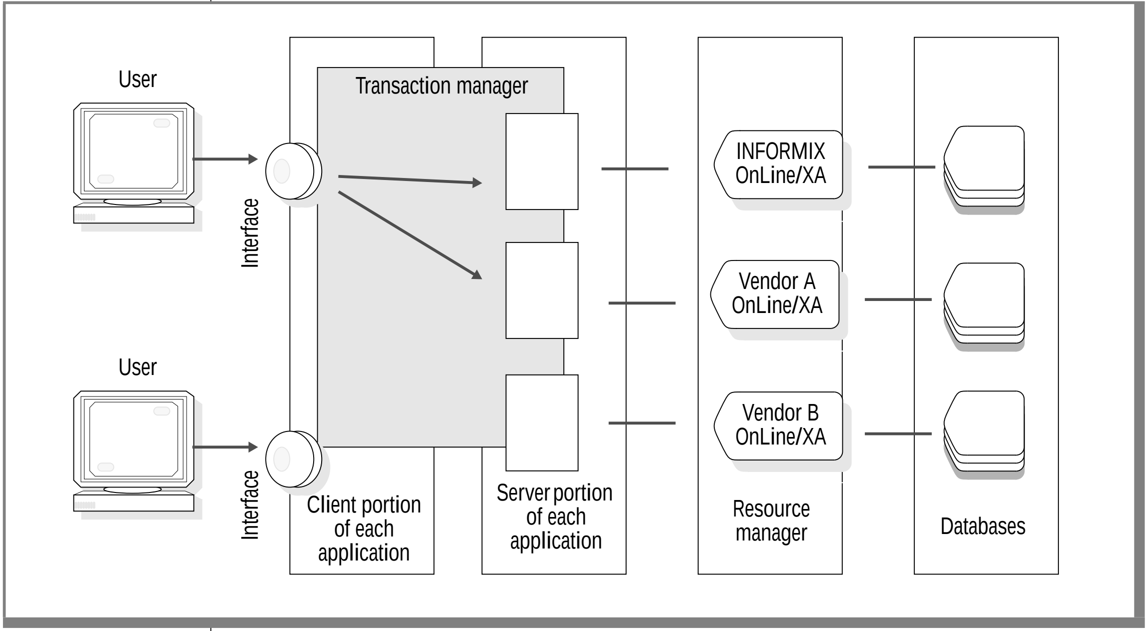
- Management of the distributed system is more involved than management of a single-host system.
- Network access is slower than local access.

Distributed Databases That Use Multiple Vendor Servers

INFORMIX-TP/XA allows you to use database management systems from multiple vendors to store and access your data. INFORMIX-TP/XA is a library of functions that allows the INFORMIX-OnLine Dynamic Server database server to act as a resource manager in a distributed transaction-processing (DTP) environment that follows an interface standard, which was defined by the X/Open Company.

The XA standard uses terminology that is different from the terminology Informix products and documentation use. A *transaction manager* acts as an intermediary and relays requests from a user interface to a *resource manager*. Transaction managers are third-party products such as TUXEDO. In this context, a resource manager corresponds to a database server. Figure 11-5 illustrates a configuration that uses transaction processing.

Figure 11-5
A Configuration That Uses a Transaction Manager



Connecting to Data on a UNIX Network

When the application and data are moved to separate computers, two questions immediately arise. What connections can you implement? How do you instruct your applications to find the data that is now somewhere else?

In fact, connecting a client application to a database server that is on a networked computer is no different from connecting to a local database server. To connect a client application with a database, you must consider the following parts of your configuration:

- Environment variables
- Connection information
- Connection statements

This section summarizes how connections are made for Version 6.0 and later clients and servers. Detailed instructions for setting up local and network connections, as well as for those between Version 6.0 servers and earlier clients are given in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*, the *INFORMIX-SE Administrator's Guide*, and the *INFORMIX-Gateway with DRDA User Manual*.

Example of Client/Server Connections

Figure 11-6 shows local and networked connections of Version 6.0 and later products. Although all these connections are possible, you cannot do them all at once. Client X can make connection 1, 2, or 3, and Client Y can make connection 4 or 5.

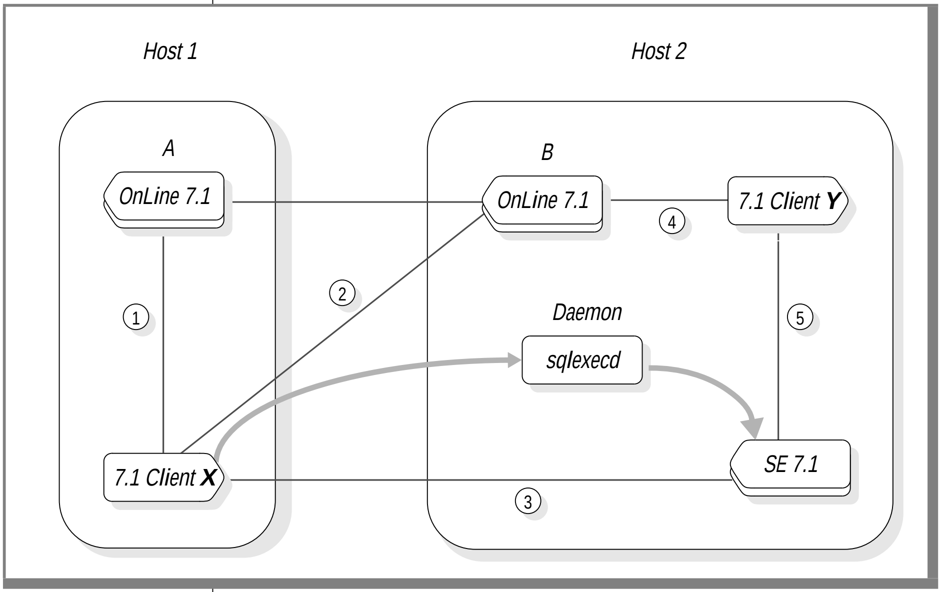


Figure 11-6
Local and Network Connection of Version 6.0 and Later Products

To connect clients directly to OnLine database servers, use either shared memory (IPC) or a network communications. OnLine database servers (OnLine A and OnLine B in Figure 11-6) can communicate with each other.

Local clients can connect directly to an INFORMIX-SE database server using unnamed pipes (IPC). Clients that are using network communications connect to INFORMIX-SE by connecting first to a *daemon*, **sqlexecd**. A daemon is a background process that listens for requests from other programs. The system administrator starts the **sqlexecd** daemon. When a client requests a connection to an INFORMIX-SE database server, **sqlexecd** notices the request and creates a temporary (light gray arrows) connection between the client and SE. This temporary connection (shown as *(3)* - *(1)* in Figure 11-6) enables the client and INFORMIX-SE database server to establish a direct connection (*3*). Then **sqlexecd** removes itself from the loop and leaves the client attached to the SE database server.

Environment Variables

The Informix administrator must make sure that each user sets the correct environment variables. The following list shows the most important environment variables used by OnLine and INFORMIX-SE:

- PATH
- INFORMIXDIR
- INFORMIXSERVER
- TERM
- DBPATH
- ONCONFIG

The **INFORMIXDIR** environment variable must be set to the full pathname of the directory where the Informix files reside. The **PATH** environment variable must include the full pathname of the directory where the executables for INFORMIX-SE and / or INFORMIX-OnLine Dynamic Server reside. These two environment variables are required. After the Informix administrator has specified them, you usually do not change them.

The **INFORMIXSERVER** environment variable is the name of the default database server. It is also a required variable. You can choose to change **INFORMIXSERVER** when you change applications.

The **TERM** (or **TERMCAP** and / or **INFORMIXTERM**) environment variable enables the clients to recognize and communicate with your terminal. These variables are system- and terminal-dependent. To set them, you might need the assistance of your system administrator.

The **DBPATH** environment variable is optional. If the application does not fully specify the location of an SE database server, the database server searches the directories listed in **DBPATH** to find the specified database. Both INFORMIX-OnLine Dynamic Server and INFORMIX-SE use the **DBPATH** environment variable to specify directory names for reports, forms, and command files.

When OnLine is initialized, it requires the **ONCONFIG** environment variable. The **ONCONFIG** environment variable is not used by SE.

These environment variables are described in detail in Chapter 4 of the *Informix Guide to SQL: Reference*.

Connection Information

The **$INFORMIXDIR/etc/sqlhosts** file specifies the location of the database server and the type of connection (protocol) for the database server. Each database server that might be accessed by an application must have an entry in **sqlhosts** file on *every* computer on the network.

In addition to the **sqlhosts** files, TCP/IP connections require entries in the UNIX systems files, **/etc/hosts** and **/etc/services**. IPX/SPX connections also require auxiliary files, However, unlike TCP/IP, the names of the auxiliary files depend on the hardware vendor.

Informix database servers follow UNIX security requirements for making connections. Thus, the UNIX system administrator might need to make modifications to the **/etc/passwd**, **/etc/hosts**, **rhosts** and other related files. These files are described in the *INFORMIX-OnLine Dynamic Server Administrator's Guide*, the *INFORMIX-SE Administrator's Guide*, the *INFORMIX-Gateway with DRDA User Manual*, and operating-system manuals.

SQL Connection Statements

Before it can do anything else, the client application must execute a CONNECT statement or a DATABASE statement to *open* a database. The CONNECT statement is preferred because it conforms with both ANSI and X/Open standards, which attempt to specify uniform syntax for networked and nonnetworked environments.

The following command is an example of the CONNECT statement:

```
CONNECT TO databasename@servername
```

The application connects to the default database server that the **INFORMIXSERVER** environment variable specifies if *servername* is omitted from the previous statement.

If *databasename* is omitted, the application connects to the database server *servername* but does not open a database. Before you can use a database, you must issue a DATABASE, CREATE DATABASE, or START DATABASE statement.

The CONNECT statement does not give any information about the location of the database server. The location information for the database server is in the **sqlhosts** file. (Refer to "Connection Information" above.)

You can also use the DISCONNECT statement to terminate the connection between your application and the database server. To reestablish an active connection and make it current, use the SET CONNECTION statement. You can also use the DORMANT clause of the SET CONNECTION statement to make the current connection dormant. Using the DORMANT clause of the SET CONNECTION statement is particularly useful when you are working on a multithreaded application. For more information regarding multithreaded applications, see Chapter 11 of the *INFORMIX-ESQL/C Programmer's Manual*.

The complete syntax for the CONNECT, DATABASE, DISCONNECT, and SET CONNECTION statements is covered in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Accessing Tables

The database that a CONNECT, DATABASE or CREATE DATABASE statement opens is the *current* database. If you are using INFORMIX-OnLine Dynamic Server, you can query tables that are not in the current database. To refer to a table in a database other than the current database, include the database name as part of the table name, as illustrated in the following SELECT statement:

```
SELECT name, number FROM salesdb:contacts
```

The database is **salesdb**. The table in **salesdb** is named **contacts**. You can use the same notation in a join. When you must 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 C.custname, S.phone
    FROM salesdb:contacts C, stores:customer S
    WHERE C.custname = S.company
```

You must qualify the database name with a *database server name* to specify a table in a database that a different OnLine database server manages. For example, the following SELECT statement refers to table **customer** from database **masterdb**, which resides on the database server **central**:

```
SELECT O.order_num, C.fname, C.lname
    FROM masterdb@central:customer C, sales@boston:orders O
    WHERE C.customer_num = O.Customer_num
    INTO TEMP mycopy
```

In the example, two tables are being joined. The joined rows are stored in a temporary table **mycopy** in the current database. The tables are located in two database servers, **central** and **boston**.

Informix allows you to *overqualify* (to give more information than is required) table names. Because both table names are fully qualified, you cannot tell whether the current database is **masterdb** or **sales**.

Using Synonyms with Table Names

A *synonym* is a name that you can use in place of another name. The main use of the CREATE SYNONYM statement is to make it more convenient to refer to tables that are not in the current database.

The preceding example has been revised as follows, to use synonyms for the table names:

```
CREATE SYNONYM mcust FOR masterdb@central:customer;

CREATE SYNONYM bords FOR sales@boston:orders;

SELECT bords.order_num, mcust.fname, mcust.lname
    FROM mcust, bords
    WHERE mcust.customer_num = bords.Customer_num
    INTO TEMP mycopy;
```

The CREATE SYNONYM statement stores the synonym name in the system catalog table **syssyntable** in the current database. The synonym is available to any query made within that database.

A short synonym makes it easier to write queries, but synonyms can play another role. They allow you to move a table to a different database, or even to a different computer, while leaving your queries the same.

Suppose you have several queries that refer to the tables **customer** and **orders**. The queries are embedded in programs, forms, and reports. The tables are part of database **stores7**, which is kept on database server **avignon**.

Now the decision is made that the same programs, forms, and reports are to be made available to users of a different computer on the network (database server **nantes**). Those users have a database that contains a table named **orders** containing the orders at their location, but they need access to the table **customer** at **avignon**.

To those users, the **customer** table is external. Does this mean you must prepare special versions of the programs and reports, versions in which the **customer** table is qualified with a database server name? A better solution is to create a synonym in the users' database, as the following example shows:

```
DATABASE stores7@nantes;
CREATE SYNONYM customer FOR stores7@avignon:customer;
```

When the stored queries are executed in your database, the name **customer** refers to the actual table. When they are executed in the other database, the name is translated through the synonym into a reference to the external table.

Synonym Chains

To continue the preceding example, suppose that a new computer is added to your network. Its name is **db_crunch**. The **customer** table and other tables are moved to it to reduce the load on **avignon**. You can reproduce the table on the new database server easily enough, but how can you redirect all accesses to it? One way is to install a synonym to replace the old table, as the following example shows:

```
DATABASE stores7@avignon EXCLUSIVE;
RENAME TABLE customer TO old_cust;
CREATE SYNONYM customer FOR stores7@db_crunch:customer;
CLOSE DATABASE;
```

When you execute a query within **stores7@avignon**, a reference to table **customer** finds the synonym and is redirected to the version on the new computer. Such redirection also happens for queries that are executed from database server **nantes**. The synonym in the database **stores7@nantes** still redirects references to **customer** to database **stores7@avignon**; however, the new synonym there sends the query to database **stores7@db_crunch**.

Chains of synonyms can be useful when, as in this example, you want to redirect all access to a table in one operation. However, you should update all users' databases as soon as possible so their synonyms point directly to the table. You incur extra overhead in handling the extra synonyms, and the table cannot be found if any computer in the chain is down.

You can run an application against a local database and later run the identical application against a database on another computer. The program runs equally well in either case (although it can run more slowly on the network database). As long as the data model is the same, a program cannot tell the difference between a local database server and a remote one.

Protecting Your Data in a Networked Environment

This section gives an overview of data-protection features that are used on a network. Chapter 4, "Modifying Data," presents a general discussion of data protection.

Data Protection with INFORMIX-SE

INFORMIX-SE databases use the normal UNIX file structures, so SE databases can be backed up with the usual operating-system backup procedures. On a network, you can write the backups to a device in another location.

Data Protection with INFORMIX-OnLine Dynamic Server

OnLine includes several tools that make multiple copies of data. Each one has its own unique task in the area of data protection. The following discussions give a general description of these tools and highlight the distinctions between them.

Data Replication

In a general sense, *data replication* means that a given piece of data has several distinct representations on several distinct servers. OnLine does data replication by using two networked computers. Each computer has an OnLine database server and databases that have identical characteristics. One database server is the *primary* server, and the other is the *secondary* server. Data is always written to the primary server and then transferred to the secondary server.

Applications can *read* data from either database server. Thus the secondary site can provide a dual purpose. It provides data protection and improved performance for users at the secondary site who need to read, but not write, data.

If the primary database server (call it serverA) fails for any reason, the secondary server (call it serverB) can become an independent database server. Users who would normally use serverA can be switched to serverB. Service to all the users can continue with a minimum of disruption while serverA is being repaired.

Data replication provides good data protection and continuity of service, but it is expensive. Memory must be provided for two complete copies of the data, shipping the data to a remote site affects performance, and management requires the attention of the OnLine administrators on both sites.

Backups

OnLine provides specialized tools for making backups. Backups can be prepared locally or on a networked computer. Because backups should be stored in a location that is physically removed from the database server, it might be convenient to build the backups on a networked computer located at a different physical site. For descriptions of backup tools for OnLine, see the *INFORMIX-OnLine Dynamic Server Archive and Backup Guide*.

Data Integrity for Distributed Data

OnLine lets you update data in several databases on different database servers. For example, a purchase order (a single transaction) might require you to update information in databases on different database servers. To maintain the integrity of the data, you should update either all the different databases or none of the databases.

Two-Phase Commit

Two-phase commit is a protocol that coordinates work performed at multiple database servers on behalf of a single transaction. Unlike the data-replication and backup tools discussed earlier in this section, two-phase commit *does not* make two copies of the data. It protects the validity of *one* transaction that involves several databases. Because two-phase commit involves only one transaction, it is not usually considered as data protection.

A transaction that involves multiple database servers is called a *global transaction*. Two-phase commit is a natural extension of transaction handling, which is discussed in "Interrupted Modifications" on page 4-27. The *INFORMIX-OnLine Dynamic Server Administrator's Guide* discusses two-phase commit in detail.

The two-phase commit begins when a client application has completed all its work and requests a commit of the global transaction.

Phase 1

The current database server asks each participating database server if it can commit its local transactions. Each database server responds Yes or No.

Phase 2

If all the database servers respond affirmatively, the current database server tells each one to commit its transactions and then the global transaction is complete. If *any* database server responds negatively or does not respond, all database servers are instructed to abort the local transactions.

Summary

A network allows a client application to run on one computer, while the database server operates in another computer to which the data is physically attached. Using a network in such a way provides distributed processing and the possibility of distributed database access. Many possible combinations of network software, operating systems, and database servers exist, and each has subtleties that must be mastered.

Using Advanced SQL

Section III

Chapter

12 Creating and Using Stored Procedures

You can write procedures using SQL and some additional statements that belong to the Stored Procedure Language (SPL) and store this procedure in the database. These stored procedures are effective tools for controlling SQL activity. This chapter provides instruction on how to write stored procedures. To help you learn how to write them, examples of working stored procedures are provided.

The syntax for each SPL statement is described in Chapter 2 of the *Informix Guide to SQL: Syntax*. Usage notes and pertinent examples accompany the syntax for each statement.

Introduction to Stored Procedures and SPL

To SQL, a stored procedure is a user-defined function. Anyone who has the Resource privilege on a database can create a stored procedure. Once the stored procedure is created, it is stored in an executable format in the database as an object of the database. You can use stored procedures to perform any function that you can perform in SQL as well as to expand what you can accomplish with SQL alone.

You write a stored procedure using SQL and SPL statements. SPL statements can be used only inside the CREATE PROCEDURE and CREATE PROCEDURE FROM statements. The CREATE PROCEDURE statement is available with DB-Access, and the CREATE PROCEDURE and CREATE PROCEDURE FROM statements are available with SQL APIs such as INFORMIX-ESQL/C and INFORMIX-ESQL/COBOL. The CREATE PROCEDURE FROM statement is also available with INFORMIX-4GL and NewEra.

What You Can Do with Stored Procedures

You can accomplish a wide range of objectives with stored procedures, including improving database performance, simplifying writing applications, and limiting or monitoring access to data.

Because a stored procedure is stored in an executable format, you can use it to execute frequently repeated tasks to improve performance. Executing a stored procedure rather than straight SQL code lets you bypass repeated parsing, validity checking, and query optimization.

Because a stored procedure is an object in the database, it is available to every application that runs on the database. Several applications can use the same stored procedure, so development time for applications is reduced.

You can write a stored procedure to be run with the DBA privilege by a user who does not have the DBA privilege. This allows you to limit and control access to data in the database. Alternatively, a stored procedure can monitor the users who access certain tables or data. (See "Controlling Access to Data Using Stored Procedures" on page 10-19 for a discussion of this topic.)

Relationship Between SQL and a Stored Procedure

You can call a procedure within data manipulation SQL statements and issue SQL statements within a procedure. See Chapter 1 of the *Informix Guide to SQL: Syntax* for a complete list of data manipulation SQL statements.

You use a stored procedure within a data manipulation SQL statement to supply values to that statement. For example, you can use a procedure 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 are two possible uses of a procedure within a data manipulation statement, but others exist. In fact, any expression within a data manipulation SQL statement can consist of a procedure call.

You can also issue SQL statements within a stored procedure 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 a stored procedure to encapsulate an SQL activity and let others know that the procedure is stored in the database so that they can execute it.

Creating and Using Stored Procedures

To write a stored procedure, put the SQL statements that you want run as part of the procedure inside the statement block in a CREATE PROCEDURE statement. You can use SPL statements to control the flow of the operation within the procedure. SPL statements include IF, FOR, and others and they are described in the *Informix Guide to SQL: Syntax*. The CREATE PROCEDURE and CREATE PROCEDURE FROM statements are also described in Chapter 1 of the *Informix Guide to SQL: Syntax*.

Creating a Procedure Using DB-Access

To create a stored procedure using DB-Access, issue the CREATE PROCEDURE statement, including all the statements that are part of the procedure in the statement block. For example, to create a procedure that reads a customer address, use a statement such as the following one:

```
CREATE PROCEDURE 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
        procedure 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 PROCEDURE
```

```
DOCUMENT 'This procedure 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 '/acctng/test/listfile' -- compile-time
warnings go here
; -- end of the procedure read_address
```

Creating a Procedure in a Program

To use NewEra, INFORMIX-4GL, or an SQL API to create a stored procedure, put the text of the CREATE PROCEDURE statement in a file. Use the CREATE PROCEDURE FROM statement, and refer to that file to compile the procedure. For example, to create a procedure 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** procedure:

```
CREATE PROCEDURE FROM 'read_add_source';
```

The following example shows how the previous SQL statement looks in an ESQL/C program:

```
/* This program creates whatever procedure 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 procedure from the pwd */

main()
{
EXEC SQL database play;
EXEC SQL create procedure from 'read_add_source';
}
```

Commenting and Documenting a Procedure

Observe that the **read_address** procedure in the previous DB-Access example includes comments and a DOCUMENT clause. The programmer incorporates the comments into the text of the procedure. Any characters that follow a double hyphen (--) are considered to be a comment. You can use the double hyphen anywhere within a line.

The text in the DOCUMENT clause should give a summary of the procedure. To extract this text, query the **sysprocbody** system catalog table. See "Looking at the Procedure Documentation" on page 12-10 for more information about reading the DOCUMENT clause.

Diagnosing Compile-Time Errors

When you issue a CREATE PROCEDURE or CREATE PROCEDURE FROM statement, the statement fails if a syntax error occurs in the body of the procedure. The database server stops processing the text of the procedure and returns the location of the error.

Finding Syntax Errors in a Procedure Using DB-Access

If a procedure created using DB-Access has a syntax error, when you choose the Modify option of the SQL menu, the cursor sits on the line that contains the offending syntax.

Finding Syntax Errors in a Procedure Using an SQL API

If a procedure created using an SQL API has a syntax error, the CREATE PROCEDURE statement fails and sets SQLCA and SQLSTATE values. The database server sets the SQLCODE field of the SQLCA to a negative number and sets the fifth element of the SQLERRD array to the character offset into the file. The following table shows the particular fields of the SQLCA for each product.

ESQL/C	ESQL/FORTRAN	ESQL/COBOL
sqlca.sqlcode SQLCODE	sqlcod	SQLCODE OF SQLCA
sqlca.sqlerrd[4]	sqlca.sqlerr(5)	SQLERRD[5] OF SQLCA

In case of syntax error, the database server sets SQLSTATE to 42000.

The following example shows how to trap for a syntax error when you are creating a procedure. It also shows how to display a message and character position where the error occurred.

```
#include <stdio.h>
EXEC SQL include sqlca;
EXEC SQL include sqlda;
EXEC SQL include datetime;
/* Program to create a procedure from procfile in pwd */

main()
{
long char_num;

EXEC SQL database play;
EXEC SQL create procedure from 'procfile';
if (sqlca.sqlcode != 0 )
{
        printf("\nsqlca.sqlcode = %ld\n", sqlca.sqlcode);
        char_num = sqlca.sqlerrd[4];
        printf("\nError in creating read_address. Check
character position
            %ld\n", char_num);
}
.
.
.
```

In the previous example, if the CREATE PROCEDURE FROM statement fails, the program displays a message in addition to the character position at which the syntax error occurred.

Looking at Compile-Time Warnings

If the database server detects a potential problem, but the procedure is syntactically 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 procedure.

To obtain the listing of compile-time warnings for your procedure, use the WITH LISTING IN clause in your CREATE PROCEDURE statement, as the following example shows:

```
CREATE PROCEDURE read_address (lastname CHAR(15)) -- one argument
    RETURNING CHAR(15), CHAR(15), CHAR(20), CHAR(15), CHAR(2), CHAR(5); -- 6 items
    .
    .
    .
    WITH LISTING IN '/acctng/test/listfile' -- compile-time warnings go here
; -- end of the procedure read_address
```

If you are working on a network, the listing file is created on the computer where the database resides. If you provide an absolute pathname and filename for the file, the file is created where you specify. If you provide a relative pathname 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.)

After you create the procedure, you can view the file that is specified in the WITH LISTING IN clause to see the warnings that it contains.

Generating the Text or Documentation

Once you create the procedure, it is stored in the **sysprocbody** system catalog table. The **sysprocbody** system catalog table contains the executable procedure as well as the text of the original CREATE PROCEDURE statement and the documentation text.

Looking at the Procedure Text

To generate the text of the procedure, select the data column from the **sysprocbody** system catalog table. The following SELECT statement reads the **read_address** procedure text:

```
SELECT data FROM informix.sysprocbody
   WHERE datakey = 'T' -- find text lines
   AND
   procid = (SELECT procid FROM informix.sysprocedures
      WHERE informix.sysprocedures.procname = 'read_address')
```

Looking at the Procedure Documentation

If you want to view only the documenting text of the procedure, use the following SELECT statement to read the documentation string. The documentation lines found in the following example are those in the DOCUMENT clause of the CREATE PROCEDURE statement:

```
SELECT data FROM informix.sysprocbody
   WHERE datakey = 'D' -- find documentation lines
   AND
   procid = (SELECT procid FROM informix.sysprocedures
      WHERE informix.sysprocedures.procname = 'read_address')
```

Executing a Procedure

You can execute a procedure in several ways. You can use the SQL statement EXECUTE PROCEDURE or either the LET or CALL SPL statement. In addition, you can execute procedures dynamically, as described in "Executing a Stored Procedure Dynamically" on page 12-12.

The **read_address** procedure returns the full name and address of a customer. To run **read_address** on a customer called "Putnum" using EXECUTE PROCEDURE, enter the following statement:

```
EXECUTE PROCEDURE read_address ('Putnum');
```

The **read_address** procedure returns values; therefore, if you are executing a procedure from an SQL API, INFORMIX-4GL, NewEra, or from another procedure, you must use an INTO clause with host variables to receive the data. For example, executing the **read_address** procedure in an ESQL/C program is accomplished with the code segment that the following example shows:

```
#include <stdio.h>
EXEC SQL include sqlca;
EXEC SQL include sqlda;
EXEC SQL include datetime;
/* Program to execute a procedure in the database named 'play'
*/

main()
{
EXEC SQL BEGIN DECLARE SECTION;
    char lname[16], fname[16], address[21];
    char city[16], state[3], zip[6];
EXEC SQL END DECLARE SECTION;
EXEC SQL connect to 'play';
EXEC SQL EXECUTE PROCEDURE read_address ('Putnum')
    INTO :lname, :fname, :address, :city, :state, :zip;
if (sqlca.sqlcode != 0 )
     printf("\nFailure on execute");
}
```

If you are executing a procedure within another procedure, you can use the SPL statements CALL or LET to run the procedure. To use the CALL statement with the **read_address** procedure, you can use the code in the following example:

```
CREATE PROCEDURE address_list ()

    DEFINE p_lname, p_fname, p_city CHAR(15);
    DEFINE p_add CHAR(20);
    DEFINE p_state CHAR(2);
    DEFINE p_zip CHAR(5);
    .
    .
    .
    CALL read_address ('Putnum') RETURNING p_fname, p_lname,
        p_add, p_city, p_state, p_zip;
    .
    .
    .
    -- use the returned data some way
END PROCEDURE;
```

The following example shows how to use the LET statement to assign values to procedural variables through a procedure call:

```
CREATE PROCEDURE address_list ()

    DEFINE p_lname, p_fname, p_city CHAR(15);
    DEFINE p_add CHAR(20);
    DEFINE p_state CHAR(2);
    DEFINE p_zip CHAR(5);
    .
    .
    .
    LET p_fname, p_lname,p_add, p_city, p_state, p_zip =
read_address ('Putnum');
    .
    .
    .
    -- use the returned data some way
END PROCEDURE;
```

Executing a Stored Procedure Dynamically

You can prepare an EXECUTE PROCEDURE statement in conjunction with the ALLOCATE DESCRIPTOR and GET DESCRIPTOR statements in an ESQL/C program. Parameters to the stored procedure can be passed in the same manner as the SELECT statement and can be passed at runtime or compile time. For a detailed example of executing a stored procedure dynamically, see Chapter 10 of the *INFORMIX-ESQL/C Programmer's Manual*. For information about dynamic SQL and using a prepared SELECT statement, see Chapter 5, "Programming with SQL."

Debugging a Procedure

Once you successfully create and run a procedure, you can encounter logic errors. If the procedure has logic errors, use the TRACE statement to help find them. You can trace the values of the following procedural entities:

- Variables
- Procedure 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 your procedure, include the TRACE statement in one of its forms.

The following methods specify the form of TRACE output:

TRACE ON	traces all statements except SQL statements. The contents of variables are printed before they are used. Procedure calls and returned values are also traced.
TRACE PROCEDURE	traces only the procedure 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 example shows how you can use the TRACE statement with a version of the **read_address** procedure. This example shows several SPL statements that have not been discussed, but the entire example demonstrates how the TRACE statement can help you monitor execution of the procedure.

```
CREATE PROCEDURE 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; -- Every expression will be traced from here on
    TRACE 'Foreach starts';-- A 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 PROCEDURE;
```

Each time you execute the traced procedure, entries are added to the file you specified using 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 generated by the procedure in the previous example. Next to each traced statement is an explanation of its contents.

`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.

Re-creating a Procedure

If a procedure exists in a database, you must drop it explicitly using the DROP PROCEDURE statement before you can create another procedure with the same name. If you debug your procedure and attempt to use the CREATE PROCEDURE statement with the same procedure name again, the attempt fails unless you first drop the existing procedure from the database.

Privileges on Stored Procedures

A stored procedure resides in the database in which it was created. As with other database objects, you need appropriate privileges to create a stored procedure. In addition, you need appropriate privileges to execute a stored procedure.

Two types of stored procedures exist in a database: DBA-privileged and owner-privileged. When you create the procedure, you specify which type it is. You need different privileges to create and execute these two types of procedures. The differences are described in the sections that follow and are summarized in Figure 12-1.

Figure 12-1
Differences Between DBA-Privileged and Owner-Privileged Procedures

	DBA-Privileged Procedure	**Owner-Privileged Procedure**
Can be created by:	Any user with the DBA privilege	Any user with at least the Resource privilege
Users who have the Execute privilege by default:	Any user with the DBA privilege	Not ANSI compliant. Public (any user with Connect database privilege) ANSI compliant. The procedure owner and any user with the DBA privilege
Privileges the procedure owner or WITH must grant another user to enable that user to run a procedure:	Execute privilege	Execute privilege and privileges on underlying objects If owner has privileges on underlying objects with the GRANT WITH option, only the Execute privilege is required.

Privileges Necessary at Creation

Only users who have the DBA privilege can create a DBA-privileged procedure. To create an owner-privileged procedure, you need to have at least the Resource privilege. See "Granting and Limiting Access to Your Database" on page 10-3.

Privileges Necessary at Execution

To run a procedure, you always need the Execute privilege for that procedure or DBA database privileges. The database server implicitly grants certain privileges to users, depending on whether the procedure is a DBA-mode procedure and if the database is ANSI compliant.

If the procedure is owner privileged, the database server grants the Execute privilege to PUBLIC. If the database is ANSI compliant, the database server grants only the Execute privilege to the owner and users with DBA status.

If the procedure is DBA privileged, the database server grants the Execute privilege to all users who have the DBA privilege.

Owner-Privileged Procedures

When you execute an owner-privileged procedure, the database server checks the existence of any referenced objects. In addition, the database server verifies that you have the necessary privileges on the referenced objects.

If you execute a procedure that references only objects that you own, no privilege conflicts occurs. If you do not own the referenced objects, and you execute a procedure that contains SELECT statements, you risk generating a conflict.

If the owner has the necessary privileges with the WITH GRANT option, those privileges are automatically conferred to you when the owner issues a GRANT EXECUTE statement.

The user who runs the procedure does not own the unqualified objects created in the course of executing the procedure. The owner of the procedure owns the unqualified objects. The following example shows lines in an owner-privileged stored procedure that create two tables. If this procedure is owned by **tony**, and a user **marty** runs the procedure, the first table, **gargantuan**, is owned by **tony**. The second table, **tiny**, is owned by **libby**. The table **gargantuan** is an unqualified name; therefore, **tony** owns the table **gargantuan**. The table **tiny** is qualified by the owner **libby**, so **libby** owns the table **tiny**.

```
CREATE PROCEDURE tryit()
    .
    .
    .
    CREATE TABLE gargantuan (col1 INT, col2 INT, col3 INT);
    CREATE TABLE libby.tiny (col1 INT, col2 INT, col3 INT);

END PROCEDURE;
```

DBA-Privileged Procedures

When you execute a DBA-privileged procedure, you assume the privileges of a DBA for the duration of the procedure. A DBA-privileged procedure acts as if the user who runs the procedure is first granted DBA privilege, then executes each statement of the procedure manually, and finally has DBA privilege revoked.

Objects created in the course of running a DBA procedure are owned by the user who runs the procedure, unless the data definition statement in the procedure explicitly names the owner to be someone else.

Privileges and Nested Procedures

DBA-privileged status is not inherited by a called procedure. For example, if a DBA-privileged procedure executes an owner-privileged procedure, the owner-privileged procedure does not run as a DBA procedure. If an owner-privileged procedure calls a DBA-privileged procedure, the statements within the DBA-privileged procedure execute as they would within any DBA-privileged procedure.

Revoking Privileges

The owner of a procedure can revoke the Execute privilege from a user. If a user loses the Execute privilege on a procedure, the Execute privilege is also revoked from all users who were granted the Execute privilege by that user.

Variables and Expressions

This section discusses how to define and use variables in SPL. The differences between SPL and SQL expressions also are covered here.

Variables

You can use a variable in a stored procedure in several ways. You can use a variable in a database query or other SQL statement wherever a constant is expected. You can use a variable with SPL statements to assign and calculate values, keep track of the number of rows returned from a query, and execute a loop as well as handle other tasks.

The value of a variable is held in memory; the variable is not a database object. Hence, rolling back a transaction does not restore values of procedural variables.

Format of Variables

A variable follows the rules of an SQL identifier. (See Chapter 1 of the *Informix Guide to SQL: Syntax*.) Once you define a variable, you can use it anywhere in the procedure as appropriate.

If you are using an SQL API, you do not have to set off the variable with a special symbol (unlike host variables in an SQL API).

Global and Local Variables

You can define a variable to be either local or global. A variable is local by default. The following definitions describe the differences between the two types:

Local	A local variable is available only within the procedure in which it is defined. Local variables do not allow a default value to be assigned at compile time.
Global	A global variable is available to other procedures run by the same user session in the same database. The values of global variables are stored in memory. The global environment is the memory used by all the procedures run within a given session on a given database server, such as all procedures run by an SQL API or in a DB-Access session. The values of the variables are lost when the session ends. Global variables require a default value to be assigned at compile time. The first definition of a global variable puts the variable into the global environment. Subsequent definitions of the same variable, in different procedures, simply bind the variable to the global environment.

Defining Variables

To define variables, use the DEFINE statement. If you list a variable in the argument list of a procedure, the variable is defined implicitly, and you do not need to define it formally with the DEFINE statement. You must assign a value, which can be null, to a variable before you can use it.

Data Types for Variables

You can define a variable as any of the data types available for columns in a table except SERIAL. The following example shows several cases of defined procedural variables:

```
DEFINE x INT;
DEFINE name CHAR(15);
DEFINE this_day DATETIME YEAR TO DAY ;
```

If you define a variable for TEXT or BYTE data, the variable does not actually contain the data; instead, it serves as a pointer to the data. However, use this procedural variable as you would use any other procedural variable. When you define a TEXT or BYTE variable, you must use the word REFERENCES, which emphasizes that these variables do not contain the data; they simply reference the data. The following example shows the definition of a TEXT and a BYTE variable:

```
DEFINE ttt REFERENCES TEXT;
DEFINE bbb REFERENCES BYTE;
```

Using Subscripts with Variables

You can use subscripts with variables that have CHAR, VARCHAR, NCHAR, NVARCHAR, BYTE or TEXT data types, just as you can with SQL column names. The subscripts indicate the starting and ending character positions of the variable. Subscripts must always be constants. You cannot use variables as subscripts. The following example illustrates the usage:

```
DEFINE name CHAR(15);
LET name[4,7] = 'Ream';
SELECT fname[1,3] INTO name[1,3] FROM customer
    WHERE lname = 'Ream';
```

The portion of the variable contents that is delimited by the two subscripts is referred to as a substring.

Scope of Variables

A variable is valid within the statement block in which it is defined. It is valid within statement blocks that are nested within that statement block as well, unless it is masked by a redefinition of a variable with the same name.

In the beginning of the following procedure, the integer variables x, y, and z are defined and initialized. 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.

```
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;
```

Variable/Keyword Ambiguity

If you define a variable as a keyword, ambiguities can occur. The following rules for identifiers help you avoid ambiguities for variables, procedure names, and system function names:

- Defined variables take the highest precedence.
- Procedures defined as such in a DEFINE statement take precedence over SQL functions.
- SQL functions take precedence over procedures that exist but are *not* identified as procedures in a DEFINE statement.

In some cases, you must change 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. Refer to Chapter 1 of the *Informix Guide to SQL: Syntax* for a list of the keywords that can be used ambiguously.

Variables and Column Names

If you use the same identifier for a procedural variable as 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 to use the identifier as a column name. In the following example, the procedure variable **lname** is the same as the column name. In the following SELECT statement, **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 FROM customer INTO lname
        WHERE customer_num = 502;
.
.
.
```

Variables and SQL Functions

If you use the same identifier for a procedural 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 following example shows a block within a 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
```

Procedure Names and SQL Functions

For information about ambiguities between procedure names and SQL function names, see the *Informix Guide to SQL: Syntax*.

SPL Expressions

You can use any SQL expression in a stored procedure except for an aggregate expression. The complete syntax and notes for SQL expressions are described in Chapter 1 of the *Informix Guide to SQL: Syntax*.

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)
```

Assigning Values to Variables

You can assign a value to a procedure variable in 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 statement.

Use the LET statement to assign a value to one or more variables. The following example illustrates several forms of the LET statement:

```
LET a = b + a;
LET a, b = c, d;
LET a, b = (SELECT fname, lname FROM customer
                WHERE customer_num = 101);
LET a, b = read_name(101);
```

Use the SELECT statement to assign a value directly from the database to a variable. The statement in the following example accomplishes the same task as the third LET statement in the previous example:

```
SELECT fname, lname into a, b FROM customer
    WHERE customer_num = 101
```

Use the CALL or EXECUTE PROCEDURE statements to assign values returned by a procedure to one or more procedural variables. Both statements in the following example return the full address from the procedure **read_address** into the specified procedural variables:

```
EXECUTE PROCEDURE 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;
```

Program Flow Control

SPL contains several statements that enable you to control the flow of your stored procedure and to make decisions based on data obtained at run time. These program-flow-control statements are described briefly in this section. Their syntax and complete descriptions are provided in Chapter 2 of the *Informix Guide to SQL: Syntax*.

Branching

Use an IF statement to form a logic branch in a stored procedure. An IF statement first evaluates a condition and, if the condition is true, the statement block contained in the THEN portion of the statement is executed. If the condition is not true, execution falls through to the next statement, unless the IF statement includes an ELSE clause or ELIF (else if) clause. The following example shows an IF statement:

```
CREATE PROCEDURE str_compare (str1 CHAR(20), str2 CHAR(20))
    RETURNING INT;
    DEFINE result INT;

    IF str1 > str2 THEN
        result = 1;
    ELIF str2 > str1 THEN
```

```
            result = -1;
        ELSE
            result = 0;
        END IF
        RETURN result;
    END PROCEDURE; -- str_compare
```

Looping

Three methods of looping exist in SPL. They are accomplished with one of the following statements:

FOR	initiates a controlled loop. Termination is guaranteed.
FOREACH	allows you to select and manipulate more than one row from the database. It declares and opens a cursor implicitly.
WHILE	initiates a loop. Termination is *not* guaranteed.

Four ways exist to leave a loop. They are accomplished with one of the following statements:

CONTINUE	skips the remaining statements in the present, identified loop and starts the next iteration of that loop.
EXIT	exits the present, identified loop. Execution resumes at the first statement after the loop.
RETURN	exits the procedure. If a return value is specified, that value is returned upon exit.
RAISE EXCEPTION	exits the loop if the exception is not trapped (caught) in the body of the loop.

See Chapter 2 of the *Informix Guide to SQL: Syntax* for more information concerning the syntax and use of these statements.

Function Handling

You can call procedures as well as run operating-system commands from within a procedure.

Calling Procedures Within a Procedure

Use a CALL statement or the SQL statement EXECUTE PROCEDURE to execute a procedure from a procedure. The following example shows a call to the **read_name** procedure using a CALL statement:

```
CREATE PROCEDURE call_test()
    RETURNING CHAR(15), CHAR(15);

    DEFINE fname, lname CHAR(15);
    CALL read_name('Putnum') RETURNING fname, lname;

    IF fname = 'Eileen' THEN RETURN 'Jessica', lname;
    ELSE RETURN fname, lname;
    END IF
END PROCEDURE;
```

Running an Operating-System Command from Within a Procedure

Use the SYSTEM statement to execute a system call from a procedure. The following example shows a call to the **echo** command:

```
CREATE DBA PROCEDURE delete_customer(cnum INT)

DEFINE username CHAR(8);

DELETE FROM customer
    WHERE customer_num = cnum;

IF username = 'acctclrk' THEN
    SYSTEM 'echo ''Delete from customer by acctclrk'' >>
/mis/records/updates' ;
END IF
END PROCEDURE; -- delete_customer
```

Calling a Procedure Recursively

You can call a procedure from itself. No restrictions apply on calling a procedure recursively.

Passing Information into and out of a Procedure

When you create a procedure, you determine whether it expects information to be passed to it by specifying an argument list. For each piece of information that the procedure expects, you specify one argument and the data type of that argument.

For example, if a procedure needs to have a single piece of integer information passed to it, you can provide a procedure heading as the following example shows:

```
CREATE PROCEDURE safe_delete(cnum INT)
```

Returning Results

A procedure that returns one or more values must contain two lines of code to accomplish the transfer of information: one line to state the data types that are going to be returned, and one line to return the values explicitly.

Specifying Return Data Types

Immediately after you specify the name and input parameters of your procedure, you must include a RETURNING clause with the data type of each value you expect to be returned. The following example shows the header of a procedure (name, parameters, and RETURNING clause) that expects one integer as input and returns one integer and one 10-byte character value:

```
CREATE PROCEDURE get_call(cnum INT)
    RETURNING INT, CHAR(10);
```

Returning the Value

Once you use the RETURNING clause to indicate the type of values that are to be returned, you can use the RETURN statement at any point in your procedure to return the same number and data types as listed in the RETURNING clause. The following example shows how you can return information from the **get_call** procedure:

```
CREATE PROCEDURE get_call(cnum INT)
    RETURNING INT, CHAR(10);
    DEFINE ncalls INT;
    DEFINE o_name CHAR(10);
    .
    .
    .
    RETURN ncalls, o_name;
    .
    .
    .
END PROCEDURE;
```

If you neglect to include a RETURN statement, you do not get an error message at compile time.

Returning More Than One Set of Values from a Procedure

If your procedure executes a SELECT statement that can return more than one row from the database, or if you return values from inside a loop, you must use the WITH RESUME keywords in the RETURN statement. Using a RETURN...WITH RESUME statement causes the value or values to be returned to the calling program or procedure. After the calling program receives the values, execution returns to the statement immediately following the RETURN...WITH RESUME statement.

The following example shows a *cursory* procedure. It returns values from a FOREACH loop and a FOR loop. This procedure is called a cursory procedure because it contains a FOREACH loop.

```
CREATE PROCEDURE 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 INT ;
```

```
        DEFINE i INT ;

        LET lcount = 0;
        TRACE ON;
        CREATE VIEW myview AS SELECT * FROM customer;
        TRACE 'Foreach starts';
        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;
        END FOREACH;

        FOR i IN (1 TO 5)
            BEGIN
             RETURN 'a', 'b', 'c', 'd', 'e' WITH RESUME;
            END
        END FOR;
    END PROCEDURE;
```

When you execute this procedure, it returns the name and address for each person with the specified last name. It also returns a sequence of letters. The calling procedure or program must be expecting multiple returned values, and it must use a cursor or a FOREACH statement to handle the multiple returned values.

Exception Handling

You can use the ON EXCEPTION statement to trap any exception (or error) that the database server returns to your procedure, or any exception raised by your procedure. The RAISE EXCEPTION statement lets you generate an exception within your procedure.

Trapping an Error 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 and precede the statement block with an ON EXCEPTION statement. If an error occurs in the block that follows the ON EXCEPTION statement, you can take recovery action.

The following example shows an ON EXCEPTION statement within a BEGIN...END 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);  -- will fail if t does not exist

LET c = (SELECT d FROM t);  -- will fail if d does not exist
END
```

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 completely.

Scope of Control of an ON EXCEPTION Statement

An ON EXCEPTION statement is valid for the statement block that follows the ON EXCEPTION statement, all the statement blocks nested within that following statement block, and all the statement blocks that follow the ON EXCEPTION statement. It is *not* valid in the statement block that contains the ON EXCEPTION statement.

The pseudocode in the following example shows where the exception is valid within the procedure. 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 -- statement block aa
            -- do action, a201 valid here
        END
        BEGIN -- statement block bb
            -- do action, a201 valid here
        END
        WHILE i < 10
            -- do something, a201 is valid here
        END WHILE

    END
    BEGIN   -- begin statement block B
        -- do something
        -- a201 is NOT valid here
    END
END PROCEDURE;
```

User-Generated Exceptions

You can generate your own error using the RAISE EXCEPTION statement, as the following pseudocode example shows. In this 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 BEGIN...END block to the last BEGIN...END block of the previous example.

```
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
```

Simulating SQL Errors

You can generate errors to simulate SQL errors, as the following example shows. Here, if the user is **pault**, then the stored procedure 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
```

Using RAISE EXCEPTION to Exit Nested Code

The following example shows how you can use the RAISE EXCEPTION statement to break out of a deeply nested block. 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.

```
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
```

Remember that a BEGIN...END block is a *single* statement. When an error occurs somewhere inside a block and the trap is outside the block, when execution resumes, the rest of the block is skipped and execution resumes 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 procedure stops, creating an error for the program or procedure that is executing the procedure.

Summary

Stored procedures provide many opportunities for streamlining your database process, including enhanced database performance, simplified applications, and limited or monitored access to data. See the *Informix Guide to SQL: Syntax* for syntax diagrams of SPL statements.

Chapter

Creating and Using Triggers

13

An SQL trigger is a mechanism that resides in the database. It is available to any user who has permission to use it. It specifies that when a particular action, an insert, a delete, or an update, occurs on a particular table, the database server should automatically perform one or more additional actions. The additional actions can be INSERT, DELETE, UPDATE, or EXECUTE PROCEDURE statements.

This chapter describes the purpose of each component of the CREATE TRIGGER statement, illustrates some uses for triggers, and describes the advantages of using a stored procedure as a triggered action.

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.

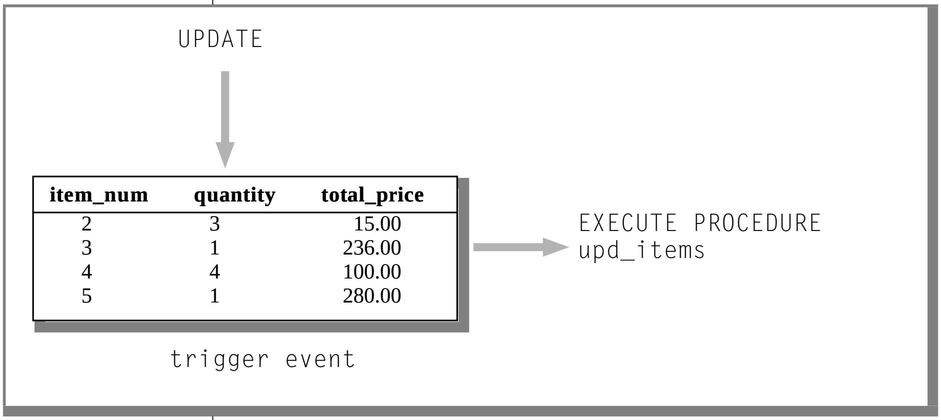
You can use triggers to perform the following actions as well as others that are not found in this list:

- 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 is, rows that have the same customer number) in the **orders** table.

How to Create a Trigger

You use the CREATE TRIGGER statement to create a trigger. The CREATE TRIGGER statement is a data definition statement that associates SQL statements with a precipitating action on a table. When the precipitating action occurs, the associated SQL statements, which are stored in the database, are triggered. Figure 13-1 illustrates the relationship of the precipitating action, or trigger event, to the triggered action.



item_num	quantity	total_price
2	3	15.00
3	1	236.00
4	4	100.00
5	1	280.00

Figure 13-1
Trigger Event and Triggered Action

The CREATE TRIGGER statement consists of clauses that perform the following actions:

- Assign a trigger name.
- Specify the trigger event, that is, the table and the type of action that initiate the trigger.
- Define the SQL actions that are triggered.

An optional clause, called the REFERENCING clause is discussed in "Using FOR EACH ROW Triggered Actions" on page 13-9.

You can create a trigger using the DB-Access utility, NewEra, INFORMIX-4GL, or one of the SQL APIs, INFORMIX-ESQL/C or INFORMIX-ESQL/COBOL. This section describes the CREATE TRIGGER statement as you would enter it using the interactive Query-language option in DB-Access. In an SQL API, you simply precede the statement with the symbol or keywords that identify it as an embedded statement. In NewEra and INFORMIX-4GL, you must end the trigger definition with the END TRIGGER keywords.

Assigning a Trigger Name

The trigger name identifies the trigger. It follows the words CREATE TRIGGER in the statement. It can be up to 18 characters in length, beginning with a letter and consisting of letters, the digits 0 to 9, and the underscore. In the following example, the portion of the CREATE TRIGGER statement that is shown assigns the name **upqty** to the trigger:

```
    CREATE TRIGGER upqty    -- assign trigger name
```

Specifying the Trigger Event

The *trigger event* is the type of 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. The trigger event can be an INSERT, DELETE, or UPDATE statement. When you define an UPDATE trigger event, you can name one or more columns in the table to activate the trigger. If you do not name any columns, then an update of any column in the table activates the trigger. You can create only one INSERT and one DELETE trigger per table, but you can create multiple UPDATE triggers as long as the triggering columns are mutually exclusive.

In the following excerpt of 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 create the trigger. If the trigger event is an insert or delete, 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
```

Defining 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, 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 can define actions for each of these times.

You define a triggered action by specifying when it occurs and then providing 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 stored procedure **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

If you combine the trigger-name clause, the trigger-event clause, and the triggered-action clause, you have a complete CREATE TRIGGER statement. The following CREATE TRIGGER statement is the result of combining the components of the statement from the preceding examples. This trigger executes the stored procedure **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 stored procedure **upd_items_p1** in this example, does not exist when the database server processes the CREATE TRIGGER statement, it returns an error.

Using 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.

Using 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 statemen*t, 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 stored procedure **upd_items_p1**, the following example shows, to calculate the total quantity on order for all items in the table. 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 stored procedure, **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 INFORMIX-OnLine Dynamic Server and the database has logging, the database server rolls back the changes made by both the triggering statement and the triggered actions. See CREATE TRIGGER in Chapter 1 of the *Informix Guide to SQL: Syntax* for more information on what happens when a trigger fails.

Using 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 statement does not process any rows, a FOR EACH ROW triggered action does not execute.

Using 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, you 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 affected by the triggering statement.

Important: *If you refer to a column name in the triggering table without using 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 within a FOR EACH ROW triggered action, unless the statement is valid independent of the triggered action. See CREATE TRIGGER in Chapter 1 of the "Informix Guide to SQL: Syntax."*

Using the WHEN Condition

As an option, 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.order_num,
        pre.unit_price, post.unit_price, CURRENT))
```

See CREATE TRIGGER in Chapter 1 of the *Informix Guide to SQL: Syntax* for more information on the WHEN condition.

Using Stored Procedures as Triggered Actions

Probably the most powerful feature of triggers is the ability to call a stored procedure as a triggered action. The EXECUTE PROCEDURE statement, which calls a stored procedure, lets you pass data from the triggering table to the stored procedure and also to update the triggering table with data returned by the stored procedure. SPL also lets you define variables, assign data to them, make comparisons, and use procedural statements to accomplish complex tasks within a triggered action.

Passing Data to a Stored Procedure

You can pass data to a stored procedure in the argument list of the EXECUTE PROCEDURE statement. The EXECUTE PROCEDURE statement in the following trigger example passes values from the **quantity** and **total_price** columns of the **items** table to the stored procedure **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 a stored procedure lets you use it in the operations that the procedure performs.

Using the Stored Procedure Language

The EXECUTE PROCEDURE statement in the preceding trigger calls the stored procedure that the following example shows. The procedure uses the 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.

Updating Nontriggering Columns with Data from a Stored Procedure

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** stored 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 stored procedure. The **total_price** column is updated for each row that the triggering statement affects.

Tracing Triggered Actions

If a triggered action does not behave as you expect, place it in a stored procedure, and use the SPL TRACE statement to monitor its operation. Before starting the trace, you must direct the output to a file with the SET DEBUG FILE TO statement. The following example shows TRACE statements that have been added to the stored procedure **items_pct.** The SET DEBUG FILE TO statement directs the trace output to the file **/usr/mydir/trig.trace**. 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 '/usr/mydir/trig.trace';
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));
```

The following example shows sample trace output from the **items_pct** procedure as it appears in the file **/usr/mydir/trig.trace**. 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
```

See Chapter 12, “Creating and Using Stored Procedures,” for more information on using the TRACE statement to diagnose logic errors in stored procedures.

Generating 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 a stored procedure, you can generate error messages for other error conditions by using 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 71 characters.

Applying 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:

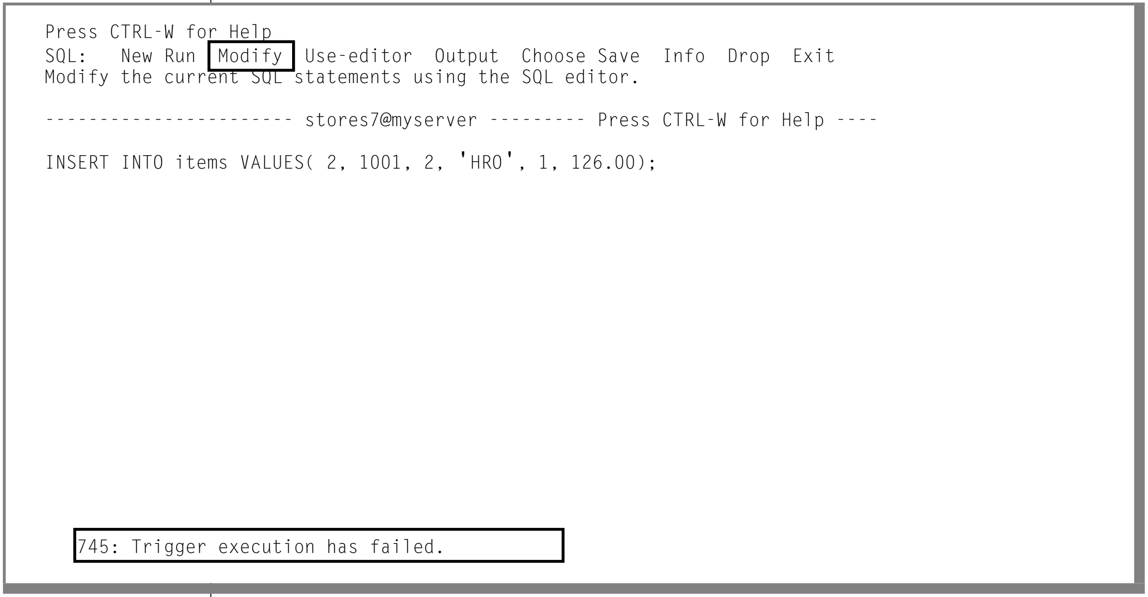
```
-745 Trigger execution has failed.
```

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 seen in Figure 13-2.

Figure 13-2
Error Message -745 with Fixed Message



```
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.

----------------------- stores7@myserver --------- Press CTRL-W for Help ----

INSERT INTO items VALUES( 2, 1001, 2, 'HRO', 1, 126.00);
```

```
745: Trigger execution has failed.
```

If you trigger the erring procedure 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 Informix application development tool provides for retrieving the text of an SQL error message.

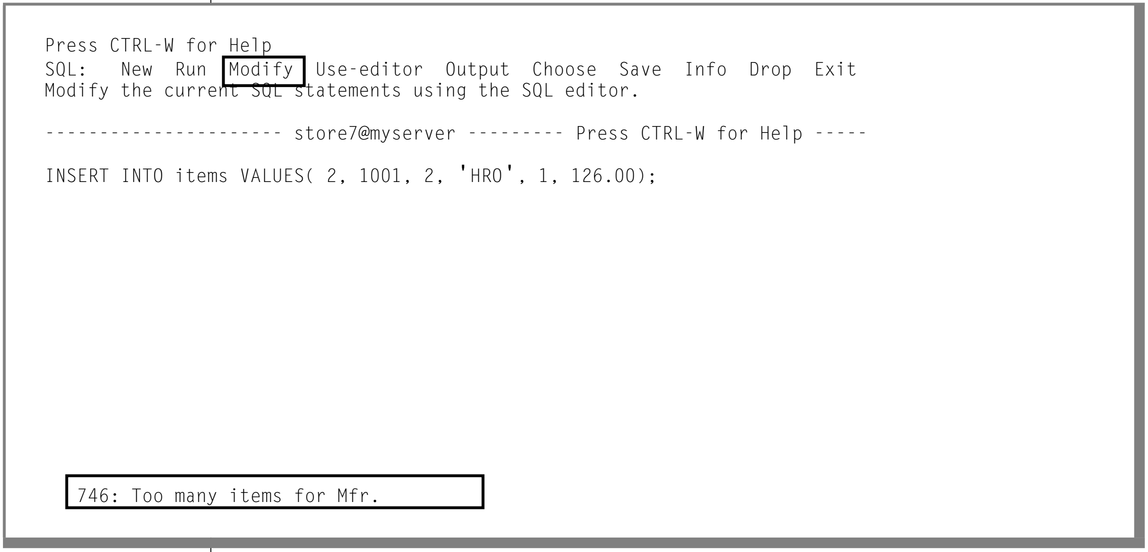
Generating a Variable Error Message

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. See the RAISE EXCEPTION statement in Chapter 12, “Creating and Using Stored Procedures,” for more information on the syntax and use of this statement.

```
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 Figure 13-3 shows.

Figure 13-3
Error Number -746 with User-Specified Message Text



```
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.
```

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 (SQLCA). See the manual for your SQL API for in-depth information about using the SQLCA.

Summary

To introduce triggers, this chapter covers the following topics:

- The purpose of each component of the CREATE TRIGGER statement
- 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
- The advantages of using stored procedures as triggered actions
- How to trace triggered actions if they are behaving unexpectedly
- How to generate two types of error messages within a triggered action

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