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Application Developer's Guide - Fundamentals

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Oracle Database Application Developer's Guide - Fundamentals, 10g Release 2 (10.2)

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Preface

The *Oracle Database Application Developer's Guide - Fundamentals* describes basic application development features of Oracle Database 10g. Information in this guide applies to features that work the same on all supported platforms, and does not include system-specific information.

Audience

Oracle Database Application Developer's Guide - Fundamentals is intended for programmers developing new applications or converting existing applications to run in the Oracle Database environment. This book will also be valuable to systems analysts, project managers, and others interested in the development of database applications.

To use this document, you need a working knowledge of application programming, and that you are acquainted with using the Structured Query Language (SQL) to access information in relational database systems. Some sections of this guide assume a familiar with object-oriented programming.

Documentation Accessibility

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Related Documents

For more information, see these Oracle resources:

- *Oracle Database PL/SQL User's Guide and Reference* to learn PL/SQL and to get a complete description of the PL/SQL high-level programming language, which is Oracle's procedural extension to SQL.
- *Oracle Call Interface Programmer's Guide* and *Oracle C++ Call Interface Programmer's Guide* to learn about the Oracle Call Interface (OCI). You can use the OCI to build third-generation language (3GL) applications that access the Oracle Database.
- *Oracle Database Security Guide* to learn about security features of the database that application developers and database administrators need to be aware of.
- The Oracle documentation for the Pro* series of precompilers, which allow you to embed SQL and PL/SQL in your programs. If you write 3GL application programs in C, C++, COBOL, or FORTRAN that incorporate embedded SQL, then refer to the corresponding precompiler manual. For example, if you program in C or C++, then refer to the *Pro*C/C++ Programmer's Guide.*
- Oracle JDeveloper 10g is an Integrated Development Environment (IDE) for building applications and Web services using the latest industry standards for Java, XML, and SQL. You can access the JDeveloper documentation at the following product page:

  `http://www.oracle.com/technology/products/jdev`
- *Oracle Database SQL Reference* and *Oracle Database Administrator's Guide* for SQL information.
- *Oracle Database Concepts* for basic Oracle Database concepts
- *Oracle XML Developer's Kit Programmer's Guide* and *Oracle XML DB Developer's Guide* for developing applications that manipulate XML data.

Many of the examples in this book use the sample schemas, which are installed by default when you select the Basic Installation option with an Oracle Database installation. Refer to *Oracle Database Sample Schemas* for information on how these schemas were created and how you can use them yourself.

Printed documentation is available for sale in the Oracle Store at

`http://oraclestore.oracle.com/`

To download free release notes, installation documentation, white papers, or other collateral, please visit the Oracle Technology Network (OTN). You must register online before using OTN; registration is free and can be done at

`http://www.oracle.com/technology/membership/`

If you already have a username and password for OTN, then you can go directly to the documentation section of the OTN Web site at

http://www.oracle.com/technology/documentation/

For additional information, see:

- *Oracle JDeveloper 10g: Empowering J2EE Development* by Harshad Oak. Apress, 2004.
- *Oracle JDeveloper 10g Handbook* by Avrom Faderman, Peter Koletzke, and Paul Dorsey. Oracle Press, 2004.
- *Oracle PL/SQL Tips and Techniques* by Joseph C. Trezzo. Oracle Press, 1999.
- *Oracle PL/SQL Programming* by Steven Feuerstein. 3rd Edition. O'Reilly & Associates, 2002.
- *Oracle PL/SQL Developer's Workbook* by Steven Feuerstein. O'Reilly & Associates, 2000.
- *Oracle PL/SQL Best Practices* by Steven Feuerstein. O'Reilly & Associates, 2001.

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

What's New in Application Development?

This section describes new features of the Oracle Database 10g Release 2 (10.2) and provides pointers to additional information. New features information from previous releases is also retained to help those users migrating to the current release.

The following sections describe the new features in Oracle Oracle Database 10g:

Oracle Database 10*g* Release 2 (10.2) New Features

This section discusses new features introduced in Oracle Database 10g Release 1 (10.1).

- **Regular expression enhancements**

  This release adds SQL support for common Perl-based extensions that are not included but do not conflict with the POSIX standard.

  See Also: Chapter 4, "Using Regular Expressions in Oracle Database" for more information

- **Unicode datatype literal enhancement**

  You can avoid data loss if the database character set cannot represent all characters in the client character set.

  See Also: "Using Character Literals in SQL Statements" on page 3-4

- **Database Change Notification**

  Database Change Notification enables client applications to receive notifications when the result set of a registered query changes. For example, if the client registers a query of the `hr.employees` table, and if a user adds an employee, then the application can receive a database change notification when a new row is added to the table. A new query of `hr.employees` returns the changed result set.

  Database Change Notification supports both mid-tier caches and server-side stored procedures. For example, a stored procedure that performs DML on registered tables can automatically send change notifications to a mid-tier application, which can keep cached data up to date.

  See Also: Chapter 13, "Developing Applications with Database Change Notification"

- **Asynchronous Commit**

  Oracle Database enables you to change the handling of commit redo depending on the needs of your application. You can change the default `COMMIT` options so that the application does not need to wait for Oracle Database to write data to the online redo logs.

  See Also: "Managing Commit Redo Behavior" on page 2-3

- **Automatic Undo Retention Enhancement**

  This feature provides maximum retention for the fixed-size undo tablespace, thereby improving flashback capability as well as other statistic collection queries in which the query length is unknown.

  See Also: "Database Administration Tasks Before Using Flashback Features" on page 10-3

- **Failover Improvements for Real Application Clusters (RAC) Distributed Transactions**

  Distributed Transactions in a RAC environment detect failures and start the failover and failback processes automatically.

  See Also: "Using XA with Oracle Real Application Clusters" on page 15-19

- **XML DB Web Services**

  Enables direct access to the Oracle database through a native Web Service. Developers can write and deploy web services that can query the database with SQL or XQuery or execute stored procedures. You can access web services through the Oracle XML DB listener.

  See Also: "Overview of Oracle Database Web Services" on page 1-14

Oracle Database 10*g* Release 1 (10.1) New Features

This section discusses new features introduced in Oracle Database 10g Release 1 (10.1).

- **Regular Expression Support**

  A set of SQL functions introduced in this release let you perform queries and manipulate string data by means of regular expressions. Refer to Chapter 4, "Using Regular Expressions in Oracle Database" for more information.

- **Oracle Expression Filter**

  Oracle Expression Filter lets you store conditional expressions in a column that you can use in the `WHERE` clause of a database query. Refer to "Representing Conditional Expressions as Data" on page 3-22 for more information.

  See Also: *Oracle Database SQL Reference*

- **Native floating-point datatypes**

  Column datatypes `BINARY_FLOAT` and `BINARY_DOUBLE` are introduced in this release. These datatypes provide an alternative to using the Oracle `NUMBER` datatype, with the following benefits:

- More efficient use of storage resources
- Faster arithmetic operations
- Support for numerical algorithms specified in the IEEE 754 Standard

Support for native floating-point datatypes in bind and fetch operations is provided for the following client interfaces:

- SQL
- PL/SQL
- OCI
- OCCI
- Pro*C/C++
- JDBC

See Also: "Representing Numeric Data" on page 3-5

- **Terabyte-Size Large Object (LOB) support**

  This release provides support for terabyte-size LOB values (from 8 to 128 terabytes) in the following programmatic environments:

  - Java (JDBC)
  - OCI
  - PL/SQL (package `DBMS_LOB`)

  You can store and manipulate LOB (`BLOB`, `CLOB`, and `NCLOB`) datatypes larger than 4GB.

  See Also: For details on terabyte-size LOB support:

  - *Oracle Database Application Developer's Guide - Large Objects*
  - *Oracle Call Interface Programmer's Guide*

- **Flashback**

  This release has new and enhanced flashback features. You can now do the following:

  - Query the transaction history of a row.
  - Obtain the SQL undo syntax for a row and perform row-level flashback operations.
  - Perform remote queries of past data.

  See Also: Chapter 10, "Developing Flashback Applications"

- **Oracle Data Provider for .NET**

  Oracle Data Provider for .NET (ODP.NET) is a new programmatic environment that implements a data provider for Oracle Database. It uses APIs native to Oracle Database to offer fast and reliable access from any .NET application to database features and data. ODP.NET also uses and inherits classes and interfaces available in the Microsoft .NET Framework Class Library.

  See Also: *Oracle Data Provider for .NET Developer's Guide*

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Orientation to Oracle Programmatic Environments

This chapter contains these topics:

Overview of Oracle Application Development

As an application developer, you have many choices when writing a program to interact with an Oracle database.

Client/Server Model

In a traditional client/server program, the code of your application runs on a machine other than the database server. Database calls are transmitted from this client machine to the database server. Data is transmitted from the client to the server for insert and update operations and returned from the server to the client for query operations. The data is processed on the client machine. Client/server programs are typically written by using precompilers, whereas SQL statements are embedded within the code of another language such as C, C++, or COBOL.

Server-Side Coding

You can develop application logic that resides entirely inside the database by using triggers that are executed automatically when changes occur in the database or stored procedures that are called explicitly. Off-loading the work from your application lets you reuse code that performs verification and cleanup and control database operations from a variety of clients. For example, by making stored procedures callable through a Web server, you can construct a Web-based user interface that performs the same functions as a client/server application.

Two-Tier Versus Three-Tier Models

Client/server computing is often referred to as a **two-tier model**: your application communicates directly with the database server. In the **three-tier model**, a separate **application server** processes the requests. The application server might be a basic Web server, or might perform advanced functions like caching and load-balancing. Increasing the processing power of this middle tier lets you lessen the resources needed by client systems, resulting in a **thin client** configuration in which the client machine might need only a Web browser or other means of sending requests over the TCP/IP or HTTP protocols.

User Interface

The interface that your application displays to end users depends on the technology behind the application as well as the needs of the users themselves. Experienced users can enter SQL commands that are passed on to the database. Novice users can be shown a graphical user interface that uses the graphics libraries of the client system (such as Windows or X-Windows). Any of these traditional user interfaces can also be provided in a Web browser by means of HTML and Java.

Stateful Versus Stateless User Interfaces

In traditional client/server applications, the application can keep a record of user actions and use this information over the course of one or more sessions. For example, past choices can be presented in a menu so that they do not have to be entered again. When the application is able to save information in this way, the application is considered **stateful**.

Web or thin-client applications that are **stateless** are easier to develop. Stateless applications gather all the required information, process it using the database, and then start over with the next user. This is a popular way to process single-screen requests such as customer registration.

There are many ways to add stateful behavior to Web applications that are stateless by default. For example, an entry form on one Web page can pass information to subsequent Web pages, allowing you to construct a wizard-like interface that remembers the user's choices through several different steps. Cookies can be used to store small items of information on the client machine, and retrieve them when the user returns to a Web site. Servlets can be used to keep a database session open and store variables between requests from the same client.

Overview of PL/SQL

This section contains the following topics:

What Is PL/SQL?

PL/SQL is Oracle's procedural extension to SQL, the standard database access language. It is an advanced 4GL (fourth-generation programming language), which means that it is an application-specific language. PL/SQL and SQL have built-in treatment of the relational database domain.

In PL/SQL, you can manipulate data with SQL statements and control program flow with procedural constructs such as loops. You can also do the following:

- Declare constants and variables
- Define procedures and functions
- Use collections and object types
- Trap runtime errors

Applications written in any of the Oracle programmatic interfaces can call PL/SQL stored procedures and send blocks of PL/SQL code to Oracle Database for execution. 3GL applications can access PL/SQL scalar and composite datatypes through host variables and implicit datatype conversion. A 3GL language is easier than assembler language for a human to understand and includes features such as named variables. Unlike 4GL, it is not specific to an application domain.

Example 1–1 provides an example of a simple PL/SQL procedure. The procedure `debit_account` withdraws money from a bank account. It accepts an account number and an amount of money as parameters. It uses the account number to retrieve the account balance from the database, then computes the new balance. If this new balance is less than zero, then the procedure jumps to an error routine; otherwise, it updates the bank account.

Example 1–1 Simple PL/SQL Example

```
PROCEDURE debit_account (p_acct_id INTEGER, p_debit_amount REAL)
IS
   v_old_balance  REAL;
   v_new_balance  REAL;
   e_overdrawn    EXCEPTION;
BEGIN
   SELECT bal
     INTO v_old_balance
   FROM accts
   WHERE acct_no = p_acct_id;
   v_new_balance := v_old_balance - p_debit_amount;
   IF v_new_balance < 0 THEN
      RAISE e_overdrawn;
   ELSE
      UPDATE accts SET bal = v_new_balance
         WHERE acct_no = p_acct_id;
   END IF;
   COMMIT;
EXCEPTION
   WHEN e_overdrawn THEN
      -- handle the error
END debit_account;
```

See Also:

- *Oracle Database PL/SQL User's Guide and Reference*
- *Oracle Database SQL Reference*

Advantages of PL/SQL

PL/SQL is a portable, high-performance transaction processing language with the following advantages:

- Integration with Oracle Database
- High Performance
- High Productivity

- Scalability
- Manageability
- Object-Oriented Programming Support
- Portability
- Security
- Built-In Packages

Integration with Oracle Database

PL/SQL enables you use all of the Oracle Database SQL data manipulation, cursor control, and transaction control statements. PL/SQL also supports the SQL functions, operators, and pseudocolumns. So, you can manipulate data in Oracle Database flexibly and safely.

PL/SQL supports all SQL datatypes. Combined with the direct access that SQL provides, these shared datatypes integrate PL/SQL with the Oracle Database data dictionary.

PL/SQL supports Dynamic SQL, which is a programming technique that enables you to build and process SQL statements "on the fly" at run time. It gives PL/SQL flexibility comparable to scripting languages such as Perl, Korn shell, and Tcl.

The `%TYPE` and `%ROWTYPE` attributes enable your code to adapt as table definitions change. For example, the `%TYPE` attribute declares a variable based on the type of a database column. If the column datatype changes, then the variable uses the correct type at runtime. This provides data independence and reduces maintenance costs.

High Performance

If your application is database intensive, then you can use PL/SQL blocks to group SQL statements before sending them to Oracle Database for execution. This coding strategy can drastically reduce the communication overhead between your application and Oracle Database.

PL/SQL stored procedures are compiled once and stored in executable form, so procedure calls are quick and efficient. A single call can start a compute-intensive stored procedure, reducing network traffic and improving round-trip response times. Executable code is automatically cached and shared among users, lowering memory requirements and invocation overhead.

High Productivity

PL/SQL adds procedural capabilities such as Oracle Forms and Oracle Reports. For example, you can use an entire PL/SQL block in an Oracle Forms trigger instead of multiple trigger steps, macros, or user exits.

PL/SQL is the same in all environments. As soon as you master PL/SQL with one Oracle tool, you can transfer your knowledge to others, and so multiply the productivity gains. For example, scripts written with one tool can be used by other tools.

Scalability

PL/SQL stored procedures increase scalability by centralizing application processing on the server. Automatic dependency tracking helps you develop scalable applications.

The shared memory facilities of the shared server enable Oracle Database to support many thousands of concurrent users on a single node. For more scalability, you can use the Oracle Connection Manager to multiplex network connections.

Manageability

After being validated, you can use a PL/SQL stored procedure in any number of applications. If its definition changes, then only the procedure is affected, not the applications that call it. This simplifies maintenance and enhancement. Also, maintaining a procedure on the Oracle Database is easier than maintaining copies on various client machines.

Object-Oriented Programming Support

You can use PL/SQL object types and collections for object-oriented programming.

Object Types An object type is a user-defined composite datatype that encapsulates a data structure along with the functions and procedures needed to manipulate the data. The variables that form the data structure are called attributes. The functions and procedures that characterize the behavior of the object type are called methods, which you can implement in PL/SQL.

Object types are an ideal object-oriented modeling tool, which you can use to reduce the cost and time required to build complex applications. Besides allowing you to create software components that are modular, maintainable, and reusable, object types allow different teams of programmers to develop software components concurrently.

Collections A collection is an ordered group of elements, all of the same type (for example, the grades for a class of students). Each element has a unique subscript that determines its position in the collection. PL/SQL offers two kinds of collections: nested tables and varrays (variable-size arrays).

Collections work like the set, queue, stack, and hash table data structures found in most third-generation programming languages. Collections can store instances of an object type and can also be attributes of an object type. Collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms. You can define collection types in a PL/SQL package, then use the same types across many applications.

Portability

Applications written in PL/SQL can run on any operating system and hardware platform on which Oracle Database runs. You can write portable program libraries and reuse them in different environments.

Security

PL/SQL stored procedures enable you to divide application logic between the client and the server, which prevents client applications from manipulating sensitive Oracle Database data. Database triggers written in PL/SQL can prevent applications from making specified updates and can audit user queries.

You can restrict access to Oracle Database data by allowing users to manipulate it only through stored procedures that have a restricted set of privileges. For example, you can grant users access to a procedure that updates a table but not grant them access to the table itself.

See Also: *Oracle Database Security Guide* for details on database security features

Built-In Packages

A package is an encapsulated collection of related program objects stored together in the database. Program objects are procedures, functions, variables, constants, cursors, and exceptions.

The following packages are especially useful in application development for Oracle Database:

- `DBMS_PIPE` is used to communicate between sessions.
- `DBMS_ALERT` is used to broadcast alerts to users.
- `DBMS_LOCK` and `DBMS_TRANSACTION` are used for lock and transaction management.
- `DBMS_AQ` is used for Advanced Queuing.
- `DBMS_LOB` is used to manipulate large objects.
- `DBMS_ROWID` is used for employing `ROWID` values.
- `UTL_RAW` is the RAW facility.
- `UTL_REF` is for work with `REF` values.

The following packages are useful for server manageability:

- `DBMS_SESSION` is for session management by DBAs.
- `DBMS_SPACE` and `DBMS_SHARED_POOL` provide space information and reserve shared pool resources.
- `DBMS_JOB` is used to schedule jobs in the server.

PL/SQL Web Development Tools

Oracle Database provides built-in tools and technologies that enable you to deploy PL/SQL applications over the Web. Thus, PL/SQL serves as an alternative to Web application frameworks such as CGI.

The **PL/SQL Web Toolkit** is a set of PL/SQL packages that you can use to develop stored procedures that can be invoked by a Web client. The PL/SQL Gateway enables an HTTP client to invoke a PL/SQL stored procedure through mod_plsql, which is a plug-in to Oracle HTTP Server. This module performs the following actions:

1. Translates a URL passed by a browser client
2. Calls an Oracle Database stored procedure with the parameters in the URL
3. Returns output (typically HTML) to the client

See Also: Chapter 11, "Developing Applications with the PL/SQL Web Toolkit" to learn how to use PL/SQL in Web development

Overview of Java Support Built Into the Database

This section provides an overview of built-in database features that support Java applications. The database includes the core JDK libraries such as `java.lang`, `java.io`, and so on. The database supports client-side Java standards such as JDBC

and SQLJ, and provides server-side JDBC and SQLJ drivers that allow data-intensive Java code to run within the database.

This section contains the following topics:

- Overview of Oracle JVM
- Overview of Oracle Extensions to JDBC
- Overview of Oracle SQLJ
- Overview of Oracle JPublisher
- Overview of Java Stored Procedures
- Overview of Oracle Database Web Services
- Overview of Writing Procedures and Functions in Java

See Also:

- *Oracle Database Concepts* for background information about Java and how the database supports it
- *Oracle Database Java Developer's Guide*
- *Oracle Database JDBC Developer's Guide and Reference*
- *Oracle Database JPublisher User's Guide*

Overview of Oracle JVM

Oracle JVM, the Java Virtual Machine provided with the Oracle Database, is compliant with the J2SE version 1.4.x specification and supports the database session architecture.

Any database session can activate a dedicated JVM. All sessions share the same JVM code and statics; however, private states for any given session are held, and subsequently garbage collected, in an individual session space.

This design provides the following benefits:

- Java applications have the same session isolation and data integrity as SQL operations.
- There is no need to run Java in a separate process for data integrity.
- Oracle JVM is a robust JVM with a small memory footprint.
- The JVM has the same linear Symmetric Multiprocessing (SMP) scalability as the database and can support thousands of concurrent Java sessions.

Oracle JVM works consistently with every platform supported by Oracle Database. Java applications that you develop with Oracle JVM can easily be ported to any supported platform.

Oracle JVM includes a deployment-time native compiler that enables Java code to be compiled once, stored in executable form, shared among users, and invoked more quickly and efficiently.

Security features of the database are also available with Oracle JVM. Java classes must be loaded in a database schema (by using Oracle JDeveloper, a third-party IDE, SQL*Plus, or the loadjava utility) before they can be invoked. Java class invocation is secured and controlled through database authentication and authorization, Java 2 security, and invoker's or definer's rights.

Overview of Oracle Extensions to JDBC

JDBC (Java Database Connectivity) is an API (Applications Programming Interface) that allows Java to send SQL statements to an object-relational database such as Oracle Database.

The JDBC standard defines four types of JDBC drivers:

- Type 1. A JDBC-ODBC bridge. Software must be installed on client systems.
- Type 2. Native methods (calls C or C++) and Java methods. Software must be installed on the client.
- Type 3. Pure Java. The client uses sockets to call middleware on the server.
- Type 4. The most pure Java solution. Talks directly to the database by using Java sockets.

JDBC is based on the X/Open SQL Call Level Interface, and complies with the SQL92 Entry Level standard.

You can use JDBC to do dynamic SQL. In dynamic SQL, the embedded SQL statement to be executed is not known before the application is run and requires input to build the statement.

The drivers that are implemented by Oracle have extensions to the capabilities in the JDBC standard that was defined by Sun Microsystems. Oracle's implementations of JDBC drivers are described in the following sections. Oracle Database support of and extensions to various levels of the JDBC standard are described in "Oracle Database Extensions to JDBC Standards" on page 1-9.

JDBC Thin Driver

The JDBC thin driver is a Type 4 (100% pure Java) driver that uses Java sockets to connect directly to a database server. It has its own implementation of a Two-Task Common (TTC), a lightweight implementation of TCP/IP from Oracle Net. It is written entirely in Java and is therefore platform-independent.

The thin driver does not require Oracle software on the client side. It does need a TCP/IP listener on the server side. Use this driver in Java applets that are downloaded into a Web browser or in applications for which you do not want to install Oracle client software. The thin driver is self-contained, but it opens a Java socket, and thus can only run in a browser that supports sockets.

JDBC OCI Driver

The OCI driver is a Type 2 JDBC driver. It makes calls to the OCI (Oracle Call Interface) written in C to interact with Oracle Database, thus using native and Java methods.

The OCI driver allows access to more features than the thin driver, such as Transparent Application Fail-Over, advanced security, and advanced LOB manipulation.

The OCI driver provides the highest compatibility between different Oracle Database versions. It also supports all installed Oracle Net adapters, including IPC, named pipes, TCP/IP, and IPX/SPX.

Because it uses native methods (a combination of Java and C) the OCI driver is platform-specific. It requires a client installation of version Oracle8*i* or later including Oracle Net, OCI libraries, CORE libraries, and all other dependent files. The OCI driver usually executes faster than the thin driver.

The OCI driver is not appropriate for Java applets, because it uses a C library that is platform-specific and cannot be downloaded into a Web browser. It is usable in J2EE components running in middle-tier application servers, such as Oracle Application Server. Oracle Application Server provides middleware services and tools that support access between applications and browsers.

JDBC Server-Side Internal Driver

The JDBC server-side internal driver is a Type 2 driver that runs inside the database server, reducing the number of round-trips needed to access large amounts of data. The driver, the Java server VM, the database, the Java native compiler which speeds execution by as much as 10 times, and the SQL engine all run within the same address space.

This driver provides server-side support for any Java program used in the database: SQLJ stored procedures, functions, triggers, and Java stored procedures. You can also call PL/SQL stored procedures, functions, and triggers.

The server driver fully supports the same features and extensions as the client-side drivers.

Oracle Database Extensions to JDBC Standards

Oracle Database includes the following extensions to the JDBC 1.22 standard:

- Support for Oracle datatypes
- Performance enhancement by row prefetching
- Performance enhancement by execution batching
- Specification of query column types to save round-trips
- Control of `DatabaseMetaData` calls

Oracle Database supports all APIs from the JDBC 2.0 standard, including the core APIs, optional packages, and numerous extensions. Some of the highlights include datasources, JTA, and distributed transactions.

Oracle Database supports the following features from the JDBC 3.0 standard:

- Support for JDK 1.4.
- Toggling between local and global transactions.
- Transaction savepoints.
- Reuse of prepared statements by connection pools.

Sample JDBC 2.0 Program

The following example shows the recommended technique for looking up a data source using JNDI in JDBC 2.0:

```
// import the JDBC packages
import java.sql.*;
import javax.sql.*;
import oracle.jdbc.pool.*;
...
   InitialContext ictx = new InitialContext();
   DataSource ds = (DataSource)ictx.lookup("jdbc/OracleDS");
   Connection conn = ds.getConnection();
   Statement stmt = conn.createStatement();
   ResultSet rs = stmt.executeQuery("SELECT last_name FROM employees");
```

```
   while ( rs.next() ) {
   out.println( rs.getString("ename") + "<br>");
   }
conn.close();
```

Sample Pre-2.0 JDBC Program

The following source code registers an Oracle JDBC thin driver, connects to the database, creates a `Statement` object, executes a query, and processes the result set.

The `SELECT` statement retrieves and lists the contents of the `last_name` column of the `hr.employees` table.

```
import java.sql.*
import java.math.*
import java.io.*
import java.awt.*

class JdbcTest {
  public static void main (String args []) throws SQLException {
    // Load Oracle driver
    DriverManager.registerDriver (new oracle.jdbc.OracleDriver());

    // Connect to the local database
    Connection conn =
      DriverManager.getConnection ("jdbc:oracle:thin:@myhost:1521:orcl",
                                   "hr", "hr");

    // Query the employee names
    Statement stmt = conn.createStatement ();
    ResultSet rset = stmt.executeQuery ("SELECT last_name FROM employees");

    // Print the name out
    while (rset.next ())
      System.out.println (rset.getString (1));
    // Close the result set, statement, and the connection
    rset.close();
    stmt.close();
    conn.close();
  }
}
```

One Oracle Database extension to the JDBC drivers is a form of the `getConnection()` method that uses a `Properties` object. The `Properties` object lets you specify user, password, and database information as well as row prefetching and execution batching.

To use the OCI driver in this code, replace the `Connection` statement with the following, where `MyHostString` is an entry in the `tnsnames.ora` file:

```
Connection conn = DriverManager.getConnection ("jdbc:oracle:oci8:@MyHostString",
    "hr", "hr");
```

If you are creating an applet, then the `getConnection()` and `registerDriver()` strings will be different.

JDBC in SQLJ Applications

JDBC code and SQLJ code (see "Overview of Oracle SQLJ" on page 1-11) interoperate, allowing dynamic SQL statements in JDBC to be used with both static and dynamic SQL statements in SQLJ. A SQLJ iterator class corresponds to the JDBC result set.

See Also: *Oracle Database JDBC Developer's Guide and Reference* for more information on JDBC

Overview of Oracle SQLJ

SQLJ is an ANSI SQL-1999 standard for embedding SQL statements in Java source code. SQLJ provides a simpler alternative to JDBC for both client-side and server-side SQL data access from Java.

A SQLJ source file contains Java source with embedded SQL statements. Oracle SQLJ supports dynamic as well as static SQL. Support for dynamic SQL is an Oracle extension to the SQLJ standard.

Note: The term "SQLJ," when used in this manual, refers to the Oracle SQLJ implementation, including Oracle SQLJ extensions.

Oracle Database provides a translator and a run time driver to support SQLJ. The SQLJ translator is 100% pure Java and is portable to any JVM that is compliant with JDK version 1.1 or higher.

The Oracle SQLJ translator performs the following tasks:

- Translates SQLJ source to Java code with calls to the SQLJ run time driver. The SQLJ translator converts the source code to pure Java source code and can check the syntax and semantics of static SQL statements against a database schema and verify the type compatibility of host variables with SQL types.
- Compiles the generated Java code with the Java compiler.
- (Optional) Creates profiles for the target database. SQLJ generates "profile" files with customization specific to Oracle Database.

Oracle Database supports SQLJ stored procedures, functions, and triggers which execute in the Oracle JVM. SQLJ is integrated with JDeveloper. Source-level debugging support for SQLJ is available in JDeveloper.

The following is an example of a simple SQLJ executable statement, which returns one value because `employee_id` is unique in the `employee` table:

```
String name;
#sql  { SELECT first_name INTO :name FROM employees WHERE employee_id=112 };
System.out.println("Name is " + name + ", employee number = " + employee_id);
```

Each host variable (or qualified name or complex Java host expression) included in a SQL expression is preceded by a colon (`:`). Other SQLJ statements declare Java types. For example, you can declare an iterator (a construct related to a database cursor) for queries that retrieve many values, as follows:

```
#sql iterator EmpIter (String EmpNam, int EmpNumb);
```

See Also: For more examples and details on Oracle SQLJ syntax:

- *Oracle Database JPublisher User's Guide*
- Sample SQLJ code available on the Oracle Technology Network Web site: `http://www.oracle.com/technology/`

Benefits of SQLJ

Oracle SQLJ extensions to Java allow rapid development and easy maintenance of applications that perform database operations through embedded SQL.

In particular, Oracle SQLJ does the following:

- Provides a concise, legible mechanism for database access from static SQL. Most SQL in applications is static. SQLJ provides more concise and less error-prone static SQL constructs than JDBC does.
- Provides an SQL Checker module for verification of syntax and semantics at translate time.
- Provides flexible deployment configurations, which makes it possible to implement SQLJ on the client, server, or middle tier.
- Supports a software standard. SQLJ is an effort of a group of vendors and will be supported by all of them. Applications can access multiple database vendors.
- Provides source code portability. Executables can be used with all of the vendor DBMSs if the code does not rely on any vendor-specific features.
- Enforces a uniform programming style for the clients and the servers.
- Integrates the SQLJ translator with **Oracle JDeveloper**, a graphical IDE that provides SQLJ translation, Java compilation, profile customizing, and debugging at the source code level, all in one step.
- Includes Oracle type extensions. Datatypes supported include: LOB datatypes, `ROWID`, `REF CURSOR`, `VARRAY`, nested table, user-defined object types, `RAW`, and `NUMBER`.

Comparing SQLJ with JDBC

JDBC provides a complete dynamic SQL interface from Java to databases. It gives developers full control over database operations. SQLJ simplifies Java database programming to improve development productivity.

JDBC provides fine-grained control of the execution of dynamic SQL from Java, whereas SQLJ provides a higher-level binding to SQL operations in a specific database schema. Following are some differences between JDBC and SQLJ:

- SQLJ source code is more concise than equivalent JDBC source code.
- SQLJ uses database connections to type-check static SQL code. JDBC, being a completely dynamic API, does not.
- SQLJ provides strong typing of query outputs and return parameters and allows type-checking on calls. JDBC passes values to and from SQL without compile-time type checking.
- SQLJ programs allow direct embedding of Java bind expressions within SQL statements. JDBC requires a separate get or set statement for each bind variable and specifies the binding by position number.
- SQLJ provides simplified rules for calling SQL stored procedures and functions. For example, the following JDBC excerpt requires a generic call to a stored procedure or function, in this case *fun*, to have the following syntax. (This example shows SQL92 and Oracle JDBC syntaxes. Both are allowed.)

```
prepStmt.prepareCall("{call fun(?,?)}");       //stored procedure SQL92
prepStmt.prepareCall("{? = call fun(?,?)}");   //stored function SQL92
prepStmt.prepareCall("begin fun(:1,:2);end;"); //stored procedure Oracle
prepStmt.prepareCall("begin :1 := fun(:2,:3);end;");//stored func Oracle
```

Following is the SQLJ equivalent:

```
#sql {call fun(param_list) };  //Stored procedure
// Declare x
...
#sql x = {VALUES(fun(param_list)) };  // Stored function
// where VALUES is the SQL construct
```

The following benefits are common to SQLJ and JDBC:

- SQLJ source files can contain JDBC calls. SQLJ and JDBC are interoperable.
- Oracle JPublisher generates custom Java classes to be used in your SQLJ or JDBC application for mappings to Oracle object types and collections.
- Java and PL/SQL stored procedures can be used interchangeably.

SQLJ Stored Procedures in the Server

SQLJ applications can be stored and executed in the server by using the following techniques:

- Translate, compile, and customize the SQLJ source code on a client and load the generated classes and resources into the server with the `loadjava` utility. The classes are typically stored in a Java archive (`.jar`) file.
- Load the SQLJ source code into the server, also using `loadjava`, where it is translated and compiled by the server's embedded translator.

> **See Also:** *Oracle Database JPublisher User's Guide* for more information on using stored procedures with Oracle SQLJ

Overview of Oracle JPublisher

Oracle JPublisher is a code generator that automates the process of creating database-centric Java classes by hand. Oracle JPublisher is a client-side utility and is built into the database system. You can run Oracle JPublisher from the command line or directly from the Oracle JDeveloper IDE.

Oracle JPublisher inspects PL/SQL packages and database object types such as SQL object types, `VARRAY` types, and nested table types, and then generates a Java class that is a wrapper around the PL/SQL package with corresponding fields and methods.

The generated Java class can be incorporated and used by Java clients or J2EE components to exchange and transfer object type instances to and from the database transparently.

> **See Also:** *Oracle Database JPublisher User's Guide*

Overview of Java Stored Procedures

Java stored procedures enable you to implement programs that run in the database server and which are independent of programs that run in the middle tier. Structuring applications in this way reduces complexity and increases reuse, security, performance, and scalability.

For example, you can create a Java stored procedure that performs operations that require data persistence and a separate program to perform presentation or business logic operations.

Java stored procedures interface with SQL by using a similar execution model as PL/SQL.

See Also: *Oracle Database Java Developer's Guide*

Overview of Oracle Database Web Services

Web services represent a distributed computing paradigm for Java application development that is an alternative to earlier Java protocols such as JDBC. It allows application-to-application interaction by means of the XML and Web protocols. For example, an electronics parts vendor can provide a Web-based programmatic interface to its suppliers for inventory management. The vendor can call a Web service as part of a program and automatically order new stock based on the data returned.

The key technologies used in Web services are:

- Web Services Description Language (WSDL), which is a standard format for creating an XML document. WSDL describes what a web service can do, where it resides, and how to invoke it. Specifically, it describes the operations and parameters, including parameter types, provided by a Web service. In addition, a WSDL document describes the location, the transport protocol, and the invocation style for the Web service.
- Simple Object Access Protocol (SOAP) messaging, which is an XML-based message protocol used by Web services. SOAP does not prescribe a specific transport mechanism such as HTTP, FTP, SMTP, or JMS; however, most Web services accept messages that use HTTP or HTTPS.
- Universal Description, Discovery, and Integration (UDDI) business registry, which is a directory that lists Web services on the internet. The UDDI registry is often compared to a telephone directory, listing unique identifiers (white pages), business categories (yellow pages), and instructions for binding to a service protocol (green pages).

Web services can use a variety of techniques and protocols. For example:

- Dispatching can occur in a synchronous (typical) or asynchronous manner.
- You can perform invocation in an RPC-style operation in which arguments are sent and a response returned, or in a message style such as a one-way SOAP document exchange.
- You can use different encoding rules: literal or encoded.

You can invoke a Web service statically, in which case you may know everything about it beforehand, or dynamically, in which case you can discover its operations and transport endpoints on the fly.

Oracle Database as a Web Service Provider

Oracle Database can function as either a Web service provider or as a Web service consumer. When used as a provider, the database enables sharing and disconnected access to stored procedures, data, metadata, and other database resources such as the queuing and messaging systems.

As a Web service provider, Oracle Database provides a disconnected and heterogeneous environment that:

- Exposes stored procedures independently of the language in which the procedures are written
- Exposes SQL Queries and XQuery

Overview of Writing Procedures and Functions in Java

Functions and procedures are named blocks that encapsulate a sequence of statements. They are like building blocks that you can use to construct modular, maintainable applications. You write these named blocks and then define them by using the `loadjava` command or SQL `CREATE FUNCTION`, `CREATE PROCEDURE`, or `CREATE PACKAGE` statements. These Java methods can accept arguments and are callable from:

- SQL `CALL` statements
- Embedded SQL `CALL` statements
- PL/SQL blocks, subprograms, and packages
- DML statements (`INSERT`, `UPDATE`, `DELETE`, and `SELECT`)
- Oracle development tools such as OCI, Pro*C/C++, and Oracle Developer
- Oracle Java interfaces such as JDBC, SQLJ statements, CORBA, and Enterprise Java Beans
- Method calls from object types

Overview of Writing Database Triggers in Java

A database trigger is a stored procedure that Oracle Database invokes ("fires") automatically when certain events occur, for example, when a DML operation modifies a certain table. Triggers enforce business rules, prevent incorrect values from being stored, and reduce the need to perform checking and cleanup operations in each application.

Why Use Java for Stored Procedures and Triggers?

- Stored procedures and triggers are compiled once, are easy to use and maintain, and require less memory and computing overhead.
- Network bottlenecks are avoided, and response time is improved. Distributed applications are easier to build and use.
- Computation-bound procedures run faster in the server.
- Data access can be controlled by letting users have only stored procedures and triggers that execute with their definer's privileges instead of invoker's rights.
- PL/SQL and Java stored procedures can call each other.
- Java in the server follows the Java language specification and can use the SQLJ standard, so that databases other than Oracle Database are also supported.
- Stored procedures and triggers can be reused in different applications as well as different geographic sites.

Overview of Pro*C/C++

The Pro*C/C++ precompiler is a software tool that allows the programmer to embed SQL statements in a C or C++ source file. Pro*C/C++ reads the source file as input and outputs a C or C++ source file that replaces the embedded SQL statements with Oracle runtime library calls and is then compiled by the C or C++ compiler.

When there are errors found during the precompilation or the subsequent compilation, modify your precompiler input file and re-run the two steps.

Implementing a Pro*C/C++ Application

The following is a simple code fragment from a C source file that queries the table `employees` in the schema `hr`:

```
...
#define  UNAME_LEN   10
...
int   emp_number;
/* Define a host structure for the output values of a SELECT statement. */
/* No declare section needed if precompiler option MODE=ORACLE          */
struct {
    VARCHAR  last_name[UNAME_LEN];
    float    salary;
    float    commission_pct;
} emprec;
/* Define an indicator structure to correspond to the host output structure. */
struct {
    short emp_name_ind;
    short sal_ind;
    short comm_ind;
} emprec_ind;
...
/* Select columns last_name, salary, and commission_pct given the user's input
/* for employee_id. */
    EXEC SQL SELECT last_name, salary, commission_pct
        INTO :emprec INDICATOR :emprec_ind
        FROM employees
        WHERE employee_id = :emp_number;
...
```

The embedded `SELECT` statement is only slightly different from an interactive (SQL*Plus) `SELECT` statement. Every embedded SQL statement begins with EXEC SQL. The colon (:), precedes every host (C) variable. The returned values of data and indicators (set when the data value is `NULL` or character columns have been truncated) can be stored in structs (such as in the preceding code fragment), in arrays, or in arrays of structs. Multiple result set values are handled very simply in a manner that resembles the case shown, where there is only one result, because of the unique employee number. You use the actual names of columns and tables in embedded SQL.

Use the default precompiler option values, or you can enter values which give you control over the use of resources, how errors are reported, the formatting of output, and how cursors (which correspond to a particular connection or SQL statement) are managed. Cursors are used when there are multiple result set values.

Enter the options either in a configuration file, on the command line, or in-line inside your source code with a special statement that begins with `EXEC ORACLE`. If there are no errors found, you can then compile, link, and execute the output source file, like any other C program that you write.

Use the precompiler to create server database access from clients that can be on many different platforms. Pro*C/C++ allows you the freedom to design your own user interfaces and to add database access to existing applications.

Before writing your embedded SQL statements, you may want to test interactive versions of the SQL in SQL*Plus. You then make only minor changes to start testing your embedded SQL application.

Highlights of Pro*C/C++ Features

The following is a short subset of the capabilities of Pro*C/C++. For complete details, refer to the *Pro*C/C++ Precompiler Programmer's Guide*.

- You can write your application in either C or C++.
- You can write multithreaded programs if your platform supports a threads package. Concurrent connections are supported in either single-threaded or multithreaded applications.
- You can improve performance by embedding PL/SQL blocks. These blocks can call functions or procedures in Java or PL/SQL that are written by you or provided in Oracle Database packages.
- Using precompiler options, you can check the syntax and semantics of your SQL or PL/SQL statements during precompilation, as well as at runtime.
- You can call stored PL/SQL and Java subprograms. Modules written in COBOL or in C can be called from Pro*C/C++. External C procedures in shared libraries are callable by your program.
- You can conditionally precompile sections of your code so that they can execute in different environments.
- You can use arrays, or structures, or arrays of structures as host and indicator variables in your code to improve performance.
- You can deal with errors and warnings so that data integrity is guaranteed. As a programmer, you control how errors are handled.
- Your program can convert between internal datatypes and C language datatypes.
- The Oracle Call Interface (OCI) and Oracle C++ Call Interface (OCCI), lower-level C and C++ interfaces, are available for use in your precompiler source.
- Pro*C/C++ supports dynamic SQL, a technique that allows users to input variable values and statement syntax.
- Pro*C/C++ can use special SQL statements to manipulate tables containing user-defined object types. An Object Type Translator (OTT) will map the object types and named collection types in your database to structures and headers that you will then include in your source.
- Two kinds of collection types, nested tables and `VARRAY`, are supported with a set of SQL statements that allow a high degree of control over data.
- Large Objects are accessed by another set of SQL statements.
- A new ANSI SQL standard for dynamic SQL is supported for new applications, so that you can execute SQL statements with a varying number of host variables. An older technique for dynamic SQL is still usable by pre-existing applications.
- Globalization support lets you use multibyte characters and UCS2 Unicode data.
- Using scrollable cursors, you can move backward and forward through a result set. For example, you can fetch the last row of the result set, or jump forward or backward to an absolute or relative position within the result set.
- A connection pool is a group of physical connections to a database that can be shared by several named connections. Enabling the connection pool option can help to optimize the performance of Pro*C/C++ application. The connection pool option is not enabled by default.

Overview of Pro*COBOL

The Pro*COBOL precompiler is a software tool that allows the programmer to embed SQL statements in a COBOL source code file. Pro*COBOL reads the source file as input and outputs a COBOL source file that replaces the embedded SQL statements with Oracle Database runtime library calls, and is then compiled by the COBOL compiler.

When there are errors found during the precompilation or the subsequent compilation, modify your precompiler input file and re-run the two steps.

How You Implement a Pro*COBOL Application

Here is a simple code fragment from a source file that queries the table `employees` in the schema `hr`:

```
...
 WORKING-STORAGE SECTION.
*
* DEFINE HOST INPUT AND OUTPUT HOST AND INDICATOR VARIABLES.
* NO DECLARE SECTION NEEDED IF MODE=ORACLE.
*
 01  EMP-REC-VARS.
     05  EMP-NAME    PIC X(10) VARYING.
     05  EMP-NUMBER  PIC S9(4) COMP VALUE ZERO.
     05  SALARY      PIC S9(5)V99 COMP-3 VALUE ZERO.
     05  COMMISSION  PIC S9(5)V99 COMP-3 VALUE ZERO.
     05  COMM-IND    PIC S9(4) COMP VALUE ZERO.
...
 PROCEDURE DIVISION.
...
     EXEC SQL
         SELECT last_name, salary, commission_pct
         INTO :EMP-NAME, :SALARY, :COMMISSION:COMM-IND
         FROM employees
         WHERE employee_id = :EMP-NUMBER
     END-EXEC.
...
```

The embedded `SELECT` statement is only slightly different from an interactive (SQL*Plus) `SELECT` statement. Every embedded SQL statement begins with EXEC SQL. The colon (:) precedes every host (COBOL) variable. The SQL statement is terminated by END-EXEC. The returned values of data and indicators (set when the data value is `NULL` or character columns have been truncated) can be stored in group items (such as in the preceding code fragment), in tables, or in tables of group items. Multiple result set values are handled very simply in a manner that resembles the case shown, where there is only one result, given the unique employee number. You use the actual names of columns and tables in embedded SQL.

Use the default precompiler option values, or enter values that give you control over the use of resources, how errors are reported, the formatting of output, and how cursors are managed (cursors correspond to a particular connection or SQL statement).

Enter the options in a configuration file, on the command line, or in-line inside your source code with a special statement that begins with EXEC ORACLE. If there are no errors found, you can then compile, link, and execute the output source file, like any other COBOL program that you write.

Use the precompiler to create server database access from clients that can be on many different platforms. Pro*COBOL allows you the freedom to design your own user interfaces and to add database access to existing COBOL applications.

The embedded SQL statements available conform to an ANSI standard, so that you can access data from many databases in a program, including remote servers networked through Oracle Net.

Before writing your embedded SQL statements, you may want to test interactive versions of the SQL in SQL*Plus. You then make only minor changes to start testing your embedded SQL application.

Highlights of Pro*COBOL Features

The following is a short subset of the capabilities of Pro*COBOL.

- You can call stored PL/SQL or Java subprograms. You can improve performance by embedding PL/SQL blocks. These blocks can call PL/SQL functions or procedures written by you or provided in Oracle Database packages.
- Precompiler options allow you to define how cursors, errors, syntax-checking, file formats, and so on, are handled.
- Using precompiler options, you can check the syntax and semantics of your SQL or PL/SQL statements during precompilation, as well as at runtime.
- You can conditionally precompile sections of your code so that they can execute in different environments.
- Use tables, or group items, or tables of group items as host and indicator variables in your code to improve performance.
- You can program how errors and warnings are handled, so that data integrity is guaranteed.
- Pro*COBOL supports dynamic SQL, a technique that allows users to input variable values and statement syntax.

See Also: *Pro*COBOL Programmer's Guide* for complete details

Overview of OCI and OCCI

The Oracle Call Interface (OCI) and Oracle C++ Call Interface (OCCI) are application programming interfaces (APIs) that allow you to create applications that use native procedures or function calls of a third-generation language to access Oracle Database and control all phases of SQL statement execution. These APIs provide:

- Improved performance and scalability through the efficient use of system memory and network connectivity
- Consistent interfaces for dynamic session and transaction management in a two-tier client/server or multitier environment
- N-tiered authentication
- Comprehensive support for application development using Oracle objects
- Access to external databases
- Ability to develop applications that service an increasing number of users and requests without additional hardware investments

OCI lets you manipulate data and schemas in a database using a host programming language, such as C. OCCI is an object-oriented interface suitable for use with C++. These APIs provide a library of standard database access and retrieval functions in the form of a dynamic runtime library (OCILIB) that can be linked in an application at runtime. This eliminates the need to embed SQL or PL/SQL within 3GL programs.

See Also: For more information about OCI and OCCI calls:

- *Oracle Call Interface Programmer's Guide*
- *Oracle C++ Call Interface Programmer's Guide*
- *Oracle Streams Advanced Queuing User's Guide and Reference*
- *Oracle Database Globalization Support Guide*
- *Oracle Database Data Cartridge Developer's Guide*

Advantages of OCI

OCI provides significant advantages over other methods of accessing Oracle Database:

- More fine-grained control over all aspects of the application design.
- High degree of control over program execution.
- Use of familiar 3GL programming techniques and application development tools such as browsers and debuggers.
- Support of dynamic SQL, method 4.
- Availability on the broadest range of platforms of all the Oracle programmatic interfaces.
- Dynamic bind and define using callbacks.
- Describe functionality to expose layers of server metadata.
- Asynchronous event notification for registered client applications.
- Enhanced array data manipulation language (DML) capability for array `INSERT`s, `UPDATE`s, and `DELETE`s.
- Ability to associate a commit request with an execute to reduce round-trips.
- Optimization for queries using transparent prefetch buffers to reduce round-trips.
- Thread safety, so you do not have to implement mutual exclusion (mutex) locks on OCI handles.
- The server connection in nonblocking mode means that control returns to the OCI code when a call is still executing or could not complete.

Parts of the OCI

The OCI encompasses four main sets of functionality:

- OCI *relational functions*, for managing database access and processing SQL statements
- OCI *navigational functions*, for manipulating objects retrieved from an Oracle Database
- OCI *datatype mapping and manipulation functions*, for manipulating data attributes of Oracle types
- OCI *external procedure functions*, for writing C callbacks from PL/SQL

Procedural and Non-Procedural Elements

The Oracle Call Interface (OCI) enables you to develop applications that combine the non-procedural data access power of SQL with the procedural capabilities of most programming languages, including C and C++. Note the following characteristics of procedural and non-procedural languages:

- In a non-procedural language program, the set of data to be operated on is specified, but what operations will be performed and how the operations are to be carried out is not specified. The non-procedural nature of SQL makes it an easy language to learn and to use to perform database transactions. It is also the standard language used to access and manipulate data in modern relational and object-relational database systems.
- In a procedural language program, the execution of most statements depends on previous or subsequent statements and on control structures, such as loops or conditional branches, which are not available in SQL. The procedural nature of these languages makes them more complex than SQL, but it also makes them very flexible and powerful.

The combination of both non-procedural and procedural language elements in an OCI program provides easy access to Oracle Database in a structured programming environment.

The OCI supports all SQL data definition, data manipulation, query, and transaction control facilities that are available through Oracle Database. For example, an OCI program can run a query against Oracle Database. The queries can require the program to supply data to the database using input (bind) variables, as follows:

```
SELECT name FROM employees WHERE empno = :empnumber
```

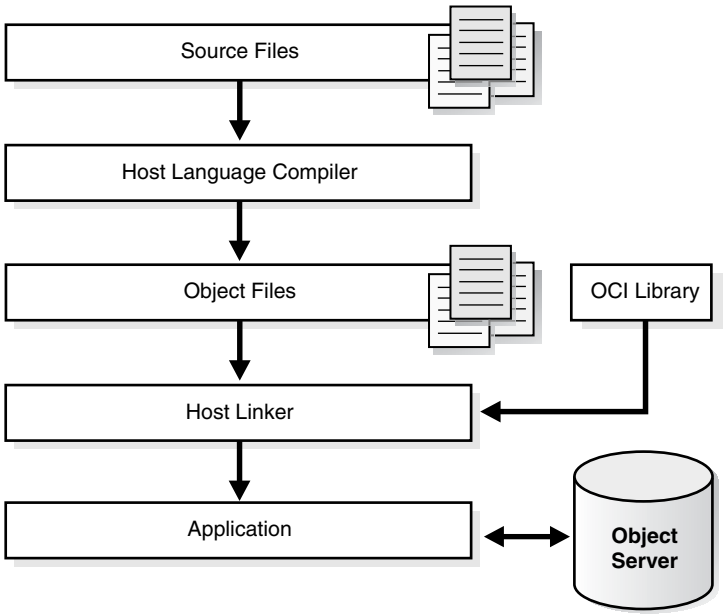
In the preceding SQL statement, `:empnumber` is a placeholder for a value that will be supplied by the application.

You can alternatively use PL/SQL, Oracle's procedural extension to SQL. The applications you develop can be more powerful and flexible than applications written in SQL alone. The OCI also provides facilities for accessing and manipulating objects in Oracle Database.

Building an OCI Application

As Figure 1–1 shows, you compile and link an OCI program in the same way that you compile and link a non-database application. There is no need for a separate preprocessing or precompilation step.

Figure 1–1 The OCI Development Process



Note: To properly link your OCI programs, it may be necessary on some platforms to include other libraries, in addition to the OCI library. Check your Oracle platform-specific documentation for further information about extra libraries that may be required.

Overview of Oracle Data Provider for .NET (ODP.NET)

Oracle Data Provider for .NET (ODP.NET) is an implementation of a data provider for Oracle Database.

ODP.NET uses APIs native to Oracle Database to offer fast and reliable access from any .NET application to database features and data. It also uses and inherits classes and interfaces available in the Microsoft .NET Framework Class Library.

For programmers using Oracle Provider for OLE DB, ADO (ActiveX Data Objects) provides an automation layer that exposes an easy programming model. ADO.NET provides a similar programming model, but without the automation layer, for better performance. More importantly, the ADO.NET model allows native providers such as ODP.NET to expose specific features and datatypes specific to Oracle Database.

See Also: *Oracle Data Provider for .NET Developer's Guide*

Using ODP.NET in a Simple Application

The following is a simple C# application that connects to Oracle Database and displays its version number before disconnecting.

```
using System;
using Oracle.DataAccess.Client;

class Example
{
  OracleConnection con;

  void Connect()
```

```
  {
    con = new OracleConnection();
    con.ConnectionString = "User Id=hr;Password=hr;Data Source=oracle";
    con.Open();
    Console.WriteLine("Connected to Oracle" + con.ServerVersion);
  }

  void Close()
  {
    con.Close();
    con.Dispose();
  }

  static void Main()
  {
    Example example = new Example();
    example.Connect();
    example.Close();
  }
}
```

Note: Additional samples are provided in directory *ORACLE_BASE**ORACLE_HOME*\ODP.NET\Samples.

Overview of Oracle Objects for OLE (OO4O)

Oracle Objects for OLE (OO4O) is a product designed to allow easy access to data stored in Oracle Database with any programming or scripting language that supports the Microsoft COM Automation and ActiveX technology. This includes Visual Basic, Visual C++, Visual Basic For Applications (VBA), IIS Active Server Pages (VBScript and JavaScript), and others.

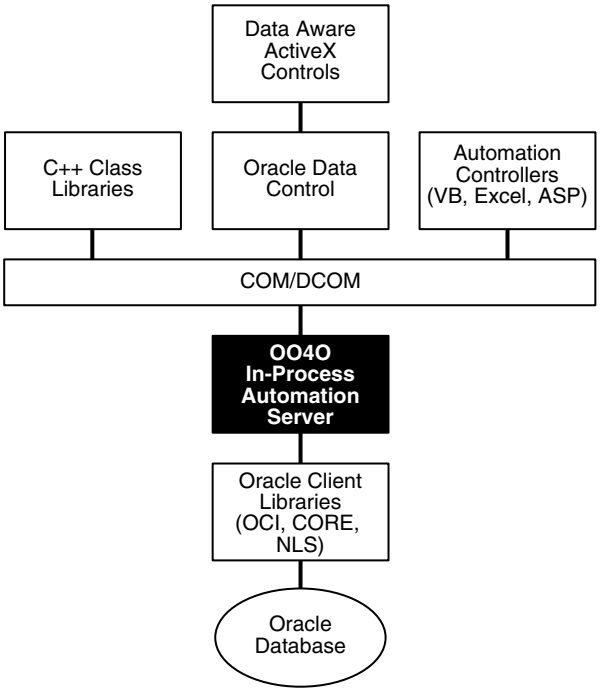
See the OO4O online help for detailed information about using OO4O.

Oracle Objects for OLE consists of the following software layers:

- OO4O "In-Process" Automation Server
- Oracle Data Control
- Oracle Objects for OLE C++ Class Library

Figure 1–2, "Software Layers" illustrates the OO4O software components.

Figure 1–2 Software Layers



OO4O Automation Server

The OO4O Automation Server is a set of COM Automation objects for connecting to Oracle Database, executing SQL statements and PL/SQL blocks, and accessing the results.

Unlike other COM-based database connectivity APIs, such as Microsoft ADO, the OO4O Automation Server has been developed and evolved specifically for use with Oracle Database.

It provides an optimized API for accessing features that are unique to Oracle Database and are otherwise cumbersome or inefficient to use from ODBC or OLE database-specific components.

OO4O provides key features for accessing Oracle Database efficiently and easily in environments ranging from the typical two-tier client/server applications, such as those developed in Visual Basic or Excel, to application servers deployed in multitiered application server environments such as Web server applications in Microsoft Internet Information Server (IIS) or Microsoft Transaction Server (MTS).

Features include:

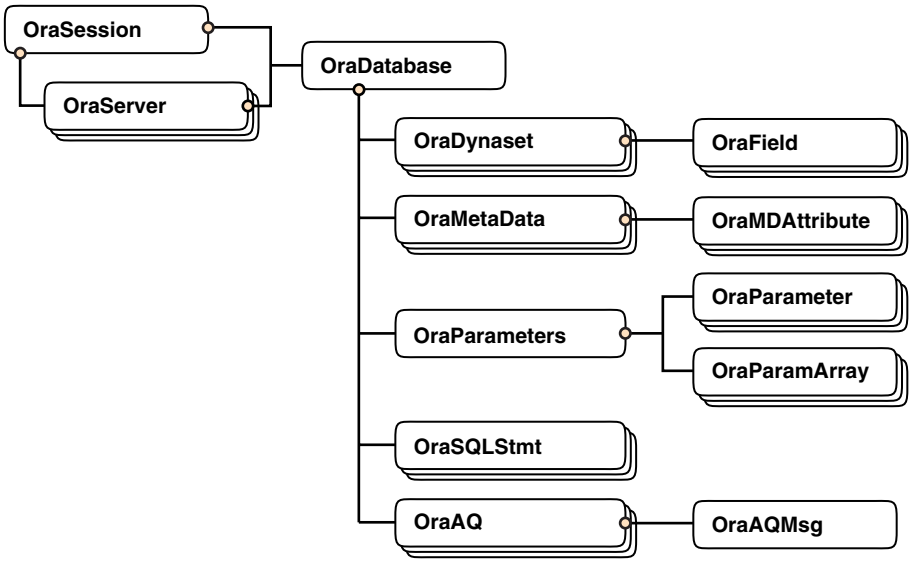
- Support for execution of PL/SQL and Java stored procedures, and PL/SQL anonymous blocks. This includes support for Oracle datatypes used as parameters to stored procedures, including PL/SQL cursors. Refer to "Support for Oracle LOB and Object Datatypes" on page 1-28.
- Support for scrollable and updatable cursors for easy and efficient access to result sets of queries.
- Thread-safe objects and Connection Pool Management Facility for developing efficient Web server applications.
- Full support for Oracle object-relational and LOB datatypes.

- Full support for Advanced Queuing.
- Support for array inserts and updates.
- Support for Microsoft Transaction Server (MTS).

OO4O Object Model

The Oracle Objects for OLE object model is illustrated in Figure 1–3, "Objects and Their Relations".

Figure 1–3 Objects and Their Relations



OraSession

An OraSession object manages collections of OraDatabase, OraConnection, and OraDynaset objects used within an application.

Typically, a single OraSession object is created for each application, but you can create named OraSession objects for shared use within and between applications.

The OraSession object is the top-most object for an application. It is the only object created by the CreateObject VB/VBA API and not by an Oracle Objects for OLE method. The following code fragment shows how to create an OraSession object:

```
Dim OraSession as Object
Set OraSession = CreateObject("OracleInProcServer.XOraSession")
```

OraServer

OraServer represents a physical network connection to Oracle Database.

The `OraServer` interface is introduced to expose the connection-multiplexing feature provided in the Oracle Call Interface. After an `OraServer` object is created, multiple user sessions (`OraDatabase`) can be attached to it by invoking the `OpenDatabase` method. This feature is particularly useful for application components, such as Internet Information Server (IIS), that use Oracle Objects for OLE in n-tier distributed environments.

The use of connection multiplexing when accessing Oracle Database with a large number of user sessions active can help reduce server processing and resource requirements while improving server scalability.

OraServer is used to share a single connection across multiple OraDatabase objects (multiplexing), whereas each OraDatabase obtained from an OraSession has its own physical connection.

OraDatabase

An `OraDatabase` interface adds additional methods for controlling transactions and creating interfaces representing of Oracle object types. Attributes of schema objects can be retrieved using the `Describe` method of the `OraDatabase` interface.

In releases prior to Oracle8*i*, an `OraDatabase` object is created by invoking the `OpenDatabase` method of an `OraSession` interface. The Oracle Net alias, user name, and password are passed as arguments to this method. In Oracle8*i* and later, invocation of this method results in implicit creation of an `OraServer` object.

An `OraDatabase` object can also be created using the `OpenDatabase` method of the `OraServer` interface.

Transaction control methods are available at the `OraDatabase` (user session) level. Transactions may be started as `Read-Write` (default), `Serializable`, or `Read-only`. Transaction control methods include:

- `BeginTrans`
- `CommitTrans`
- `RollbackTrans`

For example:

```
UserSession.BeginTrans(OO4O_TXN_READ_WRITE)
UserSession.ExecuteSQL("delete emp where empno = 1234")
UserSession.CommitTrans
```

OraDynaset

An `OraDynaset` object permits browsing and updating of data created from a SQL `SELECT` statement.

The `OraDynaset` object can be thought of as a cursor, although in actuality several real cursors may be used to implement the semantics of `OraDynaset`. An `OraDynaset` object automatically maintains a local cache of data fetched from the server and transparently implements scrollable cursors within the browse data. Large queries may require significant local disk space; application developers are encouraged to refine queries to limit disk usage.

OraField

An `OraField` object represents a single column or data item within a row of a dynaset.

If the current row is being updated, then the `OraField` object represents the currently updated value, although the value may not yet have been committed to the database.

Assignment to the `Value` property of a field is permitted only if a record is being edited (using `Edit`) or a new record is being added (using `AddNew`). Other attempts to assign data to a field's `Value` property results in an error.

OraMetaData and OraMDAttribute

An `OraMetaData` object is a collection of `OraMDAttribute` objects that represent the description information about a particular schema object in the database.

The `OraMetaData` object can be visualized as a table with three columns:

- `Metadata Attribute Name`
- `Metadata Attribute Value`
- `Flag` specifying whether the `Value` is another `OraMetaData` object

The `OraMDAttribute` objects contained in the `OraMetaData` object can be accessed by subscripting using ordinal integers or by using the name of the property. Referencing a subscript that is not in the collection results in the return of a `NULL OraMDAttribute` object.

OraParameters and OraParameter

An `OraParameter` object represents a bind variable in a SQL statement or PL/SQL block.

`OraParameter` objects are created, accessed, and removed indirectly through the `OraParameters` collection of an `OraDatabase` object. Each parameter has an identifying name and an associated value. You can automatically bind a parameter to SQL and PL/SQL statements of other objects (as noted in the object descriptions), by using the parameter name as a placeholder in the SQL or PL/SQL statement. Such use of parameters can simplify dynamic queries and increase program performance.

OraParamArray

An `OraParamArray` object represents an array-type bind variable in a SQL statement or PL/SQL block, as opposed to a scalar-type bind variable represented by the `OraParameter` object.

`OraParamArray` objects are created, accessed, and removed indirectly through the `OraParameters` collection of an `OraDatabase` object. Each `OraParamArray` object has an identifying name and an associated value.

OraSQLStmt

An `OraSQLStmt` object represents a single SQL statement. Use the `CreateSQL` method to create an `OraSQLStmt` object from an `OraDatabase` object.

During create and refresh, `OraSQLStmt` objects automatically bind all relevant, enabled input parameters to the specified SQL statement, using the parameter names as placeholders in the SQL statement. This can improve the performance of SQL statement execution without re-parsing the SQL statement.

The `OraSQLStmt` object can be used later to execute the same query using a different value for the `:SALARY` placeholder. This is done as follows (`updateStmt` is the `OraSQLStmt` object here):

```
OraDatabase.Parameters("SALARY").value = 200000
updateStmt.Parameters("ENAME").value = "KING"
updateStmt.Refresh
```

OraAQ

An `OraAQ` object is instantiated by invoking the `CreateAQ` method of the `OraDatabase` interface. It represents a queue that is present in the database.

Oracle Objects for OLE provides interfaces for accessing Oracle Advanced Queuing (AQ) feature. It makes AQ accessible from popular COM-based development environments such as Visual Basic. For a detailed description of Oracle Advanced Queuing, refer to *Oracle Streams Advanced Queuing User's Guide and Reference*.

OraAQMsg

The `OraAQMsg` object encapsulates the message to be enqueued or dequeued. The message can be of any user-defined or raw type.

For a detailed description of Oracle Advanced Queuing, refer to *Oracle Streams Advanced Queuing User's Guide and Reference.*

OraAQAgent

The `OraAQAgent` object represents a message recipient and is only valid for queues that allow multiple consumers. It is a child of `OraAQMsg`.

An `OraAQAgent` object can be instantiated by invoking the `AQAgent` method. For example:

```
Set agent = qMsg.AQAgent(name)
```

An `OraAQAgent` object can also be instantiated by invoking the `AddRecipient` method. For example:

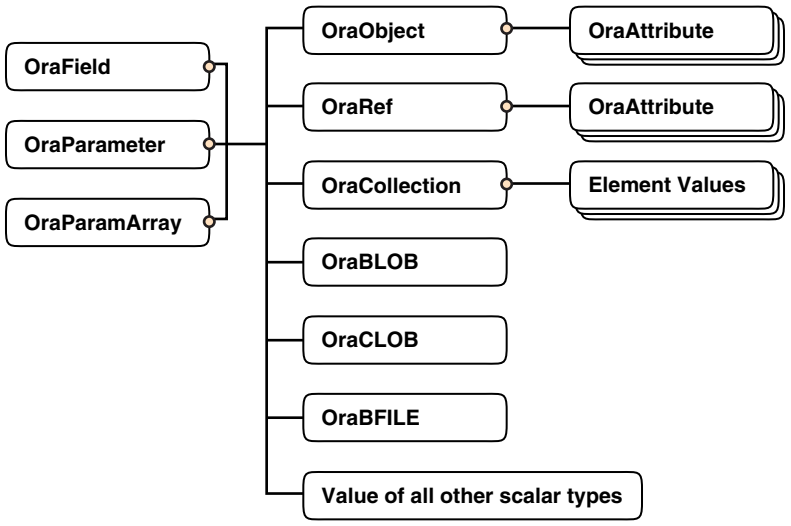
```
Set agent = qMsg.AddRecipient(name, address, protocol).
```

Support for Oracle LOB and Object Datatypes

Oracle Objects for OLE provides full support for accessing and manipulating instances of object datatypes and LOBs in Oracle Database. Figure 1–4, "Supported Oracle Datatypes" illustrates the datatypes supported by OO4O.

Instances of these types can be fetched from the database or passed as input or output variables to SQL statements and PL/SQL blocks, including stored procedures and functions. All instances are mapped to COM Automation Interfaces that provide methods for dynamic attribute access and manipulation.

Figure 1–4 Supported Oracle Datatypes



OraBLOB and OraCLOB

The `OraBlob` and `OraClob` interfaces in Oracle Objects for OLE provide methods for performing operations on large database objects of datatype `BLOB`, `CLOB`, and `NCLOB`. `BLOB`, `CLOB`, and `NCLOB` datatypes are also referred to here as **LOB** datatypes.

LOB data is accessed using `Read` and the `CopyToFile` methods.

LOB data is modified using `Write`, `Append`, `Erase`, `Trim`, `Copy`, `CopyFromFile`, and `CopyFromBFile` methods. Before modifying the content of a LOB column in a row, a row lock must be obtained. If the LOB column is a field of an `OraDynaset`, object, then the lock is obtained by invoking the `Edit` method.

OraBFILE

The `OraBFile` interface in Oracle Objects for OLE provides methods for performing operations on large database objects of datatype `BFILE`.

`BFILE` objects are large binary data objects stored in operating system files outside of the database tablespaces.

Oracle Data Control

Oracle Data Control (ODC) is an ActiveX Control that is designed to simplify the exchange of data between Oracle Database and visual controls such edit, text, list, and grid controls in Visual Basic and other development tools that support custom controls.

ODC acts as an agent to handle the flow of information from Oracle Database and a visual data-aware control, such as a grid control, that is bound to it. The data control manages various user interface (UI) tasks such as displaying and editing data. It also executes and manages the results of database queries.

Oracle Data Control is compatible with the Microsoft data control included with Visual Basic. If you are familiar with the Visual Basic data control, learning to use Oracle Data Control is quick and easy. Communication between data-aware controls and a Data Control is governed by a protocol that has been specified by Microsoft.

Oracle Objects for OLE C++ Class Library

Oracle Objects for OLE C++ Class Library is a collection of C++ classes that provide programmatic access to the Oracle Object Server. Although the class library is implemented using OLE Automation, neither the OLE development kit nor any OLE development knowledge is necessary to use it. This library helps C++ developers avoid the chore of writing COM client code for accessing the OO4O interfaces.

Additional Sources of Information

For detailed information about Oracle Objects for OLE refer to the online help provided with the OO4O product:

- Oracle Objects for OLE Help
- Oracle Objects for OLE C++ Class Library Help

To view examples of how to use Oracle Objects for OLE, refer to the samples located in the `ORACLE_HOME\OO4O` directory of the Oracle Database installation. Additional OO4O examples can be found in the following Oracle publications:

- *Oracle Database Application Developer's Guide - Large Objects*

- *Oracle Streams Advanced Queuing User's Guide and Reference*
- *Oracle Database PL/SQL Packages and Types Reference*

Choosing a Programming Environment

To choose a programming environment for a new development project:

- Review the preceding overviews and the manuals for each environment.
- Read the platform-specific manual that explains which compilers are approved for use with your platforms.
- If a particular language does not provide a feature you need, remember that PL/SQL and Java stored procedures can both be called from code written in any of the languages in this chapter. Stored procedures include triggers and object type methods.
- External procedures written in C can be called from OCI, Java, PL/SQL or SQL. The external procedure itself can call back into the database using either SQL, OCI, or Pro*C (but not C++).

The following examples illustrate easy choices:

- Pro*COBOL does not support object types or collection types, while Pro*C/C++ does.
- SQLJ does not support dynamic SQL the way that JDBC does.

Choosing Whether to Use OCI or a Precompiler

Precompiler applications typically contain less code than equivalent OCI applications, which can help productivity.

Some situations require detailed control of the database and are suited for OCI applications (either pure OCI or a precompiler application with embedded OCI calls):

- OCI provides more detailed control over multiplexing and migrating sessions.
- OCI provides dynamic bind and define using callbacks that can be used for any arbitrary structure, including lists.
- OCI has many calls to handle metadata.
- OCI allows asynchronous event notifications to be received by a client application. It provides a means for clients to generate notifications for propagation to other clients.
- OCI allows DML statements to use arrays to complete as many iterations as possible before returning any error messages.
- OCI calls for special purposes include Advanced Queuing, globalization support, Data Cartridges, and support of the date and time datatypes.
- OCI calls can be embedded in a Pro*C/C++ application.

Using Built-In Packages and Libraries

Both Java and PL/SQL have built-in packages and libraries.

PL/SQL and Java interoperate in the server. You can execute a PL/SQL package from Java or wrap a PL/SQL class with a Java wrapper so that it can be called from

distributed CORBA and EJB clients. The following table shows PL/SQL packages and their Java equivalents:

Table 1–1 PL/SQL and Java Equivalent Software

PL/SQL Package	Java Equivalent
DBMS_ALERT	Call package with SQLJ or JDBC.
DBMS_DDL	JDBC has this functionality.
DBMS_JOB	Schedule a job that has a Java Stored procedure.
DBMS_LOCK	Call with SQLJ or JDBC.
DBMS_MAIL	Use JavaMail.
DBMS_OUTPUT	Use subclass oracle.aurora.rdbms.OracleDBMSOutputStream or Java stored procedure DBMS_JAVA.SET_STREAMS.
DBMS_PIPE	Call with SQLJ or JDBC.
DBMS_SESSION	Use JDBC to execute an ALTER SESSION statement.
DBMS_SNAPSHOT	Call with SQLJ or JDBC.
DBMS_SQL	Use JDBC.
DBMS_TRANSACTION	Use JDBC to execute an ALTER SESSION statement.
DBMS_UTILITY	Call with SQLJ or JDBC.
UTL_FILE	Grant the JAVAUSERPRIV privilege and then use Java I/O entry points.

Java Compared to PL/SQL

Both Java and PL/SQL can be used to build applications in the database. Here are some guidelines for their use:

PL/SQL Is Optimized for Database Access

PL/SQL uses the same datatypes as SQL. SQL datatypes are thus easier to use and SQL operations are faster than with Java, especially when a large amount of data is involved, when mostly database access is done, or when bulk operations are used.

PL/SQL Is Integrated with the Database

PL/SQL is an extension to SQL offering data encapsulation, information hiding, overloading, and exception-handling.

Some advanced PL/SQL capabilities are not available for Java in Oracle9*i*. Examples are autonomous transactions and the dblink facility for remote databases. Code development is usually faster in PL/SQL than in Java.

Both Java and PL/SQL Have Object-Oriented Features

Java has inheritance, polymorphism, and component models for developing distributed systems. PL/SQL has inheritance and **type evolution**, the ability to change methods and attributes of a type while preserving subtypes and table data that use the type.

Java Is Used for Open Distributed Applications

Java has a richer type system than PL/SQL and is an object-oriented language. Java can use CORBA (which can have many different computer languages in its clients) and EJB. PL/SQL packages can be called from CORBA or EJB clients.

You can run XML tools, the Internet File System, or JavaMail from Java.

Many Java-based development tools are available throughout the industry.

Part I

SQL for Application Developers

This part contains the following chapters:

2

SQL Processing for Application Developers

This chapter describes how Oracle Database processes SQL statements. Before reading this chapter you should read the section "SQL Processing" in *Oracle Database Concepts*.

Topics include the following:

Grouping Operations into Transactions

This section contains the following topics:

Deciding How to Group Operations in Transactions

In general, only application designers who use the programming interfaces to Oracle Database are concerned with which types of actions should be grouped together as one transaction. You should use the following principles when deciding how to group transactions:

- Transactions must be defined properly so that work is accomplished in logical units and data is kept consistent.
- Data in all referenced tables should be in a consistent state before the transaction begins and after it ends.
- Transactions should consist of only the SQL statements or PL/SQL blocks that comprise one consistent change to the data.

For example, suppose that you write a Web application that enables users to transfer funds between accounts. The transaction should include the debit to one account, which is executed by one SQL statement, and the credit to another account, which is executed by a second SQL statement. Both statements should fail or succeed together as a unit of work; the credit should not be committed without the debit. Other non-related actions, such as a new deposit to one account, should not be included in the same transaction.

Improving Transaction Performance

As an application developer, you should consider whether you can improve performance. Consider the following performance enhancements when designing and writing your application:

- Use the `SET TRANSACTION` command with the `USE ROLLBACK SEGMENT` clause to explicitly assign a transaction to a rollback segment. This technique can eliminate the need to allocate additional extents dynamically, which can reduce system performance. Note that this clause is relevant and valid only if you use rollback segments for undo. If you use automatic undo management, then Oracle Database ignores this clause.
- Establish standards for writing SQL statements so that you can take advantage of shared SQL areas. Oracle Database recognizes identical SQL statements and allows them to share memory areas. This reduces memory usage on the database server and increases system throughput.
- Use the `ANALYZE` command to collect statistics that can be used by Oracle Database to implement a cost-based approach to SQL statement optimization. You can supply additional "hints" to the optimizer as needed.
- Call the `DBMS_APPLICATION_INFO.SET_ACTION` procedure before beginning a transaction to register and name a transaction for later use when measuring performance across an application. You should specify which type of activity a transaction performs so that the system tuners can later see which transactions are taking up the most system resources.
- Increase user productivity and query efficiency by including user-written PL/SQL functions in SQL expressions as described in "Calling Stored Functions from SQL Expressions" on page 7-36.
- Create explicit cursors when writing a PL/SQL application.
- Reduce frequency of parsing and improve performance in precompiler programs by increasing the number of cursors with `MAX_OPEN_CURSORS`.
- Use the `SET TRANSACTION` command with the `ISOLATION LEVEL` set to `SERIALIZABLE` to get ANSI/ISO serializable transactions.

See Also:

- "How Serializable Transactions Interact" on page 2-15
- "Using Cursors within Applications" on page 2-6
- *Oracle Database Concepts* for more information about transaction tuning features

Committing Transactions

To commit a transaction, use the `COMMIT` statement. The following two statements are equivalent and commit the current transaction:

```
COMMIT WORK;
COMMIT;
```

The COMMIT statements lets you include the COMMENT parameter along with a comment that provides information about the transaction being committed. This option is useful for including information about the origin of the transaction when you commit distributed transactions:

```
COMMIT COMMENT 'Dallas/Accts_pay/Trans_type 10B';
```

Managing Commit Redo Behavior

When a transaction updates the database, it generates a redo entry corresponding to this update. Oracle Database buffers this redo in memory until the completion of the transaction. When the transaction commits, the log writer (LGWR) process writes redo for the commit, along with the accumulated redo of all changes in the transaction, to disk. By default Oracle Database writes the redo to disk before the call returns to the client. This behavior introduces a latency in the commit because the application must wait for the redo to be persisted on disk.

Suppose that you are writing an application that requires very high transaction throughput. If you are willing to trade commit durability for lower commit latency, then you can change the default COMMIT options so that the application does not need to wait for Oracle Database to write data to the online redo logs.

Oracle Database enables you to change the handling of commit redo depending on the needs of your application. You can change the commit behavior in the following locations:

- COMMIT_WRITE initialization parameter at the system or session level
- COMMIT statement

The options in the COMMIT statement override the current settings in the initialization parameter. Table 2–1 describes redo persistence options that you can set in either location.

Table 2–1 Initialization Parameter and COMMIT Options for Managing Commit Redo

Option	Specifies that . . .
WAIT	The commit does not return as successful until the redo corresponding to the commit is persisted in the online redo logs (default).
NOWAIT	The commit should return to the application without waiting for the redo to be written to the online redo logs.
IMMEDIATE	The log writer process should write the redo for the commit immediately (default). In other words, this option forces a disk I/O.
BATCH	Oracle Database should buffer the redo. The log writer process is permitted to write the redo to disk in its own time.

The following example shows how to set the commit behavior to BATCH and NOWAIT in the initialization parameter file:

```
COMMIT_WRITE = BATCH, NOWAIT
```

You can change the commit behavior at the system level by executing ALTER SYSTEM as in the following example:

```
ALTER SYSTEM SET COMMIT_WRITE = BATCH, NOWAIT
```

After the initialization parameter is set, a COMMIT statement with no options conforms to the options specified in the parameter. Alternatively, you can override the current initialization parameter setting by specifying options directly on the COMMIT statement as in the following example:

```
COMMIT WRITE BATCH NOWAIT
```

In either case, your application specifies that log writer does not have to write the redo for the commit immediately to the online redo logs and should not wait for confirmation that the redo has been written to disk.

> **Note:** You cannot change the default IMMEDIATE and WAIT behavior for distributed transactions.

If your application uses OCI, then you can modify redo behavior by setting the following flags in the OCITransCommit() function within your application:

- OCI_TRANS_WRITEBATCH
- OCI_TRANS_WRITENOWAIT
- OCI_TRANS_WRITEIMMED
- OCI_TRANS_WRITEWAIT

Note that the specification of the NOWAIT and BATCH options allows a small window of vulnerability in which Oracle Database can roll back a transaction that your application view as committed. Your application must be able to tolerate the following scenarios:

- The database host crashes, which causes the database to lose redo that was buffered but not yet written to the online redo logs.
- A file I/O problem prevents log writer from writing buffered redo to disk. If the redo logs are not multiplexed, then the commit is lost.

See Also:

- *Oracle Database SQL Reference* for information on the COMMIT statement
- *Oracle Call Interface Programmer's Guide* for information about the OCITransCommit() function

Rolling Back Transactions

To roll back an entire transaction, or to roll back part of a transaction to a savepoint, use the ROLLBACK statement. For example, either of the following statements rolls back the entire current transaction:

```
ROLLBACK WORK;
ROLLBACK;
```

The WORK option of the ROLLBACK command has no function.

To roll back to a savepoint defined in the current transaction, use the TO option of the ROLLBACK command. For example, either of the following statements rolls back the current transaction to the savepoint named POINT1:

```
SAVEPOINT Point1;
...
```

```
ROLLBACK TO SAVEPOINT Point1;
ROLLBACK TO Point1;
```

Defining Transaction Savepoints

To define a *savepoint* in a transaction, use the SAVEPOINT command. The following statement creates the savepoint named ADD_EMP1 in the current transaction:

```
SAVEPOINT Add_emp1;
```

If you create a second savepoint with the same identifier as an earlier savepoint, the earlier savepoint is erased. After creating a savepoint, you can roll back to the savepoint.

There is no limit on the number of active savepoints for each session. An active savepoint is one that has been specified since the last commit or rollback.

An Example of COMMIT, SAVEPOINT, and ROLLBACK

Table 2–4 shows a series of SQL statements that illustrates the use of COMMIT, SAVEPOINT, and ROLLBACK statements within a transaction.

Table 2–2 Use of COMMIT, SAVEPOINT, and ROLLBACK

SQL Statement	Results
SAVEPOINT a;	First savepoint of this transaction
DELETE...;	First DML statement of this transaction
SAVEPOINT b;	Second savepoint of this transaction
INSERT INTO...;	Second DML statement of this transaction
SAVEPOINT c;	Third savepoint of this transaction
UPDATE...;	Third DML statement of this transaction.
ROLLBACK TO c;	UPDATE statement is rolled back, savepoint C remains defined
ROLLBACK TO b;	INSERT statement is rolled back, savepoint C is lost, savepoint B remains defined
ROLLBACK TO c;	ORA-01086 error; savepoint C no longer defined
INSERT INTO...;	New DML statement in this transaction
COMMIT;	Commits all actions performed by the first DML statement (the DELETE statement) and the last DML statement (the second INSERT statement) All other statements (the second and the third statements) of the transaction were rolled back before the COMMIT. The savepoint A is no longer active.

Ensuring Repeatable Reads with Read-Only Transactions

By default, the consistency model for Oracle Database guarantees statement-level read consistency, but does not guarantee transaction-level read consistency (repeatable reads). If you want transaction-level read consistency, and if your transaction does not require updates, then you can specify a *read-only transaction*. After indicating that your transaction is read-only, you can execute as many queries as you like against any database table, knowing that the results of each query in the read-only transaction are consistent with respect to a single point in time.

A read-only transaction does not acquire any additional data locks to provide transaction-level read consistency. The multi-version consistency model used for

statement-level read consistency is used to provide transaction-level read consistency; all queries return information with respect to the system change number (SCN) determined when the read-only transaction begins. Because no data locks are acquired, other transactions can query and update data being queried concurrently by a read-only transaction.

Long-running queries sometimes fail because undo information required for consistent read operations is no longer available. This happens when committed undo blocks are overwritten by active transactions. Automatic undo management provides a way to explicitly control when undo space can be reused; that is, how long undo information is retained. Your database administrator can specify a retention period by using the parameter `UNDO_RETENTION`.

> **See Also:** *Oracle Database Administrator's Guide* for information on long-running queries and resumable space allocation

For example, if `UNDO_RETENTION` is set to 30 minutes, then all committed undo information in the system is retained for at least 30 minutes. This ensures that all queries running for 30 minutes or less, under usual circumstances, do not encounter the OER error, "snapshot too old."

A read-only transaction is started with a `SET TRANSACTION` statement that includes the `READ ONLY` option. For example:

```
SET TRANSACTION READ ONLY;
```

The `SET TRANSACTION` statement must be the first statement of a new transaction; if any DML statements (including queries) or other non-DDL statements (such as `SET ROLE`) precede a `SET TRANSACTION READ ONLY` statement, an error is returned. Once a `SET TRANSACTION READ ONLY` statement successfully executes, only `SELECT` (without a `FOR UPDATE` clause), `COMMIT`, `ROLLBACK`, or non-DML statements (such as `SET ROLE`, `ALTER SYSTEM`, `LOCK TABLE`) are allowed in the transaction. Otherwise, an error is returned. A `COMMIT`, `ROLLBACK`, or DDL statement terminates the read-only transaction; a DDL statement causes an implicit commit of the read-only transaction and commits in its own transaction.

Using Cursors within Applications

PL/SQL implicitly declares a cursor for all SQL data manipulation statements, including queries that return only one row. For queries that return more than one row, you can explicitly declare a cursor to process the rows individually.

A **cursor** is a handle to a specific private SQL area. In other words, a cursor can be thought of as a name for a specific private SQL area. A PL/SQL **cursor variable** enables the retrieval of multiple rows from a stored procedure. Cursor variables allow you to pass cursors as parameters in your 3GL application. Cursor variables are described in *Oracle Database PL/SQL User's Guide and Reference.*

Although most Oracle Database users rely on the automatic cursor handling of the database utilities, the programmatic interfaces offer application designers more control over cursors. In application development, a cursor is a named resource available to a program, which can be specifically used for parsing SQL statements embedded within the application.

Declaring and Opening Cursors

There is no absolute limit to the total number of cursors one session can have open at one time, subject to two constraints:

- Each cursor requires virtual memory, so a session's total number of cursors is limited by the memory available to that process.
- A systemwide limit of cursors for each session is set by the initialization parameter named OPEN_CURSORS found in the parameter file (such as INIT.ORA).

See Also: *Oracle Database Reference* for descriptions of parameters

Explicitly creating cursors for precompiler programs can offer some advantages in tuning those applications. For example, increasing the number of cursors can often reduce the frequency of parsing and improve performance. If you know how many cursors may be required at a given time, then you can make sure you can open that many simultaneously.

Using a Cursor to Execute Statements Again

After each stage of execution, the cursor retains enough information about the SQL statement to reexecute the statement without starting over, as long as no other SQL statement has been associated with that cursor. The statement can be reexecuted without including the parse stage.

By opening several cursors, the parsed representation of several SQL statements can be saved. Repeated execution of the same SQL statements can thus begin at the describe, define, bind, or execute step, saving the repeated cost of opening cursors and parsing.

To understand the performance characteristics of a cursor, a DBA can retrieve the text of the query represented by the cursor using the V$SQL catalog view. Because the results of EXPLAIN PLAN on the original query might differ from the way the query is actually processed, a DBA can get more precise information by examining the VSQL_PLAN, VSQL_PLAN_STATISTICS, and V$SQL_PLAN_STATISTICS_ALL catalog views.:

- The V$SQL_PLAN view contains the execution plan information for each child cursor loaded in the library cache.
- The V$SQL_PLAN_STATISTICS view provides execution statistics at the row source level for each child cursor.
- The V$SQL_PLAN_STATISTICS_ALL view contains memory usage statistics for row sources that use SQL memory (sort or hash-join). This view concatenates information in V$SQL_PLAN with execution statistics from V$SQL_PLAN_STATISTICS and V$SQL_WORKAREA.

See Also: *Oracle Database Reference* for details on these views

Closing Cursors

Closing a cursor means that the information currently in the associated private area is lost and its memory is deallocated. Once a cursor is opened, it is not closed until one of the following events occurs:

- The user program terminates its connection to the server.
- If the user program is an OCI program or precompiler application, then it explicitly closes any open cursor during the execution of that program. (However, when this program terminates, any cursors remaining open are implicitly closed.)

Cancelling Cursors

Cancelling a cursor frees resources from the current fetch.The information currently in the associated private area is lost but the cursor remains open, parsed, and associated with its bind variables.

Note: You cannot cancel cursors using Pro*C/C++ or PL/SQL.

See Also: *Oracle Call Interface Programmer's Guide* for more information about cancelling cursors

Locking Data Explicitly

Oracle Database always performs necessary locking to ensure data concurrency, integrity, and statement-level read consistency. You can override these default locking mechanisms. For example, you might want to override the default locking of Oracle Database if:

- You want transaction-level read consistency or "repeatable reads"—where transactions query a consistent set of data for the duration of the transaction, knowing that the data has not been changed by any other transactions. This level of consistency can be achieved by using explicit locking, read-only transactions, serializable transactions, or overriding default locking for the system.
- A transaction requires exclusive access to a resource. To proceed with its statements, the transaction with exclusive access to a resource does not have to wait for other transactions to complete.

The automatic locking mechanisms can be overridden at the transaction level. Transactions including the following SQL commands override Oracle Database's default locking:

- `LOCK TABLE`
- `SELECT`, including the `FOR UPDATE` clause
- `SET TRANSACTION` with the `READ ONLY` or `ISOLATION LEVEL SERIALIZABLE` options

Locks acquired by these statements are released after the transaction is committed or rolled back.

The following sections describe each option available for overriding the default locking of Oracle Database. The initialization parameter `DML_LOCKS` determines the maximum number of DML locks allowed.

See Also: *Oracle Database Reference* for a discussion of parameters

Although the default value is usually enough, you might need to increase it if you use additional manual locks.

Caution: If you override the default locking of Oracle Database at any level, be sure that the overriding locking procedures operate correctly: Ensure that data integrity is guaranteed, data concurrency is acceptable, and deadlocks are not possible or are appropriately handled.

Choosing a Locking Strategy

A transaction explicitly acquires the specified table locks when a LOCK TABLE statement is executed. A LOCK TABLE statement manually overrides default locking. When a LOCK TABLE statement is issued on a view, the underlying base tables are locked. The following statement acquires exclusive table locks for the EMP_TAB and DEPT_TAB tables on behalf of the containing transaction:

```
LOCK TABLE Emp_tab, Dept_tab
    IN EXCLUSIVE MODE NOWAIT;
```

You can specify several tables or views to lock in the same mode; however, only a single lock mode can be specified for each LOCK TABLE statement.

> **Note:** When a table is locked, all rows of the table are locked. No other user can modify the table.

You can also indicate if you do or do not want to wait to acquire the lock. If you specify the NOWAIT option, then you only acquire the table lock if it is immediately available. Otherwise an error is returned to notify that the lock is not available at this time. In this case, you can attempt to lock the resource at a later time. If NOWAIT is omitted, then the transaction does not proceed until the requested table lock is acquired. If the wait for a table lock is excessive, then you might want to cancel the lock operation and retry at a later time; you can code this logic into your applications.

When to Lock with ROW SHARE and ROW EXCLUSIVE Mode

```
LOCK TABLE Emp_tab IN ROW SHARE MODE;
LOCK TABLE Emp_tab IN ROW EXCLUSIVE MODE;
```

ROW SHARE and ROW EXCLUSIVE table locks offer the highest degree of concurrency. You might use these locks if:

- Your transaction needs to prevent another transaction from acquiring an intervening share, share row, or exclusive table lock for a table before the table can be updated in your transaction. If another transaction acquires an intervening share, share row, or exclusive table lock, no other transactions can update the table until the locking transaction commits or rolls back.
- Your transaction needs to prevent a table from being altered or dropped before the table can be modified later in your transaction.

When to Lock with SHARE Mode

```
LOCK TABLE Emp_tab IN SHARE MODE;
```

SHARE table locks are rather restrictive data locks. You might use these locks if:

- Your transaction only queries the table, and requires a consistent set of the table data for the duration of the transaction.
- You can hold up other transactions that try to update the locked table, until all transactions that hold SHARE locks on the table either commit or roll back.
- Other transactions may acquire concurrent SHARE table locks on the same table, also allowing them the option of transaction-level read consistency.

> **Caution:** Your transaction may or may not update the table later in the same transaction. However, if multiple transactions concurrently hold share table locks for the same table, no transaction can update the table (even if row locks are held as the result of a SELECT... FOR UPDATE statement). Therefore, if concurrent share table locks on the same table are common, updates cannot proceed and deadlocks are common. In this case, use share row exclusive or exclusive table locks instead.

For example, assume that two tables, EMP_TAB and BUDGET_TAB, require a consistent set of data in a third table, DEPT_TAB. For a given department number, you want to update the information in both of these tables, and ensure that no new members are added to the department between these two transactions.

Although this scenario is quite rare, it can be accommodated by locking the DEPT_TAB table in SHARE MODE, as shown in the following example. Because the DEPT_TAB table is rarely updated, locking it probably does not cause many other transactions to wait long.

> **Note:** You may need to set up data structures similar to the following for certain examples to work:
>
> ```
> CREATE TABLE dept_tab(
>    deptno NUMBER(2) NOT NULL,
>    dname VARCHAR2(14),
>    loc VARCHAR2(13));
>
> CREATE TABLE emp_tab (
>    empno NUMBER(4) NOT NULL,
>    ename VARCHAR2(10),
>    job VARCHAR2(9),
>    mgr NUMBER(4),
>    hiredate DATE,
>    sal NUMBER(7,2),
>    comm NUMBER(7,2),
>    deptno NUMBER(2));
>
> CREATE TABLE Budget_tab (
>    totsal NUMBER(7,2),
>    deptno NUMBER(2) NOT NULL);
> ```

```
LOCK TABLE Dept_tab IN SHARE MODE;
UPDATE Emp_tab
    SET sal = sal * 1.1
    WHERE deptno IN
      (SELECT deptno FROM Dept_tab WHERE loc = 'DALLAS');
UPDATE Budget_tab
    SET Totsal = Totsal * 1.1
    WHERE Deptno IN
      (SELECT Deptno FROM Dept_tab WHERE Loc = 'DALLAS');

COMMIT; /* This releases the lock */
```

When to Lock with SHARE ROW EXCLUSIVE Mode

```
LOCK TABLE Emp_tab IN SHARE ROW EXCLUSIVE MODE;
```

You might use a SHARE ROW EXCLUSIVE table lock if:

- Your transaction requires both transaction-level read consistency for the specified table and the ability to update the locked table.
- You do not care if other transactions acquire explicit row locks (using SELECT... FOR UPDATE), which might make UPDATE and INSERT statements in the locking transaction wait and might cause deadlocks.
- You only want a single transaction to have this behavior.

When to Lock in EXCLUSIVE Mode

```
LOCK TABLE Emp_tab IN EXCLUSIVE MODE;
```

You might use an EXCLUSIVE table if:

- Your transaction requires immediate update access to the locked table. When your transaction holds an exclusive table lock, other transactions cannot lock specific rows in the locked table.
- Your transaction also ensures transaction-level read consistency for the locked table until the transaction is committed or rolled back.
- You are not concerned about low levels of data concurrency, making transactions that request exclusive table locks wait in line to update the table sequentially.

Privileges Required

You can automatically acquire any type of table lock on tables in your schema. To acquire a table lock on a table in another schema, you must have the LOCK ANY TABLE system privilege or any object privilege (for example, SELECT or UPDATE) for the table.

Letting Oracle Database Control Table Locking

Letting Oracle Database control table locking means your application needs less programming logic, but also has less control, than if you manage the table locks yourself.

Issuing the command SET TRANSACTION ISOLATION LEVEL SERIALIZABLE or ALTER SESSION ISOLATION LEVEL SERIALIZABLE preserves ANSI serializability without changing the underlying locking protocol. This technique allows concurrent access to the table while providing ANSI serializability. Getting table locks greatly reduces concurrency.

See Also:

- *Oracle Database SQL Reference* for information on the SET TRANSACTION statement
- *Oracle Database SQL Reference* for information on the ALTER SESSION statements

The settings for these parameters should be changed only when an instance is shut down. If multiple instances are accessing a single database, then all instances should use the same setting for these parameters.

Explicitly Acquiring Row Locks

You can override default locking with a SELECT statement that includes the FOR UPDATE clause. This statement acquires exclusive row locks for selected rows (as an UPDATE statement does), in anticipation of updating the selected rows in a subsequent statement.

You can use a SELECT... FOR UPDATE statement to lock a row without actually changing it. For example, several triggers in Chapter 9, "Coding Triggers", show how to implement referential integrity. In the EMP_DEPT_CHECK trigger (see "Foreign Key Trigger for Child Table"), the row that contains the referenced parent key value is locked to guarantee that it remains for the duration of the transaction; if the parent key is updated or deleted, referential integrity would be violated.

SELECT... FOR UPDATE statements are often used by interactive programs that allow a user to modify fields of one or more specific rows (which might take some time); row locks are acquired so that only a single interactive program user is updating the rows at any given time.

If a SELECT... FOR UPDATE statement is used when defining a cursor, the rows in the return set are locked when the cursor is opened (before the first fetch) rather than being locked as they are fetched from the cursor. Locks are only released when the transaction that opened the cursor is committed or rolled back, not when the cursor is closed.

Each row in the return set of a SELECT... FOR UPDATE statement is locked individually; the SELECT... FOR UPDATE statement waits until the other transaction releases the conflicting row lock. If a SELECT... FOR UPDATE statement locks many rows in a table, and if the table experiences a lot of update activity, it might be faster to acquire an EXCLUSIVE table lock instead.

Note: The return set for a SELECT... FOR UPDATE may change while the query is running; for example, if columns selected by the query are updated or rows are deleted after the query started. When this happens, SELECT... FOR UPDATE acquires locks on the rows that did not change, gets a new read-consistent snapshot of the table using these locks, and then restarts the query to acquire the remaining locks.

This can cause a deadlock between sessions querying the table concurrently with DML operations when rows are locked in a non-sequential order. To prevent such deadlocks, design your application so that any concurrent DML on the table does not affect the return set of the query. If this is not feasible, you may want to serialize queries in your application.

When acquiring row locks with SELECT... FOR UPDATE, you can specify the NOWAIT option to indicate that you are not willing to wait to acquire the lock. If you cannot acquire then lock immediately, an error is returned to signal that the lock is not possible at this time. You can try to lock the row again later.

By default, the transaction waits until the requested row lock is acquired. If the wait for a row lock is too long, you can code logic into your application to cancel the lock operation and try again later.

About User Locks

You can use Oracle Lock Management services for your applications by making calls to the DBMS_LOCK package. It is possible to request a lock of a specific mode, give it a unique name recognizable in another procedure in the same or another instance, change the lock mode, and release it. Because a reserved user lock is the same as an Oracle Database lock, it has all the features of a database lock, such as deadlock detection. Be certain that any user locks used in distributed transactions are released upon COMMIT, or an undetected deadlock can occur.

> **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for detailed information on the DBMS_LOCK package

When to Use User Locks

User locks can help to:

- Provide exclusive access to a device, such as a terminal
- Provide application-level enforcement of read locks
- Detect when a lock is released and cleanup after the application
- Synchronize applications and enforce sequential processing

Example of a User Lock

The following Pro*COBOL precompiler example shows how locks can be used to ensure that there are no conflicts when multiple people need to access a single device.

```
*****************************************************************
* Print Check                                                   *
* Any cashier may issue a refund to a customer returning goods. *
* Refunds under $50 are given in cash, more than $50 by check.  *
* This code prints the check. The one printer is opened by all  *
* the cashiers to avoid the overhead of opening and closing it  *
* for every check. This means that lines of output from multiple*
* cashiers could become interleaved if we don't ensure exclusive*
* access to the printer. The DBMS_LOCK package is used to       *
* ensure exclusive access.                                      *
*****************************************************************
CHECK-PRINT
*    Get the lock "handle" for the printer lock.
   MOVE "CHECKPRINT" TO LOCKNAME-ARR.
   MOVE 10 TO LOCKNAME-LEN.
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.ALLOCATE_UNIQUE ( :LOCKNAME, :LOCKHANDLE );
      END; END-EXEC.
*   Lock the printer in exclusive mode (default mode).
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.REQUEST ( :LOCKHANDLE );
      END; END-EXEC.
*   We now have exclusive use of the printer, print the check.
  ...
*   Unlock the printer so other people can use it
EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.RELEASE ( :LOCKHANDLE );
      END; END-EXEC.
```

Viewing and Monitoring Locks

Table 2–5 describes Oracle Database facilities to display locking information for ongoing transactions within an instance.

Table 2–3 Ways to Display Locking Information

Tool	Description
Oracle Enterprise Manager 10g Database Control	From the Additional Monitoring Links section of the Database Performance page, click Database Locks to display user blocks, blocking locks, or the complete list of all database locks. Refer to *Oracle Database 2 Day DBA* for more information.
`UTLLOCKT.SQL`	The `UTLLOCKT.SQL` script displays a simple character lock wait-for graph in tree structured fashion. Using any *ad hoc* SQL tool (such as SQL*Plus) to execute the script, it prints the sessions in the system that are waiting for locks and the corresponding blocking locks. The location of this script file is operating system dependent. (You must have run the `CATBLOCK.SQL` script before using `UTLLOCKT.SQL`.)

Using Serializable Transactions for Concurrency Control

By default, Oracle Database permits concurrently executing transactions to modify, add, or delete rows in the same table, and in the same data block. Changes made by one transaction are not seen by another concurrent transaction until the transaction that made the changes commits.

If a transaction A attempts to update or delete a row that has been locked by another transaction B (by way of a DML or `SELECT... FOR UPDATE` statement), then A's DML command blocks until B commits or rolls back. Once B commits, transaction A can see changes that B has made to the database.

For most applications, this concurrency model is the appropriate one, because it provides higher concurrency and thus better performance. But some rare cases require transactions to be serializable. **Serializable transactions** must execute in such a way that they appear to be executing one at a time (serially), rather than concurrently. Concurrent transactions executing in serialized mode can only make database changes that they could have made if the transactions ran one after the other.

Figure 2–1 shows a serializable transaction (B) interacting with another transaction (A).

The ANSI/ISO SQL standard SQL92 defines three possible kinds of transaction interaction, and four levels of isolation that provide increasing protection against these interactions. These interactions and isolation levels are summarized in Table 2–4.

Table 2–4 Summary of ANSI Isolation Levels

Isolation Level	Dirty Read[1]	Non-Repeatable Read[2]	Phantom Read[3]
`READ UNCOMMITTED`	Possible	Possible	Possible
`READ COMMITTED`	Not possible	Possible	Possible
`REPEATABLE READ`	Not possible	Not possible	Possible
`SERIALIZABLE`	Not possible	Not possible	Not possible

[1] A transaction can read uncommitted data changed by another transaction.

[2] A transaction rereads data committed by another transaction and sees the new data.

[3] A transaction can execute a query again, and discover new rows inserted by another committed transaction.

The behavior of Oracle Database with respect to these isolation levels is summarized in Table 2–5.

Table 2–5 ANSI Isolation Levels and Oracle Database

Isolation Level	Description
`READ UNCOMMITTED`	Oracle Database never permits "dirty reads." Although some other database products use this undesirable technique to improve thoughput, it is not required for high throughput with Oracle Database.
`READ COMMITTED`	Oracle Database meets the `READ COMMITTED` isolation standard. This is the default mode for all Oracle Database applications. Because an Oracle Database query only sees data that was committed at the beginning of the query (the snapshot time), Oracle Database actually offers more consistency than is required by the ANSI/ISO SQL92 standards for `READ COMMITTED` isolation.
`REPEATABLE READ`	Oracle Database does not normally support this isolation level, except as provided by `SERIALIZABLE`.
`SERIALIZABLE`	Oracle Database does not normally support this isolation level, except as provided by `SERIALIZABLE`.

How Serializable Transactions Interact

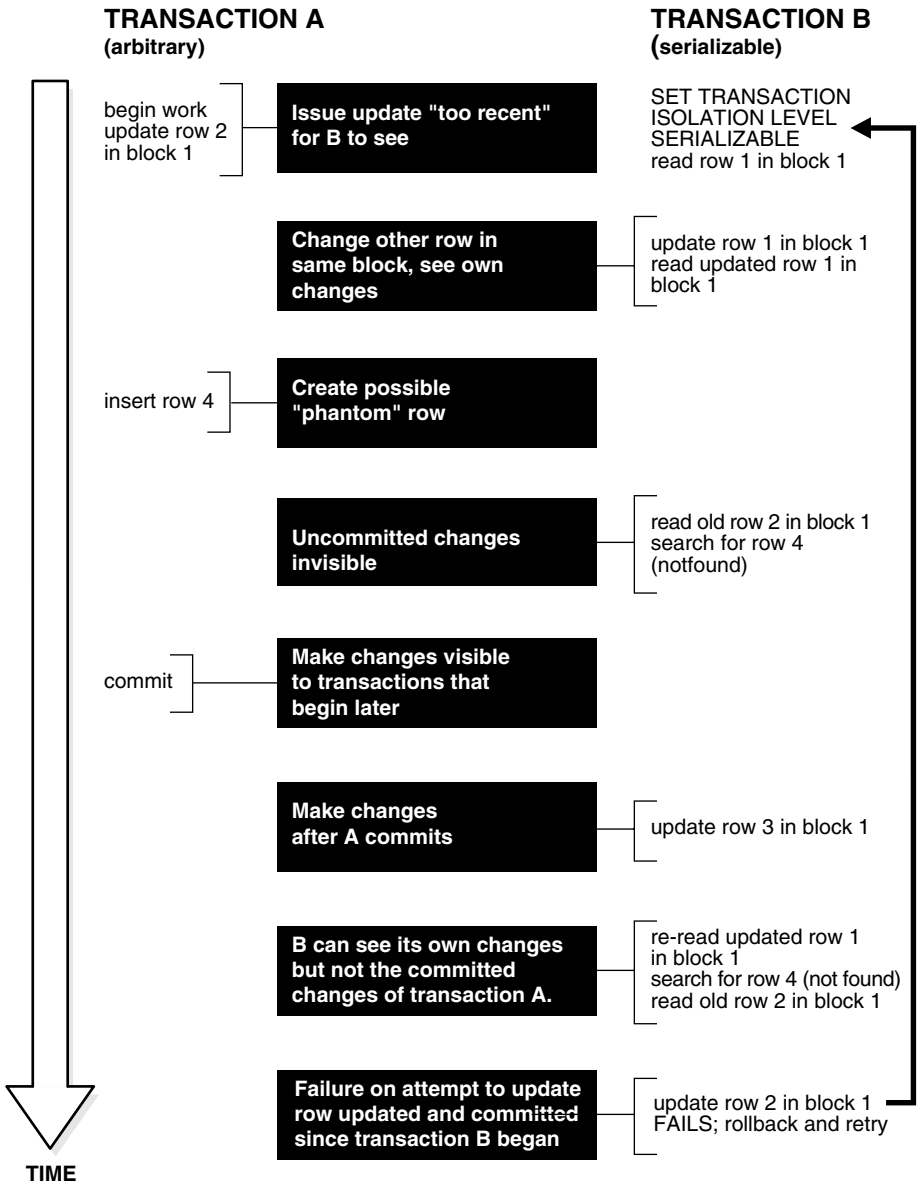
Figure 2–1 on page 2-16 shows how a serializable transaction (Transaction B) interacts with another transaction (A, which can be either `SERIALIZABLE` or `READ COMMITTED`).

When a serializable transaction fails with an `ORA-08177` error ("cannot serialize access"), the application can take any of several actions:

- Commit the work executed to that point
- Execute additional, different, statements, perhaps after rolling back to a prior savepoint in the transaction
- Roll back the entire transaction and try it again

Oracle Database stores control information in each data block to manage access by concurrent transactions. To use the `SERIALIZABLE` isolation level, you must use the `INITRANS` clause of the `CREATE TABLE` or `ALTER TABLE` command to set aside storage for this control information. To use serializable mode, `INITRANS` must be set to at least 3.

Figure 2–1 Time Line for Two Transactions



Setting the Isolation Level of a Transaction

You can change the isolation level of a transaction using the `ISOLATION LEVEL` clause of the `SET TRANSACTION` command, which must be the first command issued in a transaction.

Use the `ALTER SESSION` command to set the transaction isolation level on a session-wide basis.

> **See Also:** *Oracle Database Reference* for the complete syntax of the `SET TRANSACTION` and `ALTER SESSION` commands

The INITRANS Parameter

Oracle Database stores control information in each data block to manage access by concurrent transactions. Therefore, if you set the transaction isolation level to

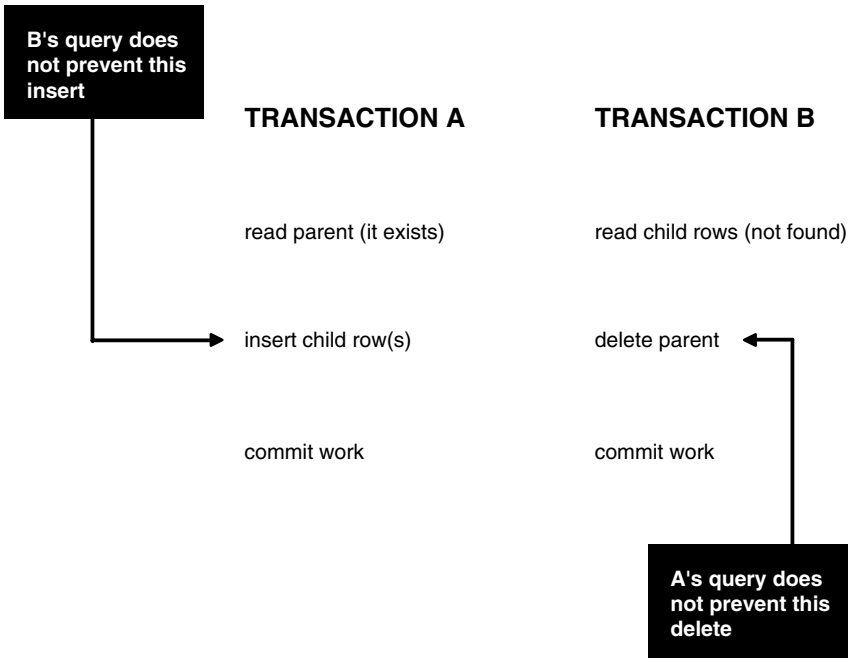
SERIALIZABLE, then you must use the ALTER TABLE command to set INITRANS to at least 3. This parameter causes Oracle Database to allocate sufficient storage in each block to record the history of recent transactions that accessed the block. Higher values should be used for tables that will undergo many transactions updating the same blocks.

Referential Integrity and Serializable Transactions

Because Oracle Database does not use read locks, even in SERIALIZABLE transactions, data read by one transaction can be overwritten by another. Transactions that perform database consistency checks at the application level should not assume that the data they read will not change during the execution of the transaction (even though such changes are not visible to the transaction). Database inconsistencies can result unless such application-level consistency checks are coded carefully, even when using SERIALIZABLE transactions. Note, however, that the examples shown in this section are applicable for both READ COMMITTED and SERIALIZABLE transactions.

Figure 2–2 on page 2-17 shows two different transactions that perform application-level checks to maintain the referential integrity parent/child relationship between two tables. One transaction checks that a row with a specific primary key value exists in the parent table before inserting corresponding child rows. The other transaction checks to see that no corresponding detail rows exist before deleting a parent row. In this case, both transactions assume (but do not ensure) that data they read will not change before the transaction completes.

Figure 2–2 Referential Integrity Check



The read issued by transaction A does not prevent transaction B from deleting the parent row, and transaction B's query for child rows does not prevent transaction A from inserting child rows. This scenario leaves a child row in the database with no corresponding parent row. This result occurs even if both A and B are SERIALIZABLE transactions, because neither transaction prevents the other from making changes in the data it reads to check consistency.

As this example shows, sometimes you must take steps to ensure that the data read by one transaction is not concurrently written by another. This requires a greater degree of transaction isolation than defined by SQL92 SERIALIZABLE mode.

Using SELECT FOR UPDATE

Fortunately, it is straightforward in Oracle Database to prevent the anomaly described:

- Transaction A can use SELECT FOR UPDATE to query and lock the parent row and thereby prevent transaction B from deleting the row.
- Transaction B can prevent Transaction A from gaining access to the parent row by reversing the order of its processing steps. Transaction B first deletes the parent row, and then rolls back if its subsequent query detects the presence of corresponding rows in the child table.

Referential integrity can also be enforced in Oracle Database using database triggers, instead of a separate query as in Transaction A. For example, an INSERT into the child table can fire a BEFORE INSERT row-level trigger to check for the corresponding parent row. The trigger queries the parent table using SELECT FOR UPDATE, ensuring that parent row (if it exists) remains in the database for the duration of the transaction inserting the child row. If the corresponding parent row does not exist, the trigger rejects the insert of the child row.

SQL statements issued by a database trigger execute in the context of the SQL statement that caused the trigger to fire. All SQL statements executed within a trigger see the database in the same state as the triggering statement. Thus, in a READ COMMITTED transaction, the SQL statements in a trigger see the database as of the beginning of the triggering statement execution, and in a transaction executing in SERIALIZABLE mode, the SQL statements see the database as of the beginning of the transaction. In either case, the use of SELECT FOR UPDATE by the trigger correctly enforces referential integrity.

READ COMMITTED and SERIALIZABLE Isolation

Oracle Database gives you a choice of two transaction isolation levels with different characteristics. Both the READ COMMITTED and SERIALIZABLE isolation levels provide a high degree of consistency and concurrency. Both levels reduce contention, and are designed for deploying real-world applications. The rest of this section compares the two isolation modes and provides information helpful in choosing between them.

Transaction Set Consistency

A useful way to describe the READ COMMITTED and SERIALIZABLE isolation levels in Oracle Database is to consider:

- A collection of database tables (or any set of data)
- A sequence of reads of rows in those tables
- The set of transactions committed at any moment

An operation (a query or a transaction) is **transaction set consistent** if its read operations all return data written by the same set of committed transactions. When an operation is not transaction set consistent, some reads reflect the changes of one set of transactions, and other reads reflect changes made by other transactions. Such an operation sees the database in a state that reflects no single set of committed transactions.

Oracle Database transactions executing in READ COMMITTED mode are transaction-set consistent on an individual-statement basis, because all rows read by a query must be committed before the query begins.

Oracle Database transactions executing in SERIALIZABLE mode are transaction set consistent on an individual-transaction basis, because all statements in a SERIALIZABLE transaction execute on an image of the database as of the beginning of the transaction.

In other database systems, a single query run in READ COMMITTED mode provides results that are not transaction set consistent. The query is not transaction set consistent, because it may see only a subset of the changes made by another transaction. For example, a join of a master table with a detail table could see a master record inserted by another transaction, but not the corresponding details inserted by that transaction, or vice versa. The READ COMMITTED mode avoids this problem, and so provides a greater degree of consistency than read-locking systems.

In read-locking systems, at the cost of preventing concurrent updates, SQL92 REPEATABLE READ isolation provides transaction set consistency at the statement level, but not at the transaction level. The absence of phantom protection means two queries issued by the same transaction can see data committed by different sets of other transactions. Only the throughput-limiting and deadlock-susceptible SERIALIZABLE mode in these systems provides transaction set consistency at the transaction level.

Comparison of READ COMMITTED and SERIALIZABLE Transactions

Table 2–6 summarizes key similarities and differences between READ COMMITTED and SERIALIZABLE transactions.

Table 2–6 Read Committed Versus Serializable Transaction

Operation	Read Committed	Serializable
Dirty write	Not Possible	Not Possible
Dirty read	Not Possible	Not Possible
Non-repeatable read	Possible	Not Possible
Phantoms	Possible	Not Possible
Compliant with ANSI/ISO SQL 92	Yes	Yes
Read snapshot time	Statement	Transaction
Transaction set consistency	Statement level	Transaction level
Row-level locking	Yes	Yes
Readers block writers	No	No
Writers block readers	No	No
Different-row writers block writers	No	No
Same-row writers block writers	Yes	Yes
Waits for blocking transaction	Yes	Yes
Subject to "can't serialize access" error	No	Yes
Error after blocking transaction aborts	No	No
Error after blocking transaction commits	No	Yes

Choosing an Isolation Level for Transactions

Choose an isolation level that is appropriate to the specific application and workload. You might choose different isolation levels for different transactions. The choice depends on performance and consistency needs, and consideration of application coding requirements.

For environments with many concurrent users rapidly submitting transactions, you must assess transaction performance against the expected transaction arrival rate and response time demands, and choose an isolation level that provides the required degree of consistency while performing well. Frequently, for high performance environments, you must trade-off between consistency and concurrency (transaction throughput).

Both Oracle Database isolation modes provide high levels of consistency and concurrency (and performance) through the combination of row-level locking and Oracle Database's multi-version concurrency control system. Because readers and writers do not block one another in Oracle Database, while queries still see consistent data, both `READ COMMITTED` and `SERIALIZABLE` isolation provide a high level of concurrency for high performance, without the need for reading uncommitted ("dirty") data.

`READ COMMITTED` isolation can provide considerably more concurrency with a somewhat increased risk of inconsistent results (due to phantoms and non-repeatable reads) for some transactions. The `SERIALIZABLE` isolation level provides somewhat more consistency by protecting against phantoms and non-repeatable reads, and may be important where a read/write transaction executes a query more than once. However, `SERIALIZABLE` mode requires applications to check for the "can't serialize access" error, and can significantly reduce throughput in an environment with many concurrent transactions accessing the same data for update. Application logic that checks database consistency must take into account the fact that reads do not block writes in either mode.

Application Tips for Transactions

When a transaction runs in serializable mode, any attempt to change data that was changed by another transaction since the beginning of the serializable transaction causes an error:

```
ORA-08177: Can't serialize access for this transaction.
```

When you get this error, roll back the current transaction and execute it again. The transaction gets a new transaction snapshot, and the operation is likely to succeed.

To minimize the performance overhead of rolling back transactions and executing them again, try to put DML statements that might conflict with other concurrent transactions near the beginning of your transaction.

Autonomous Transactions

This section gives a brief overview of autonomous transactions and what you can do with them.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference* and Chapter 9, "Coding Triggers" for detailed information on autonomous transactions

At times, you may want to commit or roll back some changes to a table independently of a primary transaction's final outcome. For example, in a stock purchase transaction, you may want to commit a customer's information regardless of whether the overall stock purchase actually goes through. Or, while running that same transaction, you may want to log error messages to a debug table even if the overall transaction rolls back. Autonomous transactions allow you to do such tasks.

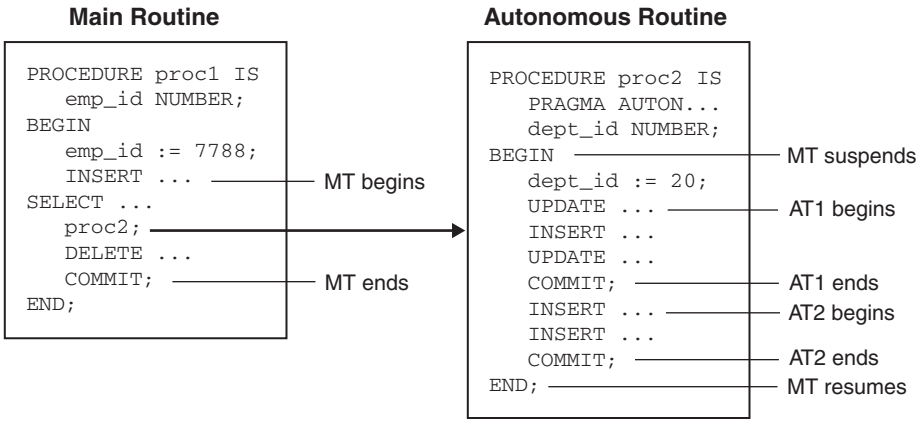
An **autonomous transaction** (AT) is an independent transaction started by another transaction, the **main transaction** (MT). It lets you suspend the main transaction, do SQL operations, commit or roll back those operations, then resume the main transaction.

An autonomous transaction executes within an **autonomous scope**. An autonomous scope is a routine you mark with the pragma (compiler directive) `AUTONOMOUS_TRANSACTION`. The pragma instructs the PL/SQL compiler to mark a routine as `autonomous` (independent). In this context, the term **routine** includes:

- Top-level (not nested) anonymous PL/SQL blocks
- Local, standalone, and packaged functions and procedures
- Methods of a SQL object type
- PL/SQL triggers

Figure 2–3 shows how control flows from the main routine (MT) to an autonomous routine (AT) and back again. As you can see, the autonomous routine can commit more than one transaction (AT1 and AT2) before control returns to the main routine.

Figure 2–3 Transaction Control Flow



When you enter the executable section of an autonomous routine, the main routine suspends. When you exit the routine, the main routine resumes.

`COMMIT` and `ROLLBACK` end the active autonomous transaction but do not exit the autonomous routine. As Figure 2–3 shows, when one transaction ends, the next SQL statement begins another transaction.

A few more characteristics of autonomous transactions:

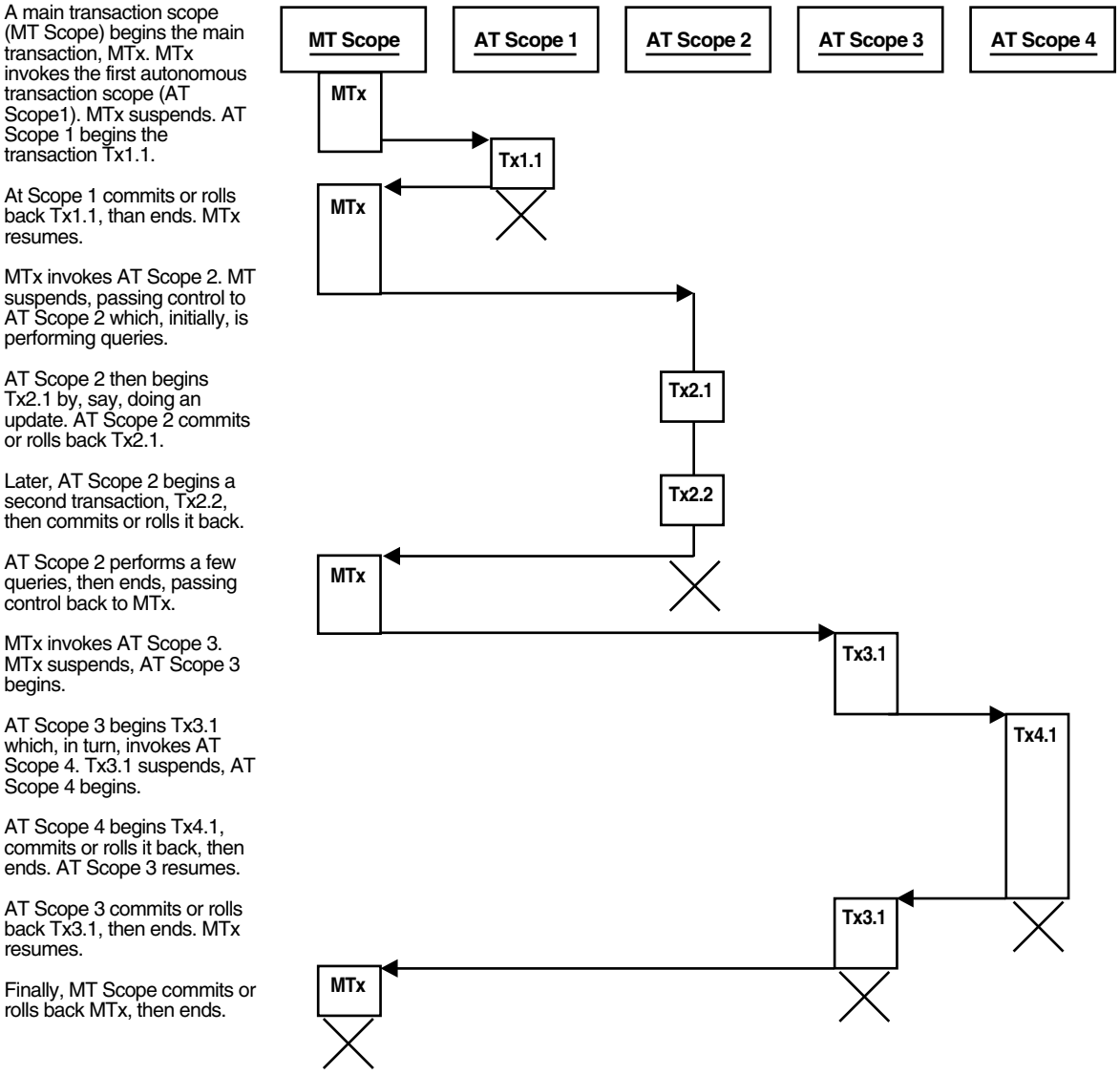
- The changes autonomous transactions effect do not depend on the state or the eventual disposition of the main transaction. For example:
  - An autonomous transaction does not see any changes made by the main transaction.

  - When an autonomous transaction commits or rolls back, it does not affect the outcome of the main transaction.

- The changes an autonomous transaction effects are visible to other transactions as soon as that autonomous transaction commits. This means that users can access the updated information without having to wait for the main transaction to commit.
- Autonomous transactions can start other autonomous transactions.

Figure 2–4 illustrates some of the possible sequences autonomous transactions can follow.

Figure 2–4 Possible Sequences of Autonomous Transactions



Examples of Autonomous Transactions

The two examples in this section illustrate some of the ways you can use autonomous transactions.

As these examples illustrate, there are four possible outcomes that can occur when you use autonomous and main transactions. Table 2–7 presents these possible outcomes. As you can see, there is no dependency between the outcome of an autonomous transaction and that of a main transaction.

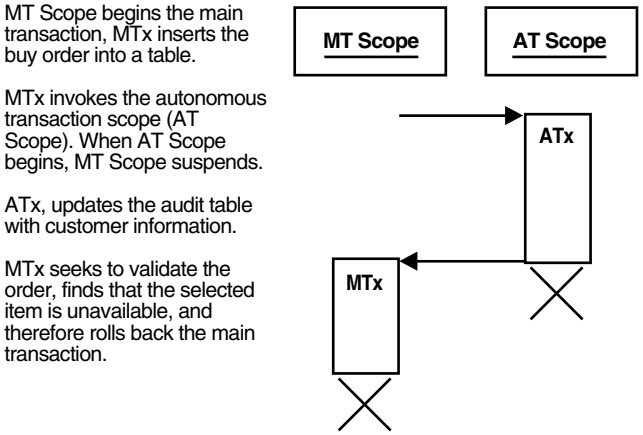
Table 2–7 Possible Transaction Outcomes

Autonomous Transaction	Main Transaction
Commits	Commits
Commits	Rolls back
Rolls back	Commits
Rolls back	Rolls back

Entering a Buy Order

In this example, illustrated by Figure 2–5, a customer enters a buy order. That customer's information (such as name, address, phone) is committed to a customer information table—even though the sale does not go through.

Figure 2–5 Example: A Buy Order



Example: Making a Bank Withdrawal

In this example, a customer tries to make a withdrawal from a bank account. In the process, a main transaction calls one of two autonomous transaction scopes (AT Scope 1, and AT Scope 2).

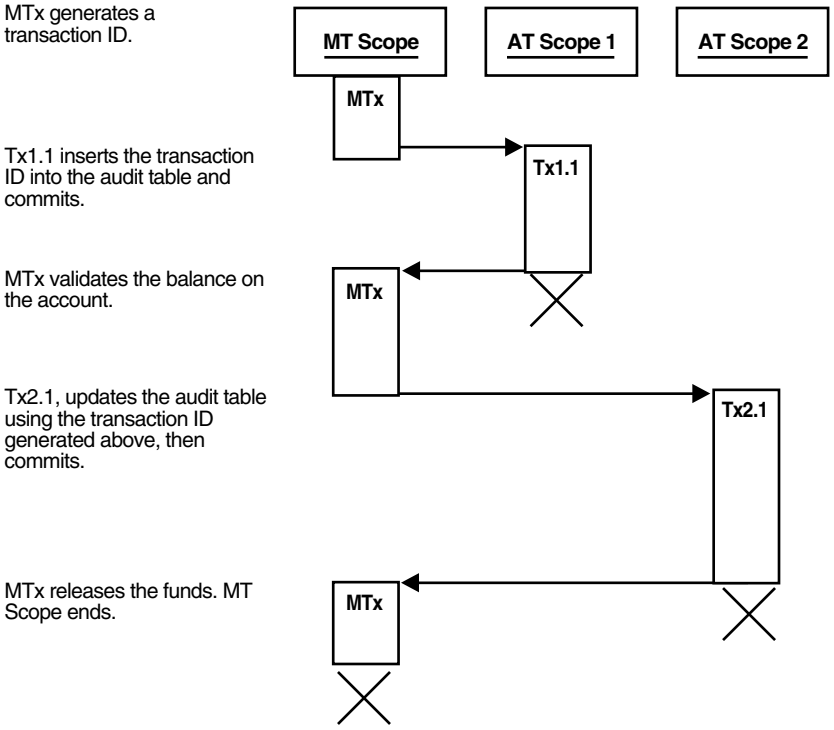
The following diagrams illustrate three possible scenarios for this transaction.

- Scenario 1: There are sufficient funds to cover the withdrawal and therefore the bank releases the funds
- Scenario 2: There are insufficient funds to cover the withdrawal, but the customer has overdraft protection. The bank therefore releases the funds.
- Scenario 3: There are insufficient funds to cover the withdrawal, the customer does not have overdraft protection, and the bank therefore withholds the requested funds.

Scenario 1

There are sufficient funds to cover the withdrawal and therefore the bank releases the funds. This is illustrated by Figure 2–6.

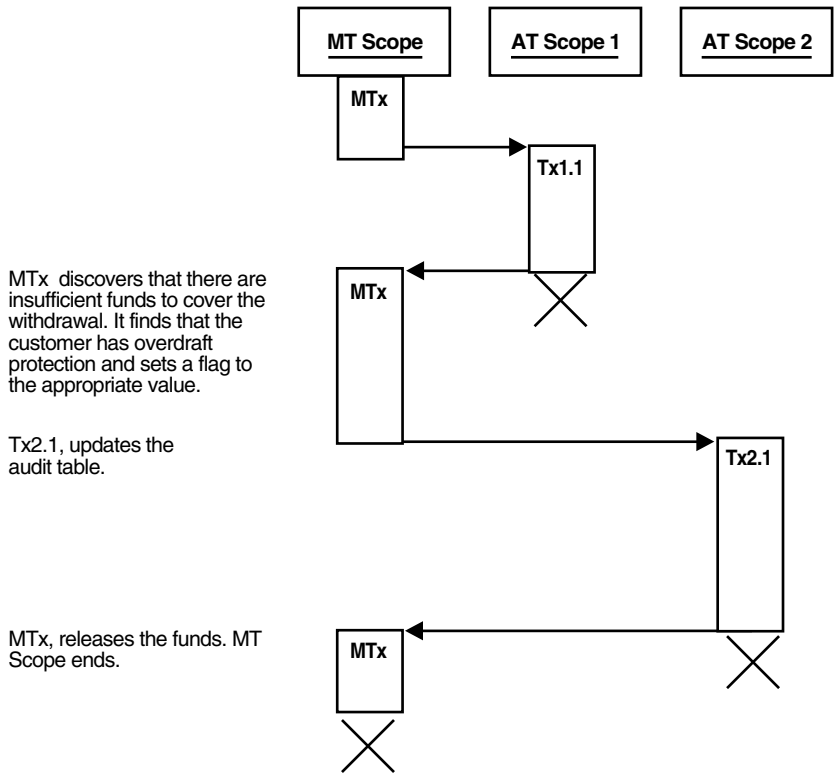
Figure 2–6 Example: Bank Withdrawal—Sufficient Funds



Scenario 2

There are insufficient funds to cover the withdrawal, but the customer has overdraft protection. The bank therefore releases the funds. This is illustrated by Figure 2–7.

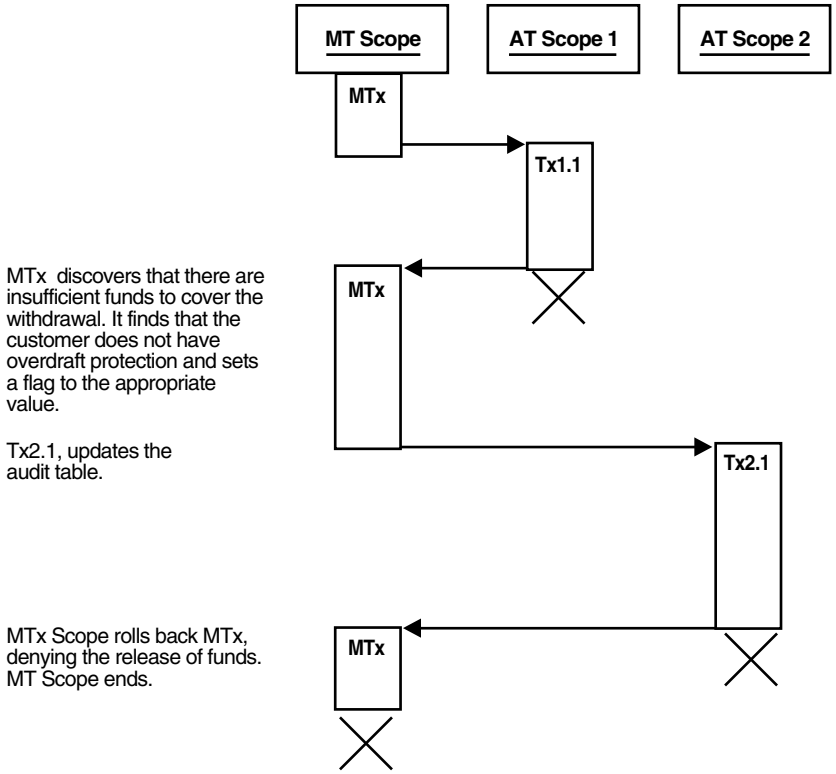
Figure 2–7 Example: Bank Withdrawal—Insufficient Funds WITH Overdraft Protection



Scenario 3

There are insufficient funds to cover the withdrawal, the customer does *not* have overdraft protection, and the bank therefore withholds the requested funds. This is illustrated by Figure 2–8.

Figure 2–8 Example: Bank Withdrawal—Insufficient Funds WITHOUT Overdraft Protection



Defining Autonomous Transactions

> **Note:** This section is provided here to round out your general understanding of autonomous transactions. For a more thorough understanding of autonomous transactions, refer to Oracle Database PL/SQL User's Guide and Reference.

To define autonomous transactions, you use the pragma (compiler directive) `AUTONOMOUS_TRANSACTION`. The pragma instructs the PL/SQL compiler to mark the procedure, function, or PL/SQL block as autonomous (independent).

You can code the pragma anywhere in the declarative section of a procedure, function, or PL/SQL block. But, for readability, code the pragma at the top of the section. The syntax follows:

```
PRAGMA AUTONOMOUS_TRANSACTION;
```

In the following example, you mark a packaged function as autonomous:

```
CREATE OR REPLACE PACKAGE Banking AS
    FUNCTION Balance (Acct_id INTEGER) RETURN REAL;
    -- add additional functions and packages
END Banking;

CREATE OR REPLACE PACKAGE BODY Banking AS
    FUNCTION Balance (Acct_id INTEGER) RETURN REAL IS
        PRAGMA AUTONOMOUS_TRANSACTION;
        My_bal REAL;
```

```
    BEGIN
       --add appropriate code
    END;
    -- add additional functions and packages...
END Banking;
```

Restrictions on Autonomous Transactions

Note the following restrictions on autonomous transactions.

- You cannot use the pragma to mark all subprograms in a package (or all methods in an object type) as autonomous. Only individual routines can be marked autonomous. For example, the following pragma is illegal:

  ```
  CREATE OR REPLACE PACKAGE Banking AS
      PRAGMA AUTONOMOUS_TRANSACTION; -- illegal
      FUNCTION Balance (Acct_id INTEGER) RETURN REAL;
      END Banking;
  ```

- You cannot execute a `PIPE ROW` statement in your autonomous routine while your autonomous transaction is open. You must close the autonomous transaction before executing the `PIPE ROW` statement. This is normally accomplished by committing or rolling back the autonomous transaction before executing the `PIPE ROW` statement.

See Also: *Oracle Database PL/SQL User's Guide and Reference*

Resuming Execution After a Storage Error Condition

When a long-running transaction is interrupted by an out-of-space error condition, your application can suspend the statement that encountered the problem and resume it after the space problem is corrected. This capability is known as **resumable storage allocation**. It lets you avoid time-consuming rollbacks, without the need to split the operation into smaller pieces and write your own code to track its progress.

See Also:

- *Oracle Database Concepts*
- *Oracle Database Administrator's Guide*

What Operations Can Be Resumed After an Error Condition?

Queries, DML operations, and certain DDL operations can all be resumed if they encounter an out-of-space error. The capability applies if the operation is performed directly by a SQL statement, or if it is performed within a stored procedure, anonymous PL/SQL block, SQL*Loader, or an OCI call such as `OCIStmtExecute()`.

Operations can be resumed after these kinds of error conditions:

- Out of space errors, such as ORA-01653.
- Space limit errors, such as ORA-01628.
- Space quota errors, such as ORA-01536.

Limitations on Resuming Operations After an Error Condition

Certain storage errors *cannot* be handled using this technique. In dictionary-managed tablespaces, you cannot resume an operation if you run into the limit for rollback

segments, or the maximum number of extents while creating an index or a table. Use locally managed tablespaces and automatic undo management in combination with this feature.

Writing an Application to Handle Suspended Storage Allocation

When an operation is suspended, your application does not receive the usual error code. Instead, perform any logging or notification by coding a trigger to detect the `AFTER SUSPEND` event and call the functions in the `DBMS_RESUMABLE` package to get information about the problem. Using this package, you can:

- Parse the error message with the `DBMS_RESUMABLE.SPACE_ERROR_INFO` function. For details about this function, refer to *Oracle Database PL/SQL Packages and Types Reference*.
- Set a new timeout value with the `SET_TIMEOUT` procedure.

Within the body of the trigger, you can perform any notifications, such as sending a mail message to alert an operator to the space problem.

Alternatively, the DBA can periodically check for suspended statements using the data dictionary views `DBA_RESUMABLE`, `USER_RESUMABLE`, and `V$_SESSION_WAIT`.

When the space condition is corrected (usually by the DBA), the suspended statement automatically resumes execution. If it is not corrected before the timeout period expires, the operation causes a `SERVERERROR` exception.

To reduce the chance of out-of-space errors within the trigger itself, you must declare it as an autonomous transaction so that it uses a rollback segment in the `SYSTEM` tablespace. If the trigger encounters a deadlock condition because of locks held by the suspended statement, the trigger is aborted and your application receives the original error condition, as if it was never suspended. If the trigger encounters an out-of-space condition, the trigger and the suspended statement are rolled back. You can prevent the rollback through an exception handler in the trigger, and just wait for the statement to be resumed.

> **See Also:** *Oracle Database Reference* for details on the `DBA_RESUMABLE`, `USER_RESUMABLE`, and `V$_SESSION_WAIT` data dictionary views

Example of Resumable Storage Allocation

This trigger handles applicable storage errors within the database. For some kinds of errors, it aborts the statement and alerts the DBA that this has happened through a mail message. For other errors that might be temporary, it specifies that the statement should wait for eight hours before resuming, with the expectation that the storage problem will be fixed by then.

```
CREATE OR REPLACE TRIGGER suspend_example
  AFTER SUSPEND
  ON DATABASE
  DECLARE
  cur_sid NUMBER;
  cur_inst NUMBER;
  err_type VARCHAR2(64);
  object_owner VARCHAR2(64);
  object_type VARCHAR2(64);
  table_space_name VARCHAR2(64);
  object_name VARCHAR2(64);
  sub_object_name VARCHAR2(64);
```

```
  msg_body VARCHAR2(64);
  ret_value boolean;
  error_txt varchar2(64);
  mail_conn utl_smtp.connection;
  BEGIN
  SELECT DISTINCT(sid) INTO cur_sid FROM v$mystat;
  cur_inst := userenv('instance');
  ret_value := dbms_resumable.space_error_info(err_type, object_owner,
  object_type, table_space_name, object_name, sub_object_name);
  IF object_type = 'ROLLBACK SEGMENT' THEN
  INSERT INTO sys.rbs_error ( SELECT sql_text, error_msg, suspend_time
  FROM dba_resumable WHERE session_id = cur_sid AND instance_id = cur_inst);
  SELECT error_msg into error_txt FROM dba_resumable WHERE session_id = cur_sid
AND instance_id = cur_inst;
  msg_body := 'Subject: Space error occurred: Space limit reached for rollback
 segment  '|| object_name || ' on ' || to_char(SYSDATE, 'Month dd, YYYY, HH:MIam')
 || '. Error message was: ' || error_txt;
  mail_conn := utl_smtp.open_connection('localhost', 25);
  utl_smtp.helo(mail_conn, 'localhost');
  utl_smtp.mail(mail_conn, 'sender@localhost');
  utl_smtp.rcpt(mail_conn, 'recipient@localhost');
  utl_smtp.data(mail_conn, msg_body);
  utl_smtp.quit(mail_conn);
  dbms_resumable.abort(cur_sid);
  ELSE
  dbms_resumable.set_timeout(3600*8);
  END IF;
  COMMIT;
  END;
```

3

Using SQL Datatypes in Application Development

This chapter discusses how to use SQL datatypes in database applications. Topics include the following:

- Representing Data with SQL Datatypes: Overview
- Representing Character Data
- Representing Numeric Data
- Representing Datetime Data
- Representing Specialized Data
- Representing Conditional Expressions as Data
- Identifying Rows by Address
- How Oracle Database Converts Datatypes

See Also:

- *Oracle Database Application Developer's Guide - Object-Relational Features* for information about more complex types, such as object types, varrays, and nested tables
- *Oracle Database Application Developer's Guide - Large Objects* for information about LOB datatypes
- *Oracle Database PL/SQL User's Guide and Reference* to learn about the PL/SQL datatypes. Many SQL datatypes are the same or similar in PL/SQL.

Representing Data with SQL Datatypes: Overview

A datatype associates a fixed set of properties with the values that can be used in a column of a table or in an argument of a procedure or function. These properties cause Oracle Database to treat values of one datatype differently from values of another datatype. For example, Oracle Database can add values of `NUMBER` datatype, but not values of `RAW` datatype.

Oracle Database provides a number of built-in datatypes as well as several categories for user-defined types that can be used as datatypes. The datatypes supported by Oracle Database can be divided into the following categories:

- Oracle built-in datatypes, which include datatypes for characters, numbers, dates and times (known as **datetime datatypes**), raw data, large objects (LOBs), and row addresses (ROWIDs).
- ANSI datatypes and datatypes from the IBM products SQL/DS and DB2, which are usable in SQL statements that create tables and clusters
- User-defined types, which use Oracle built-in datatypes and other user-defined datatypes as the building blocks of object types that model the structure and behavior of data in applications
- Oracle-supplied types, which are SQL-based interfaces for defining new types

The Oracle precompilers recognize other datatypes in embedded SQL programs. These datatypes are called **external datatypes** and are associated with host variables. You should not confuse Oracle Database built-in datatypes and user-defined types with external datatypes.

See Also:

- *Oracle Database SQL Reference* for complete reference information on the SQL datatypes
- *Pro*COBOL Programmer's Guide* and *Pro*C/C++ Programmer's Guide* for information on external datatypes, including how Oracle converts between them and built-in or user-defined types
- *Oracle Database Concepts* to learn about Oracle built-in datatypes

Representing Character Data

This section contains the following topics:

Representing Character Data: Overview

You can use the following SQL datatypes to store alphanumeric data:

- `CHAR` and `NCHAR` datatypes store fixed-length character literals.
- `VARCHAR2` and `NVARCHAR2` datatypes store variable-length character literals.
- `NCHAR` and `NVARCHAR2` datatypes store Unicode character data only.
- `CLOB` and `NCLOB` datatypes store single-byte and multibyte character strings of up to (4 gigabytes - 1) * (the value obtained from `DBMS_LOB.GETCHUNKSIZE`).
- The `LONG` datatype stores variable-length character strings containing up to two gigabytes, but with many restrictions. This datatype is provided only for backward compatibility with existing applications. In general, new applications should use `CLOB` and `NCLOB` datatypes to store large amounts of character data, and `BLOB` and `BFILE` to store large amounts of binary data.

See Also:

- *Oracle Database Application Developer's Guide - Large Objects* for information on LOB datatypes (including CLOB and NCLOB datatypes) and migration from LONG to LOB datatypes
- *Oracle Database SQL Reference* for restrictions on LONG datatypes

Specifying Column Lengths as Bytes or Characters

You can specify the lengths of CHAR and VARCHAR2 columns as either bytes or characters. The lengths of NCHAR and NVARCHAR2 columns are always specified in characters, making them ideal for storing Unicode data, where a character might consist of multiple bytes.

Consider the following list of column length specifications:

- `id VARCHAR2(32 BYTE)`

  The id column contains only single-byte data, up to 32 bytes.

- `name VARCHAR2(32 CHAR)`

  The name column contains data in the database character set. If the database character set allows multibyte characters, then the 32 characters can be stored as more than 32 bytes.

- `biography NVARCHAR2(2000)`

  The biography column can represent 2000 characters in any Unicode-representable language. The encoding depends on the national character set, but the column can contain multibyte values even if the database character set is single-byte.

- `comment VARCHAR2(2000)`

  The representation of comment as 2000 bytes or characters depends on the initialization parameter NLS_LENGTH_SEMANTICS.

When using a multibyte database character encoding scheme, consider carefully the space required for tables with character columns. If the database character encoding scheme is single-byte, then the number of bytes and the number of characters in a column is the same. If it is multibyte, however, then there generally is no such correspondence. A character might consist of one or more bytes, depending upon the specific multibyte encoding scheme and whether shift-in/shift-out control codes are present. To avoid overflowing buffers, specify data as NCHAR or NVARCHAR2 if it might use a Unicode encoding that is different from the database character set.

See Also:

- *Oracle Database Globalization Support Guide*
- *Oracle Database SQL Reference*

Choosing Between the CHAR and VARCHAR2 Datatypes

When deciding which datatype to use for a column that will store alphanumeric data in a table, consider the following points of distinction:

- Space usage

  To store data more efficiently, use the VARCHAR2 datatype. The CHAR datatype blank-pads and stores trailing blanks up to a fixed column length for all column values, whereas the VARCHAR2 datatype does not add extra blanks.

- Comparison semantics

  Use the CHAR datatype when you require ANSI compatibility in comparison semantics (when trailing blanks are not important in string comparisons). Use the VARCHAR2 when trailing blanks are important in string comparisons.

- Future compatibility

  The CHAR and VARCHAR2 datatypes are fully supported. At this time, the VARCHAR datatype automatically corresponds to the VARCHAR2 datatype and is reserved for future use.

When an application interfaces with Oracle Database, there is a character set on the client and server side. Oracle Database uses the NLS_LANGUAGE parameter to automatically convert CHAR, VARCHAR2, and LONG data from the database character set to the character set defined for the user session, if these are different.

In the section "Datatype Comparison Rules," *Oracle Database SQL Reference* explains the comparison semantics that Oracle Database uses to compare character data. Because Oracle Database blank-pads values stored in CHAR columns but not in VARCHAR2 columns, a value stored in a VARCHAR2 column can take up less space than the same value in a CHAR column. For this reason, a full table scan on a large table containing VARCHAR2 columns may read fewer data blocks than a full table scan on a table containing the same data stored in CHAR columns. If your application often performs full table scans on large tables containing character data, then you may be able to improve performance by storing data in VARCHAR2 rather than in CHAR columns.

Performance is not the only factor to consider when deciding which datatype to use. Oracle Database uses different semantics to compare values of each datatype. You might choose one datatype over the other if your application is sensitive to the differences between these semantics. For example, if you want Oracle Database to ignore trailing blanks when comparing character values, then you must store these values in CHAR columns.

> **See Also:** *Oracle Database SQL Reference* for more information on comparison semantics for these datatypes

Using Character Literals in SQL Statements

Many SQL statements, functions, expressions, and conditions require you to specify character literal values. You can specify character literals with the following notations:

- Character literals with the '*text*' notation, as in the literals 'users01.dbf' and 'Muthu''s computer'.
- National character literals with the N'*text*' or n'*text*' notation, where N or n specifies the literal using the national character set. For example, N'résumé' is a National character literal.

  Oracle Database translates N-quoted text into the national character set by way of the database character set. If client-side characters do not have corresponding encoding in the database character set, then Oracle Database converts them into question marks. To avoid the potential loss of data during the text literal conversion, set the environment variable $ORA_NCHAR_LITERAL_REPLACE to TRUE. This setting transparently replaces the N'*text*' internally and preserves the text literal for SQL processing.

The UNISTR function provides support for Unicode character literals by enabling you to specify the Unicode encoding value of characters in the string, as in UNISTR('\1234'). This technique is useful, for example, when inserting data into

NCHAR columns. Because every character has a corresponding Unicode encoding, the client application can safely send character data to the server without data loss.

Quoting Character Literals

By default you must quote character literals in single-quotes, as in 'Hello'. This technique can sometimes be inconvenient if the text itself contains single quotes. In such cases, you can also use the Q-quote mechanism, which enables you to specify q or Q followed by a single quote and then another character to be used as the quote delimiter. For example, the literal q'#it's the "final" deadline#' uses the pound sign (#) as a quote delimiter for the string it's the "final" deadline.

The Q-quote delimiter can be any single- or multibyte character except space, tab, and return. If the opening quote delimiter is a [, {, <, or (character, then the closing quote delimiter must be the corresponding], }, >, or) character. In all other cases, the opening and closing delimiter must be the identical character.

The following character literals use the alternative quoting mechanism:

```
q'(name LIKE '%DBMS_%%')'
q'<'Data,' he said, 'Make it so.'>'
q'"name like '['"'
nq'iŸ1234ï'
```

See Also:

- *Oracle Database Globalization Support Guide* to learn about national character sets
- *Oracle Database SQL Reference* to learn about character literals

Representing Numeric Data

This section contains the following topics:

What Are the Numeric Datatypes?

The following SQL datatypes store numeric data:

- NUMBER
- BINARY_FLOAT
- BINARY_DOUBLE

Use the NUMBER datatype to store real numbers in a fixed-point or floating-point format. Numbers using this datatype are guaranteed to be portable among different Oracle Database platforms, and offer up to 38 decimal digits of precision. You can store positive and negative numbers of magnitude 1 x 10^{-130} through 9.99 x10^{125}, as well as zero, in a NUMBER column.

The BINARY_FLOAT and BINARY_DOUBLE datatypes store **floating-point data** in the 32-bit IEEE 754 format and the double precision 64-bit IEEE 754 format respectively. Compared to the Oracle NUMBER datatype, arithmetic operations on floating-point data are usually faster for BINARY_FLOAT and BINARY_DOUBLE. Also, high-precision values require less space when stored as BINARY_FLOAT and BINARY_DOUBLE.

In client interfaces supported by Oracle Database, the native instruction set supplied by the hardware vendor performs arithmetic operations on BINARY_FLOAT and BINARY_DOUBLE datatypes. The term **native floating-point datatypes** refers to datatypes including BINARY_FLOAT and BINARY_DOUBLE and to all implementations of these types in supported client interfaces.

The floating-point number system is a common way of representing and manipulating numeric values in computer systems. A floating-point number is characterized by the following components:

- Binary-valued sign
- Signed exponent
- Significand
- Base

A floating-point value is the signed product of its significand and the base raised to the power of its exponent, as shown in the formula in Example 3–1.

Example 3–1 Components of a Floating-Point Number

$$(-1)^{sign} \cdot significand \cdot base^{exponent}$$

For example, the number 4.31 can be represented in the following expression:

$$(-1)^{0} \cdot 431 \cdot 10^{-2}$$

The components of the preceding expression are as follows:

- 0 is the binary-valued sign
- 431 is the significant
- 10 is the base
- -2 is the exponent

See Also:

- *Oracle Database Concepts* for information about the internal format for the NUMBER datatype

  Oracle Database SQL Reference for more information about the BINARY_FLOAT and BINARY_DOUBLE datatypes formats

Using Floating-Point Number Formats

A floating-point number format specifies how components of a floating-point number are represented. The choice of representation determines the range and precision of the values the format can represent. By definition, the range is the interval bounded by the smallest and the largest values the format can represent and the precision is the number of digits in the significand.

Formats for floating-point values support neither infinite precision nor infinite range. There are a finite number of bits to represent a number and only a finite number of

values that a format can represent. A floating-point number that uses more precision than available with a given format is rounded.

A floating-point number can be represented in a binary system (one that uses base 2), as in the IEEE 754 standard, or in a decimal system (one that uses base 10), such as Oracle NUMBER. The base affects many properties of the format, including how a numeric value is rounded.

For a decimal floating-point number format like Oracle NUMBER, rounding is done to the nearest decimal place (for example. 1000, 10, or 0.01). The IEEE 754 formats use a binary format for floating-point values and round numbers to the nearest binary place (for example: 1024, 512, or 1/64).

The native floating-point datatypes supported by the database round to the nearest binary place, so they are not satisfactory for applications that require decimal rounding. Use the Oracle NUMBER datatype for applications in which decimal rounding is required on floating-point data.

Using a Floating-Point Binary Format

The value of a floating-point number that uses a binary format is determined by the formula in Example 3–2.

Example 3–2 Components of a Floating-Point Number in Binary Format

$(-1)^s \ 2^E \ (b_0 \ b_1 \ b_2 \ \ldots \ b_{p-1})$

Table 3–1 describes the components of the formula.

Table 3–1 Components of the Binary Format for Floating-Point Numbers

Component	Specifies . . .
s	0 or 1
E	Any integer between E_{min} and E_{max}, inclusive (see Table 3–2)
b_i	0 or 1, where the sequence of bits represents a number in base 2 (see Table 3–2)

The leading bit of the significand, b_0, must be set (1), except for subnormal numbers (explained later). Consequently, the leading bit is not actually stored, so the formats provide N bits of precision although only N-1 bits are stored.

> **Note:** The IEEE 754 specification also defines extended single-precision and extended double-precision formats, which are not supported by Oracle Database.

The parameters for these formats are described in Table 3–2.

Table 3–2 Summary of Binary Format Parameters

Parameter	Single-precision (32-bit)	Double-precision (64-bit)
p	24	53
E_{min}	-126	-1022
E_{max}	+127	+1023

The storage parameters for the formats are described in Table 3–3. The in-memory formats for single-precision and double-precision datatypes are specified by IEEE 754.

Table 3–3 Summary of Binary Format Storage Parameters

Datatype	Sign bits	Exponent bits	Significand bits	Total bits
Single-precision	1	8	24 (23 stored)	32
Double-precision	1	11	53 (52 stored)	64

A significand is **normalized** when the leading bit of the significand is set. IEEE 754 defines **denormal** or **subnormal** values as numbers that are too small to be represented with an implied leading set bit in the significand. The number is too small because its exponent would be too large if its significand were normalized to have an implied leading bit set. IEEE 754 formats support subnormal values. Subnormal values preserve the following property:

if: x - y == 0.0 (using floating-point subtraction)

then: x == y

Table 3–4 shows the range and precision of the required formats in the IEEE 754 standard and those of Oracle `NUMBER`. Range limits are expressed here in terms of positive numbers; they also apply to the absolute value of a negative number. (The notation "*number* e *exponent*" used here stands for *number* multiplied by 10 raised to the *exponent* power: $number \cdot 10^{exponent}$.)

Table 3–4 Range and Precision of IEEE 754 formats

Range and Precision	Single-precision 32-bit[1]	Double-precision 64-bit[1]	Oracle NUMBER Datatype
Max positive normal number	3.40282347e+38	1.7976931348623157e+308	< 1.0e126
Min positive normal number	1.17549435e-38	2.2250738585072014e-308	1.0e-130
Max positive subnormal number	1.17549421e-38	2.2250738585072009e-308	not applicable
Min positive subnormal number	1.40129846e-45	4.9406564584124654e-324	not applicable
Precision (decimal digits)	6 - 9	15 - 17	38 - 40

[1] These numbers are quoted from the *IEEE Numerical Computation Guide*.

See Also:

- *Oracle Database SQL Reference*, section "Numeric Literals", for information about literal representation of numeric values
- *Oracle Database SQL Reference* for more information about floating-point formats

Representing Special Values with Native Floating-Point Formats

IEEE 754 allows special values to be represented. These special values are as follows:

- Positive infinity (`+INF`)
- Negative infinity (`-INF`)

- Not-a-number (NaN)
- Positive zero (+0)
- Negative zero (-0)

NaN represent results of operations that are undefined. Many bit patterns in IEEE 754 represent NaN. Bit patterns can represent NaN with and without the sign bit set. IEEE 754 distinguishes between signalling NaNs and quiet NaNs.

IEEE 754 specifies behavior for when exceptions are enabled and disabled. Oracle Database does not allow exceptions to be enabled; the database behavior is that specified by IEEE 754 for when exceptions are disabled. In particular, Oracle Database makes no distinction between signalling and quiet NaNs. Programmers who use OCI can retrieve NaN values from Oracle Database; whether a retrieved NaN value is signalling or quiet depends on the client platform and beyond the control of Oracle Database.

IEEE 754 does not define the bit pattern for either type of NaN. Positive infinity, negative infinity, positive zero, and negative zero are each represented by a specific bit pattern.

Ignoring signs, there are the following classes of values, with each of the classes except for NaN greater than the one preceding it in the list:

- Zero
- Subnormal
- Normal
- Infinity
- NaN

In IEEE 754, NaN is unordered with other classes of special values and with itself.

Behavior of Special Values for Native Floating-Point Datatypes When used with the database, special values of native floating-point datatypes behave as follows:

- All NaNs are quiet.
- IEEE 754 exceptions are not raised.
- NaN is ordered as follows:

  All non-NaN < NaN

  Any NaN == any other NaN
- -0 is converted to +0.
- All NaNs are converted to the same bit pattern.

> **See Also:** "Using Comparison Operators for Native Floating-Point Datatypes" on page 3-9 for more information on NaN compared to other values

Using Comparison Operators for Native Floating-Point Datatypes

Oracle Database defines the following comparison operators for operations involving floating-point datatypes:

- Equal to
- Not equal to

- Greater than
- Greater than or equal to
- Less than
- Less than or equal to
- Unordered

Note the following special cases:

- Comparisons ignore the sign of zero (`-0` is equal to, not less than, `+0`).
- In Oracle Database, `NaN` is equal to itself. `NaN` is greater than everything except itself. That is, `NaN == NaN` and `NaN > x`, unless *x* is `NaN`.

> **See Also:** "Behavior of Special Values for Native Floating-Point Datatypes" on page 3-9 for more information on comparison results, ordering, and other behaviors of special values

Performing Arithmetic Operations with Native Floating-Point Datatypes

Oracle Database defines operators for the following arithmetic operations:

- Multiplication
- Division
- Addition
- Subtraction
- Remainder
- Square root

You can define the mode used to round the result of the operation. Exceptions can be raised when operations are performed. Exceptions can also be disabled.

Formerly, Java required floating-point arithmetic to be exactly reproducible. IEEE 754 does not require such behavior. The standard allows for the result of operations, including arithmetic, to be delivered to a destination that uses a range greater than that used by the operands to the operation.

You can compute the result of a double-precision multiplication at an extended double-precision destination. When this is done, the result must be rounded as if the destination were single-precision or double-precision. The range of the result, that is, the number of bits used for the exponent, can use the range supported by the wider (extended double-precision) destination. This occurrence may result in a double-rounding error in which the least significant bit of the result is incorrect.

This state of affairs can only occur for double-precision multiplication and division on hardware that implements the IA-32 and IA-64 instruction set architecture. Thus, with the exception of this case, arithmetic for these datatypes is reproducible across platforms. When the result of a computation is `NaN`, all platforms produce a value for which `IS NAN` is true. However, all platforms do not have to use the same bit pattern.

Using Conversion Functions with Native Floating-Point Datatypes

Oracle Database defines functions that convert between floating-point and other formats, including string formats that use decimal precision (precision may be lost during the conversion). For example, you can use the following functions:

- TO_BINARY_DOUBLE, which converts float to double, decimal (string) to double, and float or double to integer-valued double
- TO_BINARY_FLOAT, which converts double to float, decimal (string) to float, and float or double to integer-valued float
- TO_CHAR, which converts float or double to decimal (string)
- TO_NUMBER, which converts a float, double, or string to a number

Oracle Database can raise exceptions during conversion. The IEEE 754 specification defines the following exceptions:

- Invalid
- Inexact
- Divide by zero
- Underflow
- Overflow

Oracle Database does not raise these exceptions for native floating-point datatypes. Generally, situations that would raise an exception produce the values described in Table 3–5.

Table 3–5 Values Resulting from Exceptions

Exception	Value
Underflow	0
Overflow	-INF, +INF
Invalid Operation	NaN
Divide by Zero	-INF, +INF, NaN
Inexact	Any value – rounding was performed

Client Interfaces for Native Floating-Point Datatypes

Oracle Database has implemented support for native floating-point datatypes in the following client interfaces:

- SQL
- PL/SQL
- OCI and OCCI
- Pro*C/C++
- JDBC

OCI Native Floating-Point Datatypes SQLT_BFLOAT and SQLT_BDOUBLE

The OCI API implements the IEEE 754 single precision and double precision native floating-point datatypes with the datatypes SQLT_BFLOAT and SQLT_BDOUBLE respectively. Conversions between these types and the SQL types BINARY_FLOAT and BINARY_DOUBLE are exact on platforms that implement the IEEE 754 standard for the C datatypes FLOAT and DOUBLE.

See Also: *Oracle Call Interface Programmer's Guide*

Native Floating-Point Datatypes Supported in Oracle OBJECT Types

Oracle Database supports the SQL datatypes `BINARY_FLOAT` and `BINARY_DOUBLE` as attributes of Oracle `OBJECT` types.

Pro*C/C++ Support for Native Floating-Point Datatypes

Pro*C/C++ supports the native `FLOAT` and `DOUBLE` datatypes using the column datatypes `BINARY_FLOAT` and `BINARY_DOUBLE`. You can use these datatypes in the same way that Oracle `NUMBER` datatype is used. You can bind the native C/C++ datatypes `FLOAT` and `DOUBLE` to `BINARY_FLOAT` and `BINARY_DOUBLE` types respectively by setting the Pro*C/C++ precompiler command line option `NATIVE_TYPES` to `Y` (yes) when you compile your application.

Representing Datetime Data

This section contains the following topics:

Representing Datetime Data: Overview

Oracle Database supports the following datetime datatypes:

- `DATE`
- `TIMESTAMP`
- `TIMESTAMP WITH TIME ZONE`
- `TIMESTAMP WITH LOCAL TIME ZONE`

Using the DATE Datatype

Use the `DATE` datatype to store point-in-time values (dates and times) in a table. The `DATE` datatype stores the century, year, month, day, hours, minutes, and seconds.

Using the TIMESTAMP Datatype

Use the `TIMESTAMP` datatype to store values that are precise to fractional seconds. For example, an application that must decide which of two events occurred first might use `TIMESTAMP`. An application that specifies the time for a job might use `DATE`.

Using the TIMESTAMP WITH TIME ZONE Datatype

Because `TIMESTAMP WITH TIME ZONE` can also store time zone information, it is particularly suited for recording date information that must be gathered or coordinated across geographic regions.

Using the TIMESTAMP WITH LOCAL TIME ZONE Datatype

Use TIMESTAMP WITH LOCAL TIME ZONE when the time zone is not significant. For example, you might use it in an application that schedules teleconferences, where participants each see the start and end times for their own time zone.

The TIMESTAMP WITH LOCAL TIME ZONE type is appropriate for two-tier applications in which you want to display dates and times that use the time zone of the client system. It is generally inappropriate in three-tier applications because data displayed in a Web browser is formatted according to the time zone of the Web server, not the time zone of the browser. The Web server is the database client, so its local time is used.

Representing the Difference Between Datetime Values

Use the INTERVAL DAY TO SECOND datatype to represent the precise difference between two datetime values. For example, you might use this value to set a reminder for a time 36 hours in the future or to record the time between the start and end of a race. To represent long spans of time with high precision, you can use a large value for the days portion.

Use the INTERVAL YEAR TO MONTH datatype to represent the difference between two datetime values, where the only significant portions are the year and the month. For example, you might use this value to set a reminder for a date 18 months in the future, or check whether 6 months have elapsed since a particular date.

Oracle Database stores dates in its own internal format. Date data is stored in fixed-length fields of seven bytes each, corresponding to century, year, month, day, hour, minute, and second.

> **See Also:** *Oracle Call Interface Programmer's Guide* for a complete description of the Oracle Database internal date format

Manipulating the Date Format

For input and output of dates, the standard Oracle Database default date format is DD-MON-RR. The RR datetime format element enables you store 20th century dates in the 21st century by specifying only the last two digits of the year.

As explained in *Oracle Database SQL Reference*, the century of the return value varies according to the specified two-digit year and the last two digits of the current year. For example, the following format refers to the year 2004 in a query issued between 1950 and 2049, but to the year 2005 in a query issued between 2050 and 2099:

```
'13-NOV-04'
```

Changing the Default Date Format

Use the following techniques to change the default date format:

- To change on an instance-wide basis, use the NLS_DATE_FORMAT parameter.
- To change during a session, use the ALTER SESSION statement.

To enter dates that are not in the current default date format, use the TO_DATE function with a format mask. For example:

```
SELECT TO_CHAR(TO_DATE('27-OCT-98', 'DD-MON-RR') ,'YYYY') "Year"
FROM DUAL;
```

Be careful when using a date format such as DD-MON-YY. The YY indicates the year in the current century. For example, 31-DEC-92 is December 31, 2092, not 1992 as

you might expect. If you want to indicate years in any century other than the current one, use a different format mask, such as the default RR.

> **See Also:** *Oracle Database Concepts* for information about Julian dates. Oracle Database Julian dates might not be compatible with Julian dates generated by other date algorithms.

Displaying the Current Date and Time

Use the SQL function SYSDATE to return the system date and time. You can use the FIXED_DATE initialization parameter to set SYSDATE to a constant, which can be useful for testing.

By default, SYSDATE is printed without any BC or AD qualifier. You can add BC to the format string to print the date with BC or AD as appropriate:

```
SELECT TO_CHAR(SYSDATE, 'DD-MON-YYYY BC')
FROM DUAL;

TO_CHAR(SYSDAT
--------------
24-JAN-2004 AD
```

Manipulating the Time Format

Time is stored in the following 24-hour format:

```
HH24:MI:SS
```

By default, the time in a DATE column is 12:00:00 A.M. (midnight) if no time portion is entered or if the DATE is truncated.

In a time-only entry, the date portion defaults to the first day of the current month. To enter the time portion of a date, use the TO_DATE function with a format mask indicating the time portion, as shown in Example 3–3.

Example 3–3 Indicating Time with the TO_DATE Function

```
-- create test table
CREATE TABLE birthdays
( Bname VARCHAR2(20),
  Bday  DATE
);

-- insert a row
INSERT INTO birthdays (bname, bday)
VALUES
( 'ANNIE',
  TO_DATE('13-NOV-92 10:56 A.M.','DD-MON-YY HH:MI A.M.')
);
```

Performing Date Arithmetic

Oracle Database provides a number of features to help with date arithmetic, so that you do not need to perform your own calculations on the number of seconds in a day, the number of days in each month, and so on. Some useful features include the following:

- ADD_MONTHS function, which returns the date plus the specified number of months.

- SYSDATE function, which returns the current date and time set for the operating system on which the database resides.
- SYSTIMESTAMP function, which returns the system date, including fractional seconds and time zone, of the system on which the database resides.
- TRUNC function, which when applied to a DATE value, trims off the time portion so that it represents the very beginning of the day (the stroke of midnight). By truncating two DATE values and comparing them, you can determine whether they refer to the same day. You can also use TRUNC along with a GROUP BY clause to produce daily totals.
- Arithmetic operators such as + and -. For example, SYSDATE-7 refers to 7 days before the current system date.
- INTERVAL datatypes, which enable you to represent constants when performing date arithmetic rather than performing your own calculations. For example, you can add or subtract INTERVAL constants from DATE values or subtract two DATE values and compare the result to an INTERVAL.
- Comparison operators such as >, <, =, and BETWEEN.

Converting Between Datetime Types

Oracle Database provides several useful functions that enable you to convert to a from datetime datatypes. Some useful functions include:

- EXTRACT, which extracts and returns the value of a specified datetime field from a datetime or interval value expression
- NUMTODSINTERVAL, which converts a NUMBER or expression that can be implicitly converted to a NUMBER value to an INTERVAL DAY TO SECOND literal
- NUMTOYMINTERVAL, which converts a NUMBER or expression that can be implicitly converted to a NUMBER value to an INTERVAL YEAR TO MONTH literal
- TO_DATE, which converts character data to a DATE datatype
- TO_CHAR, which converts DATE data to character data
- TO_DSINTERVAL, which converts a character string to an INTERVAL DAY TO SECOND value
- TO_TIMESTAMP, which converts character data to a value of TIMESTAMP datatype
- TO_TIMESTAMP_TZ, which converts character data to a value of TIMESTAMP WITH TIME ZONE datatype
- TO_YMINTERVAL, which converts a character string to an INTERVAL YEAR TO MONTH type

> **See Also:** *Oracle Database SQL Reference* for details about each function

Importing and Exporting Datetime Types

TIMESTAMP WITH TIME ZONE and TIMESTAMP WITH LOCAL TIME ZONE values are always stored in normalized format, so that you can export, import, and compare them without worrying about time zone offsets. DATE and TIMESTAMP values do not store an associated time zone, and you must adjust them to account for any time zone differences between source and target databases.

Representing Specialized Data

This section contains the following topics:

Representing Geographic Data

To represent Geographic Information System (GIS) or spatial data in the database, you can use Oracle Spatial features, including the type `MDSYS.SDO_GEOMETRY`. You can store the data in the database by using either an object-relational or a relational model. You can use a set of PL/SQL packages to query and manipulate the data.

> **See Also:** *Oracle Spatial User's Guide and Reference* to learn how to use `MDSYS.SDO_GEOMETRY`

Representing Multimedia Data

Oracle *inter*Media enables Oracle Database to store, manage, and retrieve images, audio, video, or other heterogeneous media data in an integrated fashion with other enterprise information. Oracle interMedia extends Oracle Database reliability, availability, and data management to multimedia content in traditional, Internet, electronic commerce, and media-rich applications.

Whether you store such multimedia data inside the database as `BLOB` or `BFILE` values, or store it externally on a Web server or other kind of server, you can use interMedia to access the data using either an object-relational or a relational model, and manipulate and query the data using a set of object types.

Oracle *inter*Media provides the `ORDAudio`, `ORDDoc`, `ORDImage`, `ORDImageSignature`, `ORDVideo`, and `SI_StillImage` object types and methods for the following purposes:

- Extracting metadata and attributes from multimedia data
- Retrieving and managing multimedia data from Oracle interMedia, Web servers, file systems, and other servers
- Performing manipulation operations on image data

> **See Also:** *Oracle interMedia Reference*to learn about the *inter*Media types

Representing Large Amounts of Data

Oracle Database provides several datatypes for representing large amounts of data. These datatypes are grouped under the general category of Large Objects (LOBs). Table 3–6 describes the different LOBs.

Table 3–6 Large Object Datatypes

Datatype	Name	Description
BLOB	Binary large object	Represents large amounts of binary data such as images, video, or other multimedia data.
CLOB	Character large object	Represents large amounts of character data. CLOB types are stored by using the database character set. Note that the database stores a CLOB up to 4,000 bytes inline as a VARCHAR2. If the CLOB exceeds this length, then the database moves the CLOB out of line.
NCLOB	National character set large objects	Represents large amounts of character data in National Character Set format.
BFILE	External large object	Stores objects in the operating system's file system, outside of the database files or tablespace. Note that the BFILE type is read-only; other LOB types are read/write. BFILE objects are also sometimes referred to as **external LOBs**.

An instance of type BLOB, CLOB, or NCLOB can exist as either a persistent LOB instance or a temporary LOB instance. Persistent and temporary instances differ as follows:

- A **temporary LOB** instance is declared in the scope of your application.
- A **persistent LOB** instance is created and stored in the database.

With the exception of declaring, freeing, creating, and committing, operations on persistent and temporary LOB instances are performed the same way.

> **See Also:** *Oracle Database Application Developer's Guide - Large Objects* for more details on using LOBs in applications

Using RAW and LONG RAW Datatypes

The RAW and LONG RAW datatypes store data that is not interpreted by Oracle Database, that is, it is not converted when moving data between different systems. These datatypes are intended for binary data and byte strings. For example, LONG RAW can store graphics, sound, documents, and arrays of binary data; the interpretation is dependent on the use.

Oracle Net and the Export and Import utilities do not perform character conversion when transmitting RAW or LONG RAW data. When Oracle Database automatically converts RAW or LONG RAW data to and from CHAR data, as is the case when entering RAW data as a literal in an INSERT statement, the database represents the data as one hexadecimal character representing the bit pattern for every four bits of RAW data. For example, one byte of RAW data with bits 11001011 is displayed and entered as CB.

You cannot index LONG RAW data, but you can index RAW data. In earlier releases, the LONG and LONG RAW datatypes were typically used to store large amounts of data. Use of these types is no longer recommended for new development. If your application still uses these types, migrate your application to use LOB types. Oracle recommends that you convert LONG RAW columns to binary LOB (BLOB) columns and convert LONG columns to character LOB (CLOB or NCLOB) columns. LOB columns are subject to far fewer restrictions than LONG and LONG RAW columns.

See Also:

- See *Oracle Database Application Developer's Guide - Large Objects* for information about the `BLOB` and `BFILE` datatypes
- See the *Oracle Database SQL Reference* for restrictions on `LONG` and `LONG RAW` datatypes

Representing Searchable Text

Rather than writing low-level code to do full-text searches, you can use Oracle Text. It stores the search data in a special kind of index, and lets you query the data with operators and PL/SQL packages. This technology enables you to create your own search engine using data from tables, files, or URLs, and combine the search logic with relational queries. You can also search XML data this way with the XPath notation.

See Also: *Oracle Text Application Developer's Guide* for more information

Representing XML

If you have information stored as files in XML format, or if you want to take an object type and store it as XML, then you can use the `XMLType` built-in type.

`XMLType` columns store their data as `CLOB`s. You can take an existing `CLOB`, `VARCHAR2`, or any object type, and call the `XMLType` constructor to turn it into an XML object.

When an XML object is inside the database, you can use queries to traverse it (using the XML XPath notation) and extract all or part of its data.

You can also produce XML output from existing relational data and split XML documents across relational tables and columns. You can use the following packages to transfer XML data into and out of relational tables:

- `DBMS_XMLQUERY`, which provides database-to-`XMLType` functionality
- `DBMS_XMLGEN`, which converts the results of a SQL query to a canonical XML format
- `DBMS_XMLSAVE`, which provides XML to database-type functionality

You can use the following SQL functions to process XML:

- `EXTRACT`, which applies a `VARCHAR2` XPath string and returns an `XMLType` instance containing an XML fragment
- `SYS_XMLAGG`, which aggregates all of the XML documents or fragments represented by an expression and produces a single XML document
- `SYS_XMLGEN`, which takes an expression that evaluates to a particular row and column of the database, and returns an instance of type `XMLType` containing an XML document
- `UPDATEXML`, which takes as arguments an `XMLType` instance and an XPath-value pair and returns an `XMLType` instance with the updated value
- `XMLAGG`, which takes a collection of XML fragments and returns an aggregated XML document
- `XMLCOLATTVAL`, which creates an XML fragment and then expands the resulting XML so that each XML fragment has the name column with the attribute name

- XMLCONCAT, which takes as input a series of XMLType instances, concatenates the series of elements for each row, and returns the concatenated series
- XMLELEMENT, which takes an element name for identifier, an optional collection of attributes for the element, and arguments that make up the content of the element
- XMLFOREST, which converts each of its argument parameters to XML, and then returns an XML fragment that is the concatenation of these converted arguments
- XMLSEQUENCE, which either takes as input an XMLType instance and returns a varray of the top-level nodes in the XMLType, or takes as input a REFCURSOR instance, with an optional instance of the XMLFormat object, and returns as an XMLSequence type an XML document for each row of the cursor

  XMLTRANSFORM, which takes as arguments an XMLType instance and an XSL style sheet, applies the style sheet to the instance, and returns an XMLType

See Also:

- *Oracle XML DB Developer's Guide* for details about the XMLType datatype
- *Oracle XML Developer's Kit Programmer's Guide* for information about client-side programming with XML
- *Oracle Database SQL Reference* for information about XML functions

Representing Dynamically Typed Data

Some languages allow datatypes to change at runtime or let a program check the type of a variable. For example, C has the union keyword and the void * pointer, while Java has the typeof operator and wrapper types such as Number. Oracle Database includes features that enable you to create variables and columns that can hold data of any type and test such data values to determine their underlying representation. Using these features, a single table column can represent a numeric value in one row, a string value in another row, and an object in another row.

You can use the built-in type SYS.ANYDATA to represent values of any scalar or object type. This type is an object type with methods to bring in a scalar value of any type, and turn the value back into a scalar or object. In the same way, you can use the built-in type SYS.ANYDATASET to represent values of any collection type.

To manipulate and check type information, you can use SYS.ANYTYPE in combination with the DBMS_TYPES package. The program in Example 3–4 represents data of different underlying types in a table, then interprets the underlying type of each row and processes each value appropriately.

Example 3–4 Accessing Information in a SYS.ANYDATA Column

```
-- This example defines and executes a PL/SQL procedure that
-- uses methods built into SYS.ANYDATA to access information about
-- data stored in a SYS.ANYDATA table column.
DROP TYPE Employee_type FORCE;
DROP TABLE mytab;
CREATE OR REPLACE TYPE Employee_type AS OBJECT ( empno NUMBER,
  ename VARCHAR2(10) );
/
CREATE TABLE mytab ( id NUMBER, data SYS.ANYDATA );
INSERT INTO mytab VALUES (1, SYS.ANYDATA.ConvertNumber(5));
INSERT INTO mytab VALUES (2,
```

```
                        SYS.ANYDATA.ConvertObject(Employee_type(5555, 'john')));
COMMIT;
CREATE OR REPLACE PROCEDURE p
IS
  CURSOR cur IS SELECT id, data FROM mytab;
  v_id           mytab.id%TYPE;
  v_data         mytab.data%TYPE;
  v_type         SYS.ANYTYPE;
  v_typecode     PLS_INTEGER;
  v_typename     VARCHAR2(60);
  v_dummy        PLS_INTEGER;
  v_n            NUMBER;
  v_employee     Employee_type;
  non_null_anytype_for_NUMBER exception;
  unknown_typename            exception;
BEGIN
  OPEN cur;
  LOOP
    FETCH cur INTO v_id, v_data;
    EXIT WHEN cur%NOTFOUND;

/* The typecode is a number that signifies what type is represented by v_data.
   GetType also produces a value of type SYS.AnyType with methods you can call
   to find precision and scale of a number, length of a string, and so on. */

    v_typecode := v_data.GetType ( v_type /* OUT */ );

/* Now we compare the typecode against constants from DBMS_TYPES to see what
   kind of data we have, and decide how to display it. */

    CASE v_typecode
      WHEN DBMS_TYPES.TYPECODE_NUMBER THEN
        IF v_type IS NOT NULL
-- This condition should never happen, but we check just in case.
          THEN RAISE non_null_anytype_for_NUMBER; END IF;
-- For each type, there is a Get method.
        v_dummy := v_data.GetNUMBER ( v_n /* OUT */ );
        DBMS_OUTPUT.PUT_LINE (
          TO_CHAR(v_id) || ': NUMBER = ' || To_Char(v_n) );
      WHEN DBMS_TYPES.TYPECODE_OBJECT THEN
        v_typename := v_data.GetTypeName();
-- An object type's name is qualified with the schema name.
        IF v_typename NOT IN ( 'HR.EMPLOYEE_TYPE' )
-- If we encounter any object type besides EMPLOYEE_TYPE, raise an exception.
          THEN RAISE unknown_typename; END IF;
        v_dummy := v_data.GetObject ( v_employee /* OUT */  );
        DBMS_OUTPUT.PUT_LINE (
          To_Char(v_id) || ': user-defined type = ' || v_typename ||
            ' ( ' || v_employee.empno || ', ' || v_employee.ename || ' )' );
    END CASE;
  END LOOP;
  CLOSE cur;
EXCEPTION
  WHEN non_null_anytype_for_NUMBER THEN
    RAISE_Application_Error ( -20000,
      'Paradox: the return AnyType instance FROM GetType ' ||
      'should be NULL for all but user-defined types' );
  WHEN unknown_typename THEN
    RAISE_Application_Error ( -20000, 'Unknown user-defined type ' ||
      v_typename || ' - program written to handle only HR.EMPLOYEE_TYPE' );
```

```
END;
/
```

The query and procedure in Example 3–4 produce output like that shown in Example 3–5.

Example 3–5 Sample Output for Example 3–4

```
SQL> SELECT t.data.gettypename() AS "Type Name" FROM mytab t;

Type Name
-------------------------------------------------------------------------------
SYS.NUMBER
HR.EMPLOYEE_TYPE

SQL> EXEC p;
1: NUMBER = 5
2: user-defined type = HR.EMPLOYEE_TYPE ( 5555, john )
```

You can access the same features through the OCI interface by using the `OCIType`, `OCIAnyData`, and `OCIAnyDataSet` interfaces.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference* for details about the `DBMS_TYPES` package
- *Oracle Database Application Developer's Guide - Object-Relational Features* for information and examples using the `ANYDATA`, `ANYDATASET`, and `ANYTYPE` types
- *Oracle Call Interface Programmer's Guide* for details about the OCI interfaces

Representing Data with ANSI/ISO, DB2, and SQL/DS Datatypes

You can define columns of tables in Oracle Database by means of ANSI/ISO, DB2, and SQL/DS datatypes. Oracle Database internally converts such datatypes to Oracle datatypes.

The ANSI datatype conversions are shown in Table 3–7. The ANSI/ISO datatypes `NUMERIC`, `DECIMAL`, and `DEC` can specify only fixed-point numbers. For these datatypes, `s` defaults to `0`.

Table 3–7 ANSI Datatype Conversions to Oracle Datatypes

ANSI SQL Datatype	Oracle Datatype
CHARACTER (*n*), CHAR (*n*)	CHAR (*n*)
NUMERIC (*p*,*s*), DECIMAL (*p*,*s*), DEC (*p*,*s*)	NUMBER (*p*,*s*)
INTEGER, INT, SMALLINT	NUMBER (38)
FLOAT (*p*)	FLOAT (*p*)
REAL	FLOAT (63)
DOUBLE PRECISION	FLOAT (126)
CHARACTER VARYING(*n*), CHAR VARYING(*n*)	VARCHAR2 (*n*)
TIMESTAMP	TIMESTAMP
TIMESTAMP WITH TIME ZONE	TIMESTAMP WITH TIME ZONE

Table 3–8 shows the DB2 and SQL/DS conversions.

Table 3–8 SQL/DS, DB2 Datatype Conversions to Oracle Datatypes

DB2 or SQL/DS Datatype	Oracle Datatype
CHARACTER (*n*)	CHAR (*n*)
VARCHAR (*n*)	VARCHAR2 (*n*)
LONG VARCHAR	LONG
DECIMAL (*p*,*s*)	NUMBER (*p*,*s*)
INTEGER, SMALLINT	NUMBER (38)
FLOAT (*p*)	FLOAT (*p*)
DATE	DATE
TIMESTAMP	TIMESTAMP

The datatypes TIME, GRAPHIC, VARGRAPHIC, and LONG VARGRAPHIC of IBM products SQL/DS and DB2 have no corresponding Oracle datatype, and they cannot be used.

Representing Conditional Expressions as Data

The Oracle Expression Filter feature enables you to store conditional expressions as data in the database. The Expression Filter provides a mechanism that you can use to place a constraint on a VARCHAR2 column to ensure that the values stored are valid SQL WHERE clause expressions. This mechanism also identifies the set of attributes that are legal to reference in the conditional expressions.

For example, suppose you create a traders table in which row holds data for a stock trading account holder. You want to define a column that stores information about stocks each trader is interested in as a conditional expression. You follow these steps:

1. Create a table traders holds data for a stock trading account holder:

```
CREATE TABLE traders
( name     VARCHAR2(50),
  email    VARCHAR2(50),
  interest VARCHAR2(50)
);
```

2. Create the user-defined datatype ticker with attributes for the trading symbol, limit price, and amount of change in the stock price:

```
CREATE OR REPLACE TYPE ticker
AS OBJECT
( symbol VARCHAR2(20),
  price  NUMBER,
  change NUMBER
);
```

3. Use the following PL/SQL block to create an attribute set ticker based on the ticker datatype:

```
BEGIN
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET( attr_set  => 'ticker',
                                    from_type => 'YES' );
END;
```

4. Associate the attribute set with the expression set stored in the database column `trader.interest` as follows:

```
BEGIN
  DBMS_EXPFIL.ASSIGN_ATTRIBUTE_SET (attr_set => 'ticker',
                                    expr_tab => 'traders',
                                    expr_col => 'interest');
END;
```

   The preceding code places a constraint on the `interest` column that ensures the column stores valid conditional expressions.

5. Populate the table with trader names, email addresses and conditional expressions that represents a stock the trader is interested in at a particular price:

```
INSERT INTO traders (name, email, interest)
  VALUES ('Vishu', 'vishu@abc.com', 'symbol = ''ABC'' AND price > 25');
```

6. Use the `EVALUATE` operator to identify the conditional expressions that evaluate to `TRUE` for a given data item. For example, the following query returns traders who are interested in a given stock quote `(symbol='ABC', price=31, change=5.2)`:

```
SELECT Name, Email
FROM Traders
WHERE EVALUATE ( interest,
                 'symbol=>''ABC'',
                 price=>31,
                 change=>5.2'
               ) = 1;
```

To speed up this type of query, you can optionally create an Oracle Expression Filter index on the `interest` column.

> **See Also:** *Oracle Database Application Developer's Guide - Rules Manager and Expression Filter* for details on Oracle Expression Filter

Identifying Rows by Address

Each row in a database table has an address called a **rowid**. You can examine a row address by querying the pseudocolumn `ROWID`, whose values are strings representing the address of each row. These strings have the datatype `ROWID` or `UROWID`. You can also create tables and clusters that contain actual columns having the `ROWID` datatype. Oracle Database does not guarantee that the values of such columns are valid rowids.

Rowid values are important for application development for the following reasons:

- They are the fastest way to access a single row.
- They can show you how the rows in a table are stored.
- They are unique identifiers for rows in a table.

> **See Also:**
>
> - *Oracle Database Concepts* for general information about the `ROWID` pseudocolumn and the `ROWID` datatype
> - *Oracle Database SQL Reference* to learn about the `ROWID` pseudocolumn

Querying the ROWID Pseudocolumn

Each table in Oracle Database has a pseudocolumn named ROWID. If the row is too large to fit within a single data block, then ROWID identifies the initial row piece. Although rowids are usually unique, different rows can have the same rowid if they are in the same data block but in different clustered tables.

The following SQL statements return the ROWID pseudocolumn of the row of the hr.employees table that satisfies the query, and inserts it into the t_tab table:

```
CREATE TABLE t_tab (col1 ROWID);
INSERT INTO t_tab
  SELECT ROWID
  FROM hr.employees
  WHERE employee_id = 7499;
```

> **Note:** Although you can use the ROWID pseudocolumn in the SELECT and WHERE clause of a query, these pseudocolumn values are not actually stored in the database. You cannot insert, update, or delete a value of the ROWID pseudocolumn.

Accessing the ROWID Datatype

In tables that are not index-organized and foreign tables, the values of the ROWID pseudocolumn have the datatype ROWID. The format of this datatype is either **extended** or **restricted**.

Restricted ROWID

Internally, the ROWID is a structure that holds information that the database server needs to access a row. The restricted internal ROWID is 6 bytes on most platforms. Each restricted rowid includes the following data:

- Datafile identifier
- Block identifier
- Row identifier

The restricted ROWID pseudocolumn is returned to client applications in the form of an 18-character string with a hexadecimal encoding of the datablock, row, and datafile components of the ROWID.

Extended ROWID

The extended ROWID datatype includes the data in the restricted rowid plus a data object number. The data object number is an identification number assigned to every database segment. The extended internal ROWID is 10 bytes on most platforms.

Data in an extended ROWID pseudocolumn is returned to the client application in the form of an 18-character string (for example, "AAAA8mAALAAAAQkAAA"), which represents a base 64 encoding of the components of the extended ROWID in a four-piece format, OOOOOOFFFBBBBBBRRR. Extended rowids are not available directly. You can use a supplied package, DBMS_ROWID, to interpret extended rowid contents. The package functions extract and provide information that would be available directly from a restricted rowid as well as information specific to extended rowids.

> **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for information about the DBMS_ROWID package

External Binary ROWID

Some client applications use a binary form of the ROWID. For example, OCI and some precompiler applications can map the ROWID datatype to a 3GL structure on bind or define calls. The size of the binary ROWID is the same for extended and restricted ROWIDs. The information for the extended ROWID is included in an unused field of the restricted ROWID structure.

The format of the extended binary ROWID, expressed as a C struct, is as follows:

```
struct riddef {
    ub4    ridobjnum; /* data obj#--this field is
                         unused in restricted ROWIDs */
    ub2    ridfilenum;
    ub1    filler;
    ub4    ridblocknum;
    ub2    ridslotnum;
}
```

Accessing the UROWID Datatype

The rows of some tables have addresses that are not physical or permanent or were not generated by Oracle Database. For example, the row addresses of index-organized tables are stored in index leaves, which can move. Oracle provides these tables with logical row identifiers, called **logical rowids**. Rowids of foreign tables, such as DB2 tables accessed through a gateway, are not standard Oracle Database rowids. Oracle provides foreign tables with identifiers called **foreign rowids**.

Oracle Database uses universal rowids (urowids) to store the addresses of index-organized and foreign tables. Both types of urowid are stored in the ROWID pseudocolumn, as are the physical rowids of heap-organized tables.

Oracle creates logical rowids based on the primary key of the table. The logical rowids do not change as long as the primary key does not change. The ROWID pseudocolumn of an index-organized table has a datatype of UROWID. You can access this pseudocolumn as you would the ROWID pseudocolumn of a heap-organized table (that is, using a SELECT ... ROWID statement). If you want to store the rowids of an index-organized table, then you can define a column of type UROWID for the table and retrieve the value of the ROWID pseudocolumn into that column.

How Oracle Database Converts Datatypes

In some cases, Oracle Database allows data of one datatype where it expects data of a different datatype. Generally, an expression cannot contain values with different datatypes. However, Oracle Database can use various SQL functions to automatically convert data to the expected datatype.

> **See Also:** *Oracle Database SQL Reference* for details about datatype conversion

Datatype Conversion During Assignments

The datatype conversion for an assignment succeeds if Oracle Database can convert the datatype of the value used in the assignment to that of the assignment target.

For the examples in the following list, assume a package with a public variable and a table declared as in the following statements:

```
CREATE PACKAGE Test_Pack AS var1 CHAR(5); END;
CREATE TABLE Table1_tab (col1 NUMBER);
```

- `variable := expression`

  The datatype of `expression` must be either the same as, or convertible to, the datatype of `variable`. For example, Oracle Database automatically converts the data provided in the following assignment within the body of a stored procedure:

  ```
  VAR1 := 0;
  ```

- `INSERT INTO Table1_tab VALUES (expression1, expression2, ...)`

  The datatypes of `expression1`, `expression2`, and so on, must be either the same as, or convertible to, the datatypes of the corresponding columns in `Table1_tab`. For example, Oracle Database automatically converts the data provided in the following `INSERT` statement for `Table1_tab`:

  ```
  INSERT INTO Table1_tab VALUES (
  '
  19
  '
  );
  ```

- `UPDATE Table1_tab SET column = expression`

  The datatype of `expression` must be either the same as, or convertible to, the datatype of `column`. For example, Oracle Database automatically converts the data provided in the following `UPDATE` statement issued against `Table1_tab`:

  ```
  UPDATE Table1_tab SET col1 =
  '
  30
  '
  ;
  ```

- `SELECT column INTO variable FROM Table1_tab`

  The datatype of `column` must be either the same as, or convertible to, the datatype of `variable`. For example, Oracle Database automatically converts data selected from the table before assigning it to the variable in the following statement:

  ```
  SELECT Col1 INTO Var1 FROM Table1_tab WHERE Col1 = 30;
  ```

Datatype Conversion During Expression Evaluation

For expression evaluation, Oracle Database can automatically perform the same conversions as for assignments. An expression is converted to a type based on its context. For example, operands to arithmetic operators are converted to `NUMBER`, and operands to string functions are converted to `VARCHAR2`.

Oracle Database can automatically convert the following:

- `VARCHAR2` or `CHAR` to `NUMBER`
- `VARCHAR2` or `CHAR` to `DATE`

Character to `NUMBER` conversions succeed only if the character string represents a valid number. Character to `DATE` conversions succeed only if the character string satisfies the session default format, which is specified by the initialization parameter `NLS_DATE_FORMAT`.

Some common types of expressions follow:

- Simple expressions, such as:

```
commission + '500'
```

- Boolean expressions, such as:

```
bonus > salary / '10'
```

- Function and procedure calls, such as:

```
MOD (counter, '2')
```

- `WHERE` clause conditions, such as:

```
WHERE hiredate = TO_DATE('1997-01-01','yyyy-mm-dd')
```

- `WHERE` clause conditions, such as:

```
WHERE rowid = 'AAAAaoAATAAAADAAA'
```

In general, Oracle Database uses the rule for expression evaluation when a datatype conversion is needed in places not covered by the rule for assignment conversions.

In assignments of the form:

```
variable := expression
```

Oracle Database first evaluates *expression* using the conversion rules for expressions; *expression* can be as simple or complex as desired. If it succeeds, then the evaluation of *expression* results in a single value and datatype. Then, Oracle Database tries to assign this value to the target variable using the conversion rules for assignments.

4

Using Regular Expressions in Oracle Database

This chapter introduces regular expression support for Oracle Database. This chapter covers the following topics:

- Using Regular Expressions with Oracle Database: Overview
- Regular Expression Metacharacters in Oracle Database
- Using Regular Expressions in SQL Statements: Scenarios

See Also:

- *Oracle Database SQL Reference* for information about Oracle Database SQL functions for regular expressions
- *Oracle Database Globalization Support Guide* for details on using SQL regular expression functions in a multilingual environment
- *Oracle Regular Expressions Pocket Reference* by Jonathan Gennick, O'Reilly & Associates
- *Mastering Regular Expressions* by Jeffrey E. F. Friedl, O'Reilly & Associates

Using Regular Expressions with Oracle Database: Overview

This section contains the following topics:

- What Are Regular Expressions?
- How Are Oracle Database Regular Expressions Useful?
- Oracle Database Implementation of Regular Expressions
- Oracle Database Support for the POSIX Regular Expression Standard

What Are Regular Expressions?

Regular expressions enable you to search for patterns in string data by using standardized syntax conventions. You specify a regular expression by means of the following types of characters:

- Metacharacters, which are operators that specify search algorithms
- Literals, which are the characters for which you are searching

A regular expression can specify complex patterns of character sequences. For example, the following regular expression searches for the literals `f` or `ht`, the `t` literal, the `p` literal optionally followed by the `s` literal, and finally the colon (`:`) literal:

```
(f|ht)tps?:
```

The parentheses are metacharacters that group a series of pattern elements to a single element; the pipe symbol (`|`) matches one of the alternatives in the group. The question mark (`?`) is a metacharacter indicating that the preceding pattern, in this case the `s` character, is optional. Thus, the preceding regular expression matches the `http:`, `https:`, `ftp:`, and `ftps:` strings.

How Are Oracle Database Regular Expressions Useful?

Regular expressions are a powerful text processing component of programming languages such as Perl and Java. For example, a Perl script can process each HTML file in a directory, read its contents into a scalar variable as a single string, and then use regular expressions to search for URLs in the string. One reason that many developers write in Perl is for its robust pattern matching functionality.

Oracle's support of regular expressions enables developers to implement complex match logic in the database. This technique is useful for the following reasons:

- By centralizing match logic in Oracle Database, you avoid intensive string processing of SQL results sets by middle-tier applications. For example, life science customers often rely on Perl to do pattern analysis on bioinformatics data stored in huge databases of DNAs and proteins. Previously, finding a match for a protein sequence such as `[AG].{4}GK[ST]` would be handled in the middle tier. The SQL regular expression functions move the processing logic closer to the data, thereby providing a more efficient solution.
- Prior to Oracle Database 10*g*, developers often coded data validation logic on the client, requiring the same validation logic to be duplicated for multiple clients. Using server-side regular expressions to enforce constraints solves this problem.
- The built-in SQL and PL/SQL regular expression functions and conditions make string manipulations more powerful and less cumbersome than in previous releases of Oracle Database.

Oracle Database Implementation of Regular Expressions

Oracle Database implements regular expression support with a set of Oracle Database SQL functions and conditions that enable you to search and manipulate string data. You can use these functions in any environment that supports Oracle Database SQL. You can use these functions on a text literal, bind variable, or any column that holds character data such as `CHAR`, `NCHAR`, `CLOB`, `NCLOB`, `NVARCHAR2`, and `VARCHAR2` (but not `LONG`).

Table 4–1 gives a brief description of the regular expression functions and conditions.

Table 4–1 SQL Regular Expression Functions and Conditions

SQL Element	Category	Description
`REGEXP_LIKE`	`Condition`	Searches a character column for a pattern. Use this function in the `WHERE` clause of a query to return rows matching a regular expression. The condition is also valid in a constraint or as a PL/SQL function returning a boolean. The following `WHERE` clause filters employees with a first name of Steven or Stephen: `WHERE REGEXP_LIKE(first_name, '^Ste(v|ph)en$')`

Table 4–1 (Cont.) SQL Regular Expression Functions and Conditions

SQL Element	Category	Description
REGEXP_REPLACE	Function	Searches for a pattern in a character column and replaces each occurrence of that pattern with the specified string. The following function puts a space after each character in the country_name column: `REGEXP_REPLACE(country_name, '(.)', '\1 ')`
REGEXP_INSTR	Function	Searches a string for a given occurrence of a regular expression pattern and returns an integer indicating the position in the string where the match is found. You specify which occurrence you want to find and the start position. For example, the following performs a boolean test for a valid email address in the email column: `REGEXP_INSTR(email, '\w+@\w+(\.\w+)+') > 0`
REGEXP_SUBSTR	Function	Returns the substring matching the regular expression pattern that you specify. The following function uses the x flag to match the first string by ignoring spaces in the regular expression: `REGEXP_SUBSTR('oracle', 'o r a c l e', 1, 1, 'x')`

A string literal in a REGEXP function or condition conforms to the rules of SQL text literals. By default, regular expressions must be enclosed in single quotes. If your regular expression includes the single quote character, then enter two single quotation marks to represent one single quotation mark within the expression. This technique ensures that the entire expression is interpreted by the SQL function and improves the readability of your code. You can also use the q-quote syntax to define your own character to terminate a text literal. For example, you could delimit your regular expression with the pound sign (#) and then use a single quote within the expression.

Note: If your expression comes from a column or a bind variable, then the same rules for quoting do not apply.

See Also:

- *Oracle Database SQL Reference* for syntax, descriptions, and examples of the REGEXP functions and conditions
- *Oracle Database SQL Reference* for a discussion of character literals

Oracle Database Support for the POSIX Regular Expression Standard

Oracle's implementation of regular expressions conforms to the following standards:

- IEEE Portable Operating System Interface (POSIX) standard draft 1003.2/D11.2
- Unicode Regular Expression Guidelines of the Unicode Consortium

Oracle Database follows the exact syntax and matching semantics for these operators as defined in the POSIX standard for matching ASCII (English language) data. You can find the POSIX standard draft at the following URL:

http://www.opengroup.org/onlinepubs/007908799/xbd/re.html

Oracle Database enhances regular expression support in the following ways:

- Extends the matching capabilities for multilingual data beyond what is specified in the POSIX standard.

- Adds support for the common Perl regular expression extensions that are not included in the POSIX standard but do not conflict with it. Oracle Database provides built-in support for some of the most heavily used Perl regular expression operators, for example, character class shortcuts, the non-greedy modifier, and so on.

Oracle Database supports a set of common metacharacters used in regular expressions. The behavior of supported metacharacters and related features is described in "Regular Expression Metacharacters in Oracle Database" on page 4-4.

> **Note:** The interpretation of metacharacters differs between tools that support regular expressions. If you are porting regular expressions from another environment to Oracle Database, ensure that the regular expression syntax is supported and the behavior is what you expect.

Regular Expression Metacharacters in Oracle Database

This section contains the following topics:

- POSIX Metacharacters in Oracle Database Regular Expressions
- Regular Expression Operator Multilingual Enhancements
- Perl-Influenced Extensions in Oracle Regular Expressions

POSIX Metacharacters in Oracle Database Regular Expressions

Table 4–2 lists the list of metacharacters supported for use in regular expressions passed to SQL regular expression functions and conditions. These metacharacters conform to the POSIX standard; any differences in behavior from the standard are noted in the "Description" column.

Table 4–2 POSIX Metacharacters in Oracle Database Regular Expressions

Syntax	Operator Name	Description	Example
`.`	Any Character — Dot	Matches any character in the database character set. If the `n` flag is set, it matches the newline character. The newline is recognized as the linefeed character (`\x0a`) on UNIX and Windows or the carriage return character (`\x0d`) on Macintosh platforms. **Note:** In the POSIX standard, this operator matches any English character except NULL and the newline character.	The expression `a.b` matches the strings `abb`, `acb`, and `adb`, but does not match `acc`.
`+`	One or More — Plus Quantifier	Matches one or more occurrences of the preceding subexpression.	The expression `a+` matches the strings `a`, `aa`, and `aaa`, but does not match `bbb`.
`?`	Zero or One — Question Mark Quantifier	Matches zero or one occurrence of the preceding subexpression.	The expression `ab?c` matches the strings `abc` and `ac`, but does not match `abbc`.
`*`	Zero or More — Star Quantifier	Matches zero or more occurrences of the preceding subexpression. By default, a quantifier match is greedy because it matches as many times as possible while still allowing the rest of the match to succeed.	The expression `ab*c` matches the strings `ac`, `abc`, and `abbc`, but does not match `abb`.
`{`*m*`}`	Interval—Exact Count	Matches exactly *m* occurrences of the preceding subexpression.	The expression `a{3}` matches the strings `aaa`, but does not match `aa`.
`{`*m*`,}`	Interval—At Least Count	Matches at least *m* occurrences of the preceding subexpression.	The expression `a{3,}` matches the strings `aaa` and `aaaa`, but does not match `aa`.

Table 4–2 (Cont.) POSIX Metacharacters in Oracle Database Regular Expressions

Syntax	Operator Name	Description	Example
`{m,n}`	Interval—Between Count	Matches at least *m*, but not more than *n* occurrences of the preceding subexpression.	The expression `a{3,5}` matches the strings `aaa`, `aaaa`, and `aaaaa`, but does not match `aa`.
`[ ... ]`	Matching Character List	Matches any single character in the list within the brackets. The following operators are allowed within the list, but other metacharacters included are treated as literals: ■ Range operator: `-` ■ POSIX character class: `[: :]` ■ POSIX collation element: `[. .]` ■ POSIX character equivalence class: `[= =]` A dash (`-`) is a literal when it occurs first or last in the list, or as an ending range point in a range expression, as in `[#--]`. A right bracket (`]`) is treated as a literal if it occurs first in the list. **Note:** In the POSIX standard, a range includes all collation elements between the start and end of the range in the linguistic definition of the current locale. Thus, ranges are linguistic rather than byte values ranges; the semantics of the range expression are independent of character set. In Oracle Database, the linguistic range is determined by the `NLS_SORT` initialization parameter.	The expression `[abc]` matches the first character in the strings `all`, `bill`, and `cold`, but does not match any characters in `doll`.
`[^ ... ]`	Non-Matching Character List	Matches any single character not in the list within the brackets. Characters not in the non-matching character list are returned as a match. Refer to the description of the Matching Character List operator for an account of metacharacters allowed in the character list.	The expression `[^abc]` matches the character `d` in the string `abcdef`, but not the character `a`, `b`, or `c`. The expression `[^abc]+` matches the sequence `def` in the string `abcdef`, but not `a`, `b`, or `c`. The expression `[^a-i]` excludes any character between `a` and `i` from the search result. This expression matches the character `j` in the string `hij`, but does not match any characters in the string `abcdefghi`.
`|`	Or	Matches one of the alternatives.	The expression `a|b` matches character `a` or character `b`.
`( ... )`	Subexpression or Grouping	Treats the expression within parentheses as a unit. The subexpression can be a string of literals or a complex expression containing operators.	The expression `(abc)?def` matches the optional string `abc`, followed by `def`. Thus, the expression matches `abcdefghi` and `def`, but does not match `ghi`.
`\n`	Backreference	Matches the n^{th} preceding subexpression, that is, whatever is grouped within parentheses, where *n* is an integer from 1 to 9. The parentheses cause an expression to be remembered; a backreference refers to it. A backreference counts subexpressions from left to right, starting with the opening parenthesis of each preceding subexpression. The expression is invalid if the source string contains fewer than *n* subexpressions preceding the `\n`. Oracle supports the backreference expression in the regular expression pattern and the replacement string of the `REGEXP_REPLACE` function.	The expression `(abc|def)xy\1` matches the strings `abcxyabc` and `defxydef`, but does not match `abcxydef` or `abcxy`. A backreference enables you to search for a repeated string without knowing the actual string ahead of time. For example, the expression `^(.*)\1$` matches a line consisting of two adjacent instances of the same string.
`\`	Escape Character	Treats the subsequent metacharacter in the expression as a literal. Use a backslash (`\`) to search for a character that is normally treated as a metacharacter. Use consecutive backslashes (`\\`) to match the backslash literal itself.	The expression `\+` searches for the plus character (`+`). It matches the plus character in the string `abc+def`, but does not match `abcdef`.

Table 4–2 (Cont.) POSIX Metacharacters in Oracle Database Regular Expressions

Syntax	Operator Name	Description	Example
^	Beginning of Line Anchor	Matches the beginning of a string (default). In multiline mode, it matches the beginning of any line within the source string.	The expression `^def` matches `def` in the string `defghi` but does not match `def` in `abcdef`.
$	End of Line Anchor	Matches the end of a string (default). In multiline mode, it matches the beginning of any line within the source string.	The expression `def$` matches `def` in the string `abcdef` but does not match `def` in the string `defghi`.
`[:class:]`	POSIX Character Class	Matches any character belonging to the specified POSIX character *`class`*. You can use this operator to search for characters with specific formatting such as uppercase characters, or you can search for special characters such as digits or punctuation characters. The full set of POSIX character classes is supported. **Note:** In English regular expressions, range expressions often indicate a character class. For example, `[a-z]` indicates any lowercase character. This convention is not useful in multilingual environments, where the first and last character of a given character class may not be the same in all languages. Oracle supports the character classes in Table 4–3 based on character class definitions in Globalization classification data.	The expression `[[:upper:]]+` searches for one or more consecutive uppercase characters. This expression matches `DEF` in the string `abcDEFghi` but does not match the string `abcdefghi`.
`[.element.]`	POSIX Collating Element Operator	Specifies a collating element to use in the regular expression. The *`element`* must be a defined collating element in the current locale. Use any collating element defined in the locale, including single-character and multicharacter elements. The `NLS_SORT` initialization parameter determines supported collation elements. This operator lets you use a multicharacter collating element in cases where only one character would otherwise be allowed. For example, you can ensure that the collating element `ch`, when defined in a locale such as Traditional Spanish, is treated as one character in operations that depend on the ordering of characters.	The expression `[[.ch.]]` searches for the collating element `ch` and matches `ch` in string `chabc`, but does not match `cdefg`. The expression `[a-[.ch.]]` specifies the range `a` to `ch`.
`[=character=]`	POSIX Character Equivalence Class	Matches all characters that are members of the same character equivalence class in the current locale as the specified *`character`*. The character equivalence class must occur within a character list, so the character equivalence class is always nested within the brackets for the character list in the regular expression. Usage of character equivalents depends on how canonical rules are defined for your database locale. Refer to the *Oracle Database Globalization Support Guide* for more information on linguistic sorting and string searching.	The expression `[[=n=]]` searches for characters equivalent to `n` in a Spanish locale. It matches both `N` and `ñ` in the string `El Niño`.

See Also: *Oracle Database SQL Reference* for syntax, descriptions, and examples of the `REGEXP` functions and conditions

Regular Expression Operator Multilingual Enhancements

When applied to multilingual data, Oracle's implementation of the POSIX operators extends beyond the matching capabilities specified in the POSIX standard. Table 4–3 shows the relationship of the operators in the context of the POSIX standard.

- The first column lists the supported operators.
- The second column indicates whether the POSIX standard for Basic Regular Expression (BRE) defines the operator.

- The third column indicates whether the POSIX standard for Extended Regular Expression (ERE) defines the operator.
- The fourth column indicates whether the Oracle Database implementation extends the operator's semantics for handling multilingual data.

Oracle Database lets you enter multibyte characters directly, if you have a direct input method, or use functions to compose the multibyte characters. You cannot use the Unicode hexadecimal encoding value of the form `\xxxx`. Oracle evaluates the characters based on the byte values used to encode the character, not the graphical representation of the character.

Table 4–3 POSIX and Multilingual Operator Relationships

Operator	POSIX BRE syntax	POSIX ERE Syntax	Multilingual Enhancement
`\`	Yes	Yes	--
`*`	Yes	Yes	--
`+`	--	Yes	--
`?`	--	Yes	--
`|`	--	Yes	--
`^`	Yes	Yes	Yes
`$`	Yes	Yes	Yes
`.`	Yes	Yes	Yes
`[ ]`	Yes	Yes	Yes
`( )`	Yes	Yes	--
`{m}`	Yes	Yes	--
`{m,}`	Yes	Yes	--
`{m,n}`	Yes	Yes	--
`\n`	Yes	Yes	Yes
`[..]`	Yes	Yes	Yes
`[::]`	Yes	Yes	Yes
`[==]`	Yes	Yes	Yes

Perl-Influenced Extensions in Oracle Regular Expressions

Table 4–4 describes Perl-influenced metacharacters supported in Oracle Database regular expression functions and conditions. These metacharacters are not in the POSIX standard, but are common at least partly due to the popularity of Perl. Note that Perl character class matching is based on the locale model of the operating system, whereas Oracle Database regular expressions are based on the language-specific data of the database. In general, a regular expression involving locale data cannot be expected to produce the same results between Perl and Oracle Database.

Table 4–4 Perl-Influenced Extensions in Oracle Regular Expressions

Reg. Exp.	Matches . . .	Example
`\d`	A digit character. It is equivalent to the POSIX class `[[:digit:]]`.	The expression `^\(\d{3}\) \d{3}-\d{4}$` matches `(650) 555-1212` but does not match `650-555-1212`.
`\D`	A non-digit character. It is equivalent to the POSIX class `[^[:digit:]]`.	The expression `\w\d\D` matches `b2b` and `b2_` but does not match `b22`.
`\w`	A word character, which is defined as an alphanumeric or underscore (_) character. It is equivalent to the POSIX class `[[:alnum:]_]`. Note that if you do not want to include the underscore character, you can use the POSIX class `[[:alnum:]]`.	The expression `\w+@\w+(\.\w+)+` matches the string `jdoe@company.co.uk` but not the string `jdoe@company`.
`\W`	A non-word character. It is equivalent to the POSIX class `[^[:alnum:]_]`.	The expression `\w+\W\s\w+` matches the string `to: bill` but not the string `to bill`.
`\s`	A whitespace character. It is equivalent to the POSIX class `[[:space:]]`.	The expression `\(\w\s\w\s\)` matches the string `(a b )` but not the string `(ab)`.
`\S`	A non-whitespace character. It is equivalent to the POSIX class `[^[:space:]]`.	The expression `\(\w\S\w\S\)` matches the string `(abde)` but not the string `(a b d e)`.
`\A`	Only at the beginning of a string. In multi-line mode, that is, when embedded newline characters in a string are considered the termination of a line, `\A` does not match the beginning of each line.	The expression `\AL` matches only the first `L` character in the string `Line1\nLine2\n`, regardless of whether the search is in single-line or multi-line mode.
`\Z`	Only at the end of string or before a newline ending a string. In multi-line mode, that is, when embedded newline characters in a string are considered the termination of a line, `\Z` does not match the end of each line.	In the expression `\s\Z,` the `\s` matches the last space in the string `L i n e \n`, regardless of whether the search is in single-line or multi-line mode.
`\z`	Only at the end of a string.	In the expression `\s\z`, the `\s` matches the newline in the string `L i n e \n`, regardless of whether the search is in single-line or multi-line mode.
`*?`	The preceding pattern element 0 or more times (non-greedy). Note that this quantifier matches the empty string whenever possible.	The expression `\w*?x\w` is "non-greedy" and so matches `abxc` in the string `abxcxd`. The expression `\w*x\w` is "greedy" and so matches `abxcxd in the string abxcxd`. The expression `\w*?x\w` also matches the string `xa`.
`+?`	The preceding pattern element 1 or more times (non-greedy).	The expression `\w+?x\w` is "non-greedy" and so matches `abxc` in the string `abxcxd`. The expression `\w+x\w` is "greedy" and so matches `abxcxd in the string abxcxd`. The expression `\w+?x\w` does not match the string `xa`, but does match the string `axa`.
`??`	The preceding pattern element 0 or 1 time (non-greedy). Note that this quantifier matches the empty string whenever possible.	The expression `a??aa` is "non-greedy" and matches `aa` in the string `aaaa`. The expression `a?aa` is "greedy" and so matches `aaa` in the string `aaaa`.
`{n}?`	The preceding pattern element exactly `n` times (non-greedy). In this case `{n}?` is equivalent to `{n}`.	The expression `(a|aa){2}?` matches `aa` in the string `aaaa`.
`{n,}?`	The preceding pattern element at least `n` times (non-greedy).	The expression `a{2,}?` is "non-greedy" and matches `aa` in the string `aaaaa`. The expression `a{2,}` is "greedy" and so matches `aaaaa`.
`{n,m}?`	At least `n` but not more than `m` times (non-greedy). Note that `{0,m}?` matches the empty string whenever possible.	The expression `a{2,4}?` is "non-greedy" and matches `aa` in the string `aaaaa`. The expression `a{2,4}` is "greedy" and so matches `aaaa`.

The Oracle Database regular expression functions and conditions support the pattern matching modifiers described in Table 4–5.

Table 4–5 Pattern Matching Modifiers

Mod.	Description	Example
i	Specifies case-insensitive matching.	The following regular expression returns AbCd: `REGEXP_SUBSTR('AbCd', 'abcd', 1, 1, 'i')`
c	Specifies case-sensitive matching.	The following regular expression fails to match: `REGEXP_SUBSTR('AbCd', 'abcd', 1, 1, 'c')`
n	Allows the period (.), which by default does not match newlines, to match the newline character.	The following regular expression matches the string, but would not match if the n flag were not specified: `REGEXP_SUBSTR('a'||CHR(10)||'d', 'a.d', 1, 1, 'n')`
m	Performs the search in multi-line mode. The metacharacter ^ and $ signify the start and end, respectively, of any line anywhere in the source string, rather than only at the start or end of the entire source string.	The following regular expression returns ac: `REGEXP_SUBSTR('ab'||CHR(10)||'ac', '^a.', 1, 2, 'm')`
x	Ignores whitespace characters in the regular expression. By default, whitespace characters match themselves.	The following regular expression returns abcd: `REGEXP_SUBSTR('abcd', 'a b c d', 1, 1, 'x')`

Using Regular Expressions in SQL Statements: Scenarios

This section contains the following scenarios:

- Using an Integrity Constraint to Enforce a Phone Number Format
- Using Back References to Reposition Characters

Using an Integrity Constraint to Enforce a Phone Number Format

Regular expressions are a useful way to enforce integrity constraints. For example, suppose that you want to ensure that phone numbers are entered into the database in a standard format. Example 4–1 creates a `contacts` table and adds a check constraint to the `p_number` column to enforce the following format mask:

```
(XXX) XXX-XXXX
```

Example 4–1 Enforcing a Phone Number Format with Regular Expressions

```
CREATE TABLE contacts
(
  l_name    VARCHAR2(30),
  p_number  VARCHAR2(30)
    CONSTRAINT p_number_format
      CHECK ( REGEXP_LIKE ( p_number, '^\(\d{3}\) \d{3}-\d{4}$' ) )
);
```

Table 4–6 explains the elements of the regular expression.

Table 4–6 Explanation of the Regular Expression Elements in Example 4–1

Regular Expression Element	Matches . . .
^	The beginning of the string.

Table 4–6 (Cont.) Explanation of the Regular Expression Elements in Example 4–1

Regular Expression Element	Matches . . .
`\(`	A left parenthesis. The backward slash (`\`) is an escape character that indicates that the left parenthesis following it is a literal rather than a grouping expression.
`\d{3}`	Exactly three digits.
`\)`	A right parenthesis. The backward slash (`\`) is an escape character that indicates that the right parenthesis following it is a literal rather than a grouping expression.
(space character)	A space character.
`\d{3}`	Exactly three digits.
-	A hyphen.
`\d{4}`	Exactly four digits.
`$`	The end of the string.

Example 4–2 shows a SQL script that attempts to insert seven phone numbers into the `contacts` table. Only the first two `INSERT` statements use a format that conforms to the `p_number_format` constraint; the remaining statements generate check constraint errors.

Example 4–2 insert_contacts.sql

```
-- first two statements use valid phone number format
INSERT INTO contacts (p_number)
  VALUES(  '(650) 555-5555'   );
INSERT INTO contacts (p_number)
  VALUES(  '(215) 555-3427'   );
-- remaining statements generate check contraint errors
INSERT INTO contacts (p_number)
  VALUES(  '650 555-5555'     );
INSERT INTO contacts (p_number)
  VALUES(  '650 555 5555'     );
INSERT INTO contacts (p_number)
  VALUES(  '650-555-5555'     );
INSERT INTO contacts (p_number)
  VALUES(  '(650)555-5555'    );
INSERT INTO contacts (p_number)
  VALUES(  ' (650) 555-5555'  );
/
```

Using Back References to Reposition Characters

As explained in Table 4–2, back references store matched subexpressions in a temporary buffer, thereby enabling you to reposition characters. You access buffers with the `\n` notation, where `\n` is a number between 1 and 9. Each subexpression is contained in parentheses and is numbered from left to right.

Example 4–3 creates a `famous_people` table and populates the `famous_people.names` column with names in different formats.

Example 4–3 Using Back References to Reposition Characters

```
CREATE TABLE famous_people
  ( names VARCHAR2(30) );
```

```
-- populate table with data
INSERT INTO famous_people
  VALUES ('John Quincy Adams');
INSERT INTO famous_people
  VALUES ('Harry S. Truman');
INSERT INTO famous_people
  VALUES ('John Adams');
INSERT INTO famous_people
  VALUES (' John Quincy Adams');
INSERT INTO famous_people
  VALUES ('John_Quincy_Adams');
COMMIT;
```

Example 4–4 shows a query that repositions names in the format "first middle last" to the format "last, first middle". It ignores names not in the format "first middle last".

Example 4–4 Using Back References to Reposition Characters

```
SELECT names "names",
  REGEXP_REPLACE(names,
                 '^(\S+)\s(\S+)\s(\S+)$',
                 '\3, \1 \2')
  AS "names after regexp"
FROM famous_people;
```

Table 4–7 explains the elements of the regular expression.

Table 4–7 Explanation of the Regular Expression Elements in Example 4–4

Regular Expression Element	Description
`^`	Matches the beginning of the string.
`$`	Matches the end of the string.
`(\S+)`	Matches one or more non-space characters. The parentheses are not escaped so they function as a grouping expression.
`\s`	Matches a whitespace character.
`\1`	Substitutes the first subexpression, that is, the first group of parentheses in the matching pattern.
`\2`	Substitutes the second subexpression, that is, the second group of parentheses in the matching pattern.
`\3`	Substitutes the third subexpression, that is, the third group of parentheses in the matching pattern.
`,`	Inserts a comma character.

Example 4–5 shows the result set of the query in Example 4–4. The regular expression matched only the first two rows.

Example 4–5 Result Set of Regular Expression Query

```
names
-----------------------------
names after regexp
-----------------------------
John Quincy Adams
Adams, John Quincy
```

```
Harry S. Truman
Truman, Harry S.

John Adams
John Adams

 John Quincy Adams
 John Quincy Adams

John_Quincy_Adams
John_Quincy_Adams
```

5

Using Indexes in Application Development

This chapter discusses considerations for using the different types of indexes in an application. The topics include:

- Guidelines for Application-Specific Indexes
- Creating Indexes: Basic Examples
- When to Use Domain Indexes
- When to Use Function-Based Indexes

See Also:

- *Oracle Database Administrator's Guide* for information about creating and managing indexes
- *Oracle Database Performance Tuning Guide* for detailed information about using indexes
- *Oracle Database SQL Reference* for the syntax of commands to work with indexes
- *Oracle Database Administrator's Guide* for information on creating hash clusters to improve performance, as an alternative to indexing

Guidelines for Application-Specific Indexes

You can create indexes on columns to speed up queries. Indexes provide faster access to data for operations that return a small portion of a table's rows.

In general, you should create an index on a column in any of the following situations:

- The column is queried frequently.
- A referential integrity constraint exists on the column.
- A `UNIQUE` key integrity constraint exists on the column.

You can create an index on any column; however, if the column is not used in any of these situations, creating an index on the column does not increase performance and the index takes up resources unnecessarily.

Although the database creates an index for you on a column with an integrity constraint, explicitly creating an index on such a column is recommended.

You can use the following techniques to determine which columns are best candidates for indexing:

- Use the EXPLAIN PLAN feature to show a theoretical execution plan of a given query statement.
- Use the V$SQL_PLAN view to determine the actual execution plan used for a given query statement.

Sometimes, if an index is not being used by default and it would be most efficient to use that index, you can use a query hint so that the index is used.

The following sections explain how to create, alter, and drop indexes using SQL commands, and give guidelines for managing indexes.

> **See Also:** *Oracle Database Performance Tuning Guide* for information on using the V$SQL_PLAN view, the EXPLAIN PLAN statement, query hints, and measuring the performance benefits of indexes

Create Indexes After Inserting Table Data

Typically, you insert or load data into a table (using SQL*Loader or Import) before creating indexes. Otherwise, the overhead of updating the index slows down the insert or load operation. The *exception* to this rule is that you must create an index for a cluster before you insert any data into the cluster.

Switch Your Temporary Tablespace to Avoid Space Problems Creating Indexes

When you create an index on a table that already has data, Oracle Database must use sort space to create the index. The database uses the sort space in memory allocated for the creator of the index (the amount for each user is determined by the initialization parameter SORT_AREA_SIZE), but the database must also swap sort information to and from temporary segments allocated on behalf of the index creation. If the index is extremely large, it can be beneficial to complete the following steps:

1. Create a new temporary tablespace using the CREATE TABLESPACE command.
2. Use the TEMPORARY TABLESPACE option of the ALTER USER command to make this your new temporary tablespace.
3. Create the index using the CREATE INDEX command.
4. Drop this tablespace using the DROP TABLESPACE command. Then use the ALTER USER command to reset your temporary tablespace to your original temporary tablespace.

Under certain conditions, you can load data into a table with the SQL*Loader "direct path load", and an index can be created as data is loaded.

> **See Also:** *Oracle Database Utilities* for information on direct path load

Index the Correct Tables and Columns

Use the following guidelines for determining when to create an index:

- Create an index if you frequently want to retrieve less than about 15% of the rows in a large table. This threshold percentage varies greatly, however, according to the relative speed of a table scan and how clustered the row data is about the index key. The faster the table scan, the lower the percentage; the more clustered the row data, the higher the percentage.
- Index columns that are used for joins to improve join performance.

- Primary and unique keys automatically have indexes, but you might want to create an index on a foreign key; see Chapter 6, "Maintaining Data Integrity in Application Development" for more information.
- Small tables do not require indexes; if a query is taking too long, then the table might have grown from small to large.

Some columns are strong candidates for indexing. Columns with one or more of the following characteristics are good candidates for indexing:

- Values are unique in the column, or there are few duplicates.
- There is a wide range of values (good for regular indexes).
- There is a small range of values (good for bitmap indexes).
- The column contains many nulls, but queries often select all rows having a value. In this case, a comparison that matches all the non-null values, such as:

  ```
  WHERE COL_X >= -9.99 *power(10,125)
  ```

  is preferable to

  ```
  WHERE COL_X IS NOT NULL
  ```

  This is because the first uses an index on `COL_X` (assuming that `COL_X` is a numeric column).

Columns with the following characteristics are less suitable for indexing:

- There are many nulls in the column and you do not search on the non-null values.

`LONG` and `LONG RAW` columns cannot be indexed.

The size of a single index entry cannot exceed roughly one-half (minus some overhead) of the available space in the data block. Consult with the database administrator for assistance in determining the space required by an index.

Limit the Number of Indexes for Each Table

The more indexes, the more overhead is incurred as the table is altered. When rows are inserted or deleted, all indexes on the table must be updated. When a column is updated, all indexes on the column must be updated.

You must weigh the performance benefit of indexes for queries against the performance overhead of updates. For example, if a table is primarily read-only, you might use more indexes; but, if a table is heavily updated, you might use fewer indexes.

Choose the Order of Columns in Composite Indexes

Although you can specify columns in any order in the `CREATE INDEX` command, the order of columns in the `CREATE INDEX` statement can affect query performance. In general, you should put the column expected to be used most often first in the index. You can create a composite index (using several columns), and the same index can be used for queries that reference all of these columns, or just some of them.

For example, assume the columns of the `VENDOR_PARTS` table are as shown in Figure 5–1.

Figure 5–1 The VENDOR_PARTS Table

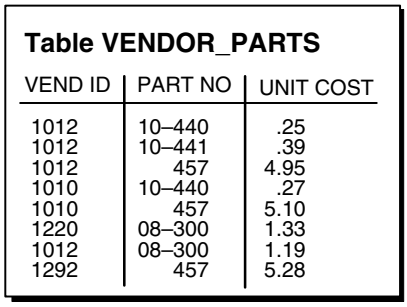


Table VENDOR_PARTS

VEND ID	PART NO	UNIT COST
1012	10–440	.25
1012	10–441	.39
1012	457	4.95
1010	10–440	.27
1010	457	5.10
1220	08–300	1.33
1012	08–300	1.19
1292	457	5.28

Assume that there are five vendors, and each vendor has about 1000 parts.

Suppose that the `VENDOR_PARTS` table is commonly queried by SQL statements such as the following:

```
SELECT * FROM vendor_parts
    WHERE part_no = 457 AND vendor_id = 1012;
```

To increase the performance of such queries, you might create a composite index putting the most selective column first; that is, the column with the *most* values:

```
CREATE INDEX ind_vendor_id
    ON vendor_parts (part_no, vendor_id);
```

Composite indexes speed up queries that use the *leading portion* of the index. So in this example, queries with `WHERE` clauses using only the `PART_NO` column also note a performance gain. Because there are only five distinct values, placing a separate index on `VENDOR_ID` would serve no purpose.

Gather Statistics to Make Index Usage More Accurate

The database can use indexes more effectively when it has statistical information about the tables involved in the queries. You can gather statistics when the indexes are created by including the keywords `COMPUTE STATISTICS` in the `CREATE INDEX` statement. As data is updated and the distribution of values changes, you or the DBA can periodically refresh the statistics by calling procedures like `DBMS_STATS.GATHER_TABLE_STATISTICS` and `DBMS_STATS.GATHER_SCHEMA_STATISTICS`.

Drop Indexes That Are No Longer Required

You might drop an index if:

- It does not speed up queries. The table might be very small, or there might be many rows in the table but very few index entries.
- The queries in your applications do not use the index.
- The index must be dropped before being rebuilt.

When you drop an index, all extents of the index's segment are returned to the containing tablespace and become available for other objects in the tablespace.

Use the SQL command `DROP INDEX` to drop an index. For example, the following statement drops a specific named index:

```
DROP INDEX Emp_ename;
```

If you drop a table, then all associated indexes are dropped.

To drop an index, the index must be contained in your schema or you must have the DROP ANY INDEX system privilege.

Privileges Required to Create an Index

When using indexes in an application, you might need to request that the DBA grant privileges or make changes to initialization parameters.

To create a new index, you must own, or have the INDEX object privilege for, the corresponding table. The schema that contains the index must also have a quota for the tablespace intended to contain the index, or the UNLIMITED TABLESPACE system privilege. To create an index in another user's schema, you must have the CREATE ANY INDEX system privilege.

Creating Indexes: Basic Examples

You can create an index for a table to improve the performance of queries issued against the corresponding table. You can also create an index for a cluster. You can create a *composite* index on multiple columns up to a maximum of 32 columns. A composite index key cannot exceed roughly one-half (minus some overhead) of the available space in the data block.

Oracle Database automatically creates an index to enforce a UNIQUE or PRIMARY KEY integrity constraint. In general, it is better to create such constraints to enforce uniqueness, instead of using the obsolete CREATE UNIQUE INDEX syntax.

Use the SQL command CREATE INDEX to create an index.

In this example, an index is created for a single column, to speed up queries that test that column:

```
CREATE INDEX emp_ename ON emp_tab(ename);
```

In this example, several storage settings are explicitly specified for the index:

```
CREATE INDEX emp_ename ON emp_tab(ename)
   TABLESPACE users
   STORAGE (INITIAL     20K
            NEXT        20k
            PCTINCREASE 75)
            PCTFREE      0
            COMPUTE STATISTICS;
```

In this example, the index applies to two columns, to speed up queries that test either the first column or both columns:

```
CREATE INDEX emp_ename ON emp_tab(ename, empno) COMPUTE STATISTICS;
```

In this example, the query is going to sort on the function UPPER(ENAME). An index on the ENAME column itself would not speed up this operation, and it might be slow to call the function for each result row. A function-based index precomputes the result of the function for each column value, speeding up queries that use the function for searching or sorting:

```
CREATE INDEX emp_upper_ename ON emp_tab(UPPER(ename)) COMPUTE STATISTICS;
```

When to Use Domain Indexes

Domain indexes are appropriate for special-purpose applications implemented using data cartridges. The domain index helps to manipulate complex data, such as spatial, audio, or video data. If you need to develop such an application, refer to *Oracle Database Data Cartridge Developer's Guide*.

Oracle Database supplies a number of specialized data cartridges to help manage these kinds of complex data. So, if you need to create a search engine, or a geographic information system, you can do much of the work simply by creating the right kind of index.

When to Use Function-Based Indexes

A function-based index is an index built on an expression. It extends your indexing capabilities beyond indexing on a column. A function-based index increases the variety of ways in which you can access data.

Note:

- The index is more effective if you gather statistics for the table or schema, using the procedures in the `DBMS_STATS` package.
- The index cannot contain any null values. Either make sure the appropriate columns contain no null values, or use the `NVL` function in the index expression to substitute some other value for nulls.

The expression indexed by a function-based index can be an arithmetic expression or an expression that contains a PL/SQL function, package function, C callout, or SQL function. Function-based indexes also support linguistic sorts based on collation keys, efficient linguistic collation of SQL statements, and case-insensitive sorts.

Like other indexes, function-based indexes improve query performance. For example, if you need to access a computationally complex expression often, then you can store it in an index. Then when you need to access the expression, it is already computed. You can find a detailed description of the advantages of function-based indexes in "Advantages of Function-Based Indexes" on page 5-6.

Function-based indexes have all of the same properties as indexes on columns. Unlike indexes on columns which can be used by both cost-based and rule-based optimization, however, function-based indexes can be used by only by cost-based optimization. Other restrictions on function-based indexes are described in "Restrictions for Function-Based Indexes" on page 5-8.

See Also:

- *Oracle Database Concepts*
- *Oracle Database Administrator's Guide* for information on creating function-based indexes

Advantages of Function-Based Indexes

Function-based indexes:

- *Increase the number of situations where the optimizer can perform a range scan instead of a full table scan.* For example, consider the expression in this `WHERE` clause:

```
CREATE INDEX Idx ON Example_tab(Column_a + Column_b);
SELECT * FROM Example_tab WHERE Column_a + Column_b < 10;
```

The optimizer can use a range scan for this query because the index is built on (`column_a` + `column_b`). Range scans typically produce fast response times if the predicate selects less than 15% of the rows of a large table. The optimizer can estimate how many rows are selected by expressions more accurately if the expressions are materialized in a function-based index. (Expressions of function-based indexes are represented as virtual columns and `ANALYZE` can build histograms on such columns.)

- *Precompute the value of a computationally intensive function and store it in the index.* An index can store computationally intensive expression that you access often. When you need to access a value, it is already computed, greatly improving query execution performance.
- *Create indexes on object columns and REF columns.* Methods that describe objects can be used as functions on which to build indexes. For example, you can use the `MAP` method to build indexes on an object type column.
- *Create more powerful sorts.* You can perform case-insensitive sorts with the `UPPER` and `LOWER` functions, descending order sorts with the `DESC` keyword, and linguistic-based sorts with the `NLSSORT` function.

> **Note:** Oracle Database sorts columns with the `DESC` keyword in descending order. Such indexes are treated as function-based indexes. Descending indexes cannot be bitmapped or reverse, and cannot be used in bitmapped optimizations. To get the `DESC` functionality prior to Oracle Database version 8, remove the `DESC` keyword from the `CREATE INDEX` statement.

Another function-based index calls the object method `distance_from_equator` for each city in the table. The method is applied to the object column `Reg_Obj`. A query could use this index to quickly find cities that are more than 1000 miles from the equator:

```
CREATE INDEX Distance_index
ON Weatherdata_tab (Distance_from_equator (Reg_obj));

SELECT * FROM Weatherdata_tab
WHERE (Distance_from_equator (Reg_Obj)) > '1000';
```

Another index stores the temperature delta and the maximum temperature. The result of the delta is sorted in descending order. A query could use this index to quickly find table rows where the temperature delta is less than 20 and the maximum temperature is greater than 75.

```
CREATE INDEX compare_index
ON Weatherdata_tab ((Maxtemp - Mintemp) DESC, Maxtemp);

SELECT * FROM Weatherdata_tab
WHERE ((Maxtemp - Mintemp) < '20' AND Maxtemp > '75');
```

Examples of Function-Based Indexes

This section presents several examples of function-based indexes.

Example: Function-Based Index for Case-Insensitive Searches

The following command allows faster case-insensitive searches in table EMP_TAB.

```
CREATE INDEX Idx ON Emp_tab (UPPER(Ename));
```

The SELECT command uses the function-based index on UPPER(e_name) to return all of the employees with name like :KEYCOL.

```
SELECT * FROM Emp_tab WHERE UPPER(Ename) like :KEYCOL;
```

Example: Precomputing Arithmetic Expressions with a Function-Based Index

The following command computes a value for each row using columns A, B, and C, and stores the results in the index.

```
CREATE INDEX Idx ON Fbi_tab (A + B * (C - 1), A, B);
```

The SELECT statement can either use index range scan (since the expression is a prefix of index IDX) or index fast full scan (which may be preferable if the index has specified a high parallel degree).

```
SELECT a FROM Fbi_tab WHERE A + B * (C - 1) < 100;
```

Example: Function-Based Index for Language-Dependent Sorting

This example demonstrates how a function-based index can be used to sort based on the collation order for a national language. The NLSSORT function returns a sort key for each name, using the collation sequence GERMAN.

```
CREATE INDEX Nls_index
    ON Nls_tab (NLSSORT(Name, 'NLS_SORT = German'));
```

The SELECT statement selects all of the contents of the table and orders it by NAME. The rows are ordered using the German collation sequence. The Globalization Support parameters are not needed in the SELECT statement, because in a German session, NLS_SORT is set to German and NLS_COMP is set to ANSI.

```
SELECT * FROM Nls_tab WHERE Name IS NOT NULL
    ORDER BY Name;
```

Restrictions for Function-Based Indexes

Note the following restrictions for function-based indexes:

- Only cost-based optimization can use function-based indexes. Remember to call DBMS_STATS.GATHER_TABLE_STATISTICS or DBMS_STATS.GATHER_SCHEMA_STATISTICS, for the function-based index to be effective.
- Any top-level or package-level PL/SQL functions that are used in the index expression must be declared as DETERMINISTIC. That is, they always return the same result given the same input, for example, the UPPER function. You must ensure that the subprogram really is deterministic, because Oracle Database does not check that the assertion is true.

  The following semantic rules demonstrate how to use the keyword DETERMINISTIC:

  - You can declare a top level subprogram as DETERMINISTIC.
  - You can declare a PACKAGE level subprogram as DETERMINISTIC in the PACKAGE specification but not in the PACKAGE BODY. Errors are raised if DETERMINISTIC is used inside a PACKAGE BODY.

  - You can declare a private subprogram (declared inside another subprogram or a PACKAGE BODY) as DETERMINISTIC.
  - A DETERMINISTIC subprogram can call another subprogram whether the called program is declared as DETERMINISTIC or not.
- If you change the semantics of a DETERMINISTIC function and recompile it, then existing function-based indexes and materialized views report results for the prior version of the function. Thus, if you change the semantics of a function, you must manually rebuild any dependent function-based indexes and materialized views.
- Expressions in a function-based index cannot contain any aggregate functions. The expressions should reference only columns in a row in the table.
- You must analyze the table or index before the index is used.
- Bitmap optimizations cannot use descending indexes.
- Function-based indexes are not used when OR-expansion is done.
- The index function cannot be marked NOT NULL. To avoid a full table scan, you must ensure that the query cannot fetch null values.
- Function-based indexes cannot use expressions that return VARCHAR2 or RAW data types of unknown length from PL/SQL functions. A workaround is to limit the size of the function's output by indexing a substring of known length:

```
-- INITIALS() might return 1 letter, 2 letters, 3 letters, and so on.
-- We limit the return value to 10 characters for purposes of the index.
CREATE INDEX func_substr_index ON
  emp_tab(substr(initials(ename),1,10);

-- Call SUBSTR both when creating the index and when referencing
-- the function in queries.
SELECT SUBSTR(initials(ename),1,10) FROM emp_tab;
```

See Also: *Oracle Database SQL Reference* for an account of CREATE FUNCTION restrictions

6

Maintaining Data Integrity in Application Development

This chapter explains how to enforce the business rules associated with your database and prevent the entry of invalid information into tables by using integrity constraints. Topics include the following:

Overview of Integrity Constraints

You can define integrity constraints to enforce business rules on data in your tables. Business rules specify conditions and relationships that must always be true, or must always be false. Because each company defines its own policies about things like salaries, employee numbers, inventory tracking, and so on, you can specify a different set of rules for each database table.

When an integrity constraint applies to a table, all data in the table must conform to the corresponding rule. When you issue a SQL statement that modifies data in the table, Oracle Database ensures that the new data satisfies the integrity constraint, without the need to do any checking within your program.

When to Enforce Business Rules with Integrity Constraints

You can enforce rules by defining integrity constraints more reliably than by adding logic to your application. Oracle Database can check that all the data in a table obeys an integrity constraint faster than an application can.

Example of an Integrity Constraint for a Business Rule

To ensure that each employee works for a valid department, first create a rule that all values in the department table are *unique*:

```
ALTER TABLE Dept_tab
    ADD PRIMARY KEY (Deptno);
```

Then, create a rule that every department listed in the employee table must match one of the values in the department table:

```
ALTER TABLE Emp_tab
    ADD FOREIGN KEY (Deptno) REFERENCES Dept_tab(Deptno);
```

When you add a new employee record to the table, Oracle Database automatically checks that its department number appears in the department table.

To enforce this rule without integrity constraints, you can use a *trigger* to query the department table and test that each new employee's department is valid. But this method is less reliable than the integrity constraint. `SELECT` in Oracle Database uses "consistent read", so the query might miss uncommitted changes from other transactions.

When to Enforce Business Rules in Applications

You might enforce business rules through application logic as well as through integrity constraints, if you can filter out bad data before attempting an insert or update. This might let you provide instant feedback to the user, and reduce the load on the database. This technique is appropriate when you can determine that data values are wrong or out of range without checking against any data already in the table.

Creating Indexes for Use with Constraints

All enabled unique and primary keys require corresponding indexes. You should create these indexes by hand, rather than letting the database create them for you. Note that:

- Constraints use existing indexes where possible, rather than creating new ones.
- Unique and primary keys can use non-unique as well as unique indexes. They can even use just the first few columns of non-unique indexes.
- At most one unique or primary key can use each non-unique index.
- The column orders in the index and the constraint do not need to match.
- If you need to check whether an index is used by a constraint, for example when you want to drop the index, the object number of the index used by a unique or primary key constraint is stored in `CDEF$.ENABLED` for that constraint. It is not shown in any catalog view.

You should almost always index foreign keys; the database does not do this for you automatically.

When to Use NOT NULL Integrity Constraints

By default, all columns can contain nulls. Only define `NOT NULL` constraints for columns of a table that absolutely require values at all times.

For example, a new employee's manager or hire date might be temporarily omitted. Some employees might not have a commission. Columns like these should not have

NOT NULL integrity constraints. However, an employee name might be required from the very beginning, and you can enforce this rule with a NOT NULL integrity constraint.

NOT NULL constraints are often combined with other types of integrity constraints to further restrict the values that can exist in specific columns of a table. Use the combination of NOT NULL and UNIQUE key integrity constraints to force the input of values in the UNIQUE key; this combination of data integrity rules eliminates the possibility that any new row' data will ever attempt to conflict with an existing row's data.

Because Oracle Database indexes do not store keys that are all null, if you want to allow index-only scans of the table or some other operation that requires indexing all rows, you must put a NOT NULL constraint on at least one indexed column.

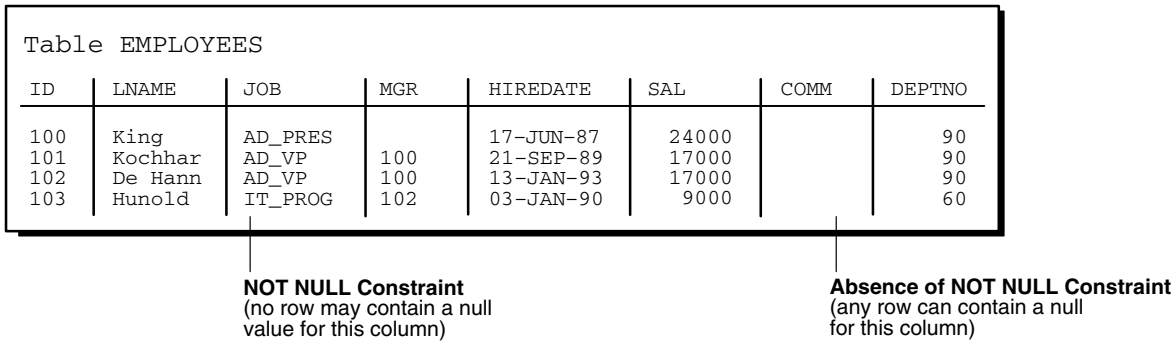
See Also: "Defining Relationships Between Parent and Child Tables" on page 6-8

A NOT NULL constraint is specified like this:

```
ALTER TABLE emp MODIFY ename NOT NULL;
```

Figure 6–1 shows an example of a table with NOT NULL integrity constraints.

Figure 6–1 Table with NOT NULL Integrity Constraints



When to Use Default Column Values

Assign default values to columns that contain a typical value. For example, in the DEPT_TAB table, if most departments are located at one site, then the default value for the LOC column can be set to this value (such as NEW YORK).

Default values can help avoid errors where there is a number, such as zero, that applies to a column that has no entry. For example, a default value of zero can simplify testing, by changing a test like this:

```
IF sal IS NOT NULL AND sal < 50000
```

to the simpler form:

```
IF sal < 50000
```

Depending upon your business rules, you might use default values to represent zero or false, or leave the default values as NULL to signify an unknown value.

Defaults are also useful when you use a view to make a subset of a table's columns visible. For example, you might allow users to insert rows through a view. The base table might also have a column named INSERTER, not included in the definition of the

view, to log the user that inserts each row. To record the user name automatically, define a default value that calls the USER function:

```
CREATE TABLE audit_trail
(
    value1   NUMBER,
    value2   VARCHAR2(32),
    inserter VARCHAR2(30) DEFAULT USER
);
```

Setting Default Column Values

Default values can be defined using any literal, or almost any expression, including calls to the following:

- SYSDATE
- SYS_CONTEXT
- USER
- USERENV
- UID

Default values cannot include expressions that refer to a sequence, PL/SQL function, column, LEVEL, ROWNUM, or PRIOR. The datatype of a default literal or expression must match or be convertible to the column datatype.

Sometimes the default value is the result of a SQL function. For example, a call to SYS_CONTEXT can set a different default value depending on conditions such as the user name. To be used as a default value, a SQL function must have parameters that are all literals, cannot reference any columns, and cannot call any other functions.

If you do not explicitly define a default value for a column, the default for the column is implicitly set to NULL.

You can use the keyword DEFAULT within an INSERT statement instead of a literal value, and the corresponding default value is inserted.

Choosing a Table's Primary Key

Each table can have one primary key, which uniquely identifies each row in a table and ensures that no duplicate rows exist. Use the following guidelines when selecting a primary key:

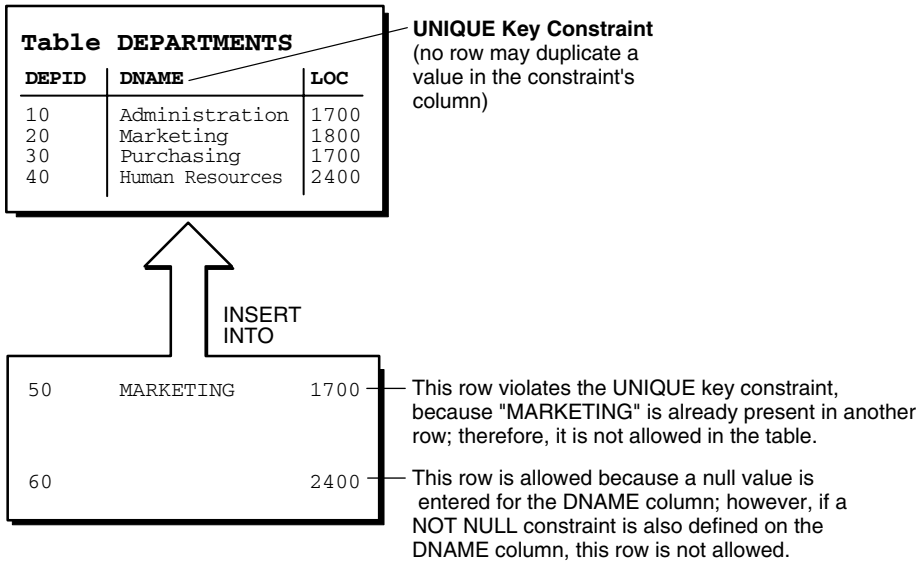
- Whenever practical, use a column containing a sequence number. It is a simple way to satisfy all the other guidelines.
- Choose a column whose data values are unique, because the purpose of a primary key is to uniquely identify each row of the table.
- Choose a column whose data values are never changed. A primary key value is only used to identify a row in the table, and its data should never be used for any other purpose. Therefore, primary key values should rarely or never be changed.
- Choose a column that does not contain any nulls. A PRIMARY KEY constraint, by definition, does not allow any row to contain a null in any column that is part of the primary key.
- Choose a column that is short and numeric. Short primary keys are easy to type. You can use sequence numbers to easily generate numeric primary keys.

- Minimize your use of composite primary keys. Although composite primary keys are allowed, they do not satisfy all of the other recommendations. For example, composite primary key values are long and cannot be assigned by sequence numbers.

When to Use UNIQUE Key Integrity Constraints

Choose columns for unique keys carefully. The purpose of these constraints is different from that of primary keys. Unique key constraints are appropriate for any column where duplicate values are not allowed. Primary keys identify each row of the table uniquely, and typically contain values that have no significance other than being unique. Figure 6–2 shows an example of a table with a unique key constraint.

Figure 6–2 Table with a UNIQUE Key Constraint



Note: You cannot have identical values in the non-null columns of a composite `UNIQUE` key constraint (`UNIQUE` key constraints allow `NULL` values).

Some examples of good unique keys include:

- An employee social security number (the primary key might be the employee number)
- A truck license plate number (the primary key might be the truck number)
- A customer phone number, consisting of the two columns `AREA_CODE` and `LOCAL_PHONE` (the primary key might be the customer number)
- A department name and location (the primary key might be the department number)

Constraints On Views: for Performance, Not Data Integrity

The constraints discussed throughout this chapter apply to tables, not views.

Although you can declare constraints on views, such constraints do not help maintain data integrity. Instead, they are used to enable query rewrites on queries involving

views, which helps performance with materialized views and other data warehousing features. Such constraints are always declared with the `DISABLE` keyword, and you cannot use the `VALIDATE` keyword. The constraints are never enforced, and there is no associated index.

> **See Also:** *Oracle Database Data Warehousing Guide* for information on query rewrite, materialized views, and the performance reasons for declaring constraints on views

Enforcing Referential Integrity with Constraints

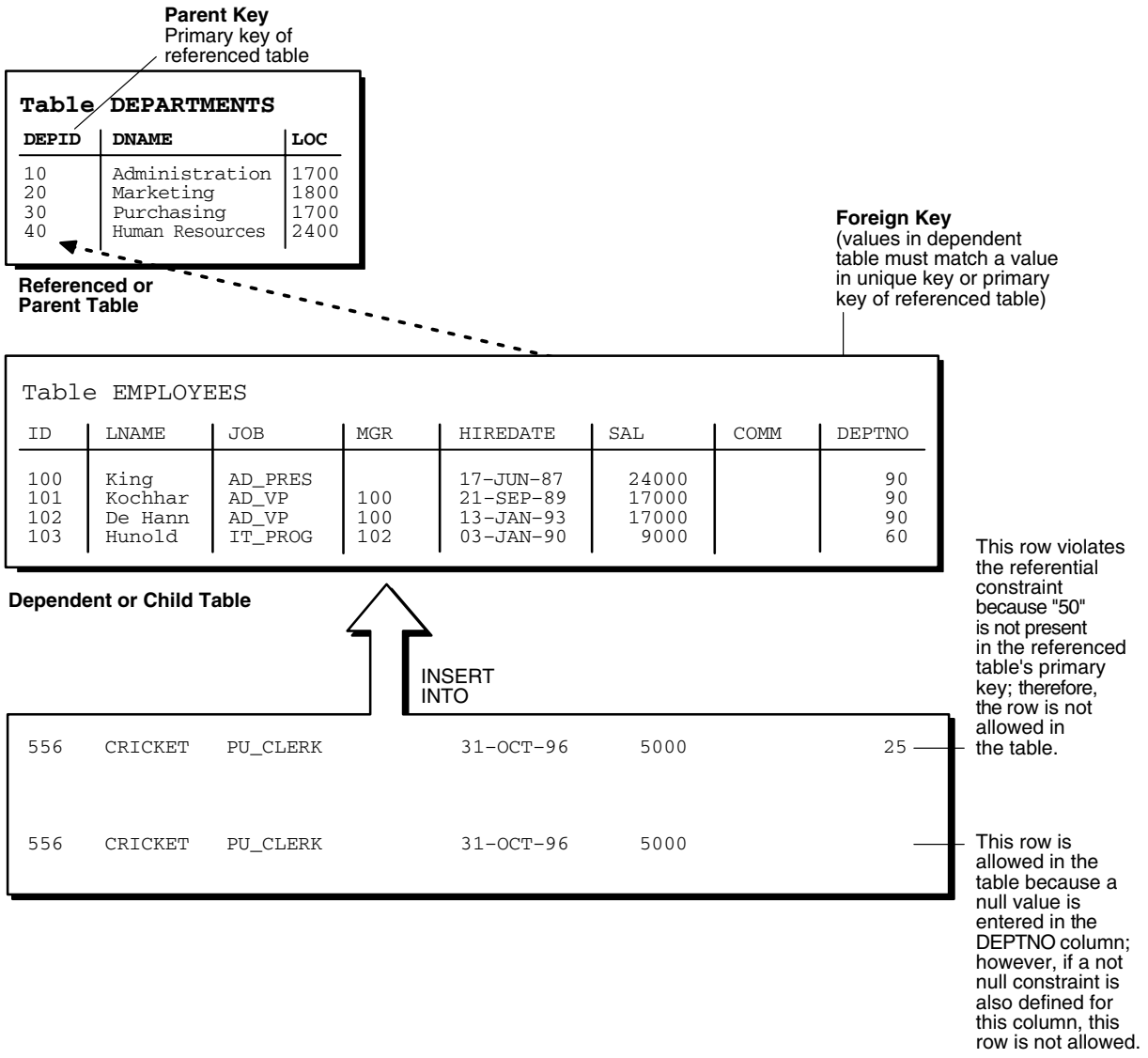
Whenever two tables contain one or more common columns, Oracle Database can enforce the relationship between the two tables through a referential integrity constraint. Define a `PRIMARY` or `UNIQUE` key constraint on the column in the parent table (the one that has the complete set of column values). Define a `FOREIGN KEY` constraint on the column in the child table (the one whose values must refer to existing values in the other table).

> **See Also:** "Defining Relationships Between Parent and Child Tables" on page 6-8 for information on defining additional integrity constraints, including the foreign key

Figure 6–3 shows a foreign key defined on the department number. It guarantees that every value in this column must match a value in the primary key of the department table. This constraint prevents erroneous department numbers from getting into the employee table.

Foreign keys can be comprised of multiple columns. Such a **composite foreign key** must reference a composite primary or unique key of the exact same structure, with the same number of columns and the same datatypes. Because composite primary and unique keys are limited to 32 columns, a composite foreign key is also limited to 32 columns.

Figure 6–3 Tables with Referential Integrity Constraints



About Nulls and Foreign Keys

Foreign keys allow key values that are all NULL, even if there are no matching PRIMARY or UNIQUE keys.

- By default (without any NOT NULL or CHECK clauses), the FOREIGN KEY constraint enforces the "match none" rule for composite foreign keys in the ANSI/ISO standard.
- To enforce the **match full** rule for NULL values in composite foreign keys, which requires that all components of the key be NULL or all be non-NULL, define a CHECK constraint that allows only all nulls or all non-nulls in the composite foreign key. For example, with a composite key comprised of columns A, B, and C:

```
CHECK ((A IS NULL AND B IS NULL AND C IS NULL) OR
       (A IS NOT NULL AND B IS NOT NULL AND C IS NOT NULL))
```

- In general, it is not possible to use declarative referential integrity to enforce the **match partial** rule for NULL values in composite foreign keys, which requires the

non-NULL portions of the key to appear in the corresponding portions in the primary or unique key of a single row in the referenced table. You can often use triggers to handle this case, as described in Chapter 9, "Coding Triggers".

Defining Relationships Between Parent and Child Tables

Several relationships between parent and child tables can be determined by the other types of integrity constraints defined on the foreign key in the child table.

No Constraints on the Foreign Key When no other constraints are defined on the foreign key, any number of rows in the child table can reference the same parent key value. This model allows nulls in the foreign key.

This model establishes a one-to-many relationship between the parent and foreign keys that allows undetermined values (nulls) in the foreign key. An example of such a relationship is shown in Figure 6–3, "Tables with Referential Integrity Constraints" between the `employee` and `department` tables. Each department (parent key) has many employees (foreign key), and some employees might not be in a department (nulls in the foreign key).

NOT NULL Constraint on the Foreign Key When nulls are not allowed in a foreign key, each row in the child table must explicitly reference a value in the parent key because nulls are not allowed in the foreign key.

Any number of rows in the child table can reference the same parent key value, so this model establishes a one-to-many relationship between the parent and foreign keys. However, each row in the child table must have a reference to a parent key value; the absence of a value (a null) in the foreign key is not allowed. The same example in the previous section can be used to illustrate such a relationship. However, in this case, employees must have a reference to a specific department.

UNIQUE Constraint on the Foreign Key When a UNIQUE constraint is defined on the foreign key, only one row in the child table can reference a given parent key value. This model allows nulls in the foreign key.

This model establishes a one-to-one relationship between the parent and foreign keys that allows undetermined values (nulls) in the foreign key. For example, assume that the employee table had a column named MEMBERNO, referring to an employee membership number in the company insurance plan. Also, a table named INSURANCE has a primary key named MEMBERNO, and other columns of the table keep respective information relating to an employee insurance policy. The MEMBERNO in the employee table should be both a foreign key and a unique key:

- To enforce referential integrity rules between the EMP_TAB and INSURANCE tables (the FOREIGN KEY constraint)
- To guarantee that each employee has a unique membership number (the UNIQUE key constraint)

UNIQUE and NOT NULL Constraints on the Foreign Key When both UNIQUE and NOT NULL constraints are defined on the foreign key, only one row in the child table can reference a given parent key value, and because NULL values are not allowed in the foreign key, each row in the child table must explicitly reference a value in the parent key.

This model establishes a one-to-one relationship between the parent and foreign keys that does not allow undetermined values (nulls) in the foreign key. If you expand the previous example by adding a NOT NULL constraint on the MEMBERNO column of the

employee table, in addition to guaranteeing that each employee has a unique membership number, you also ensure that no undetermined values (nulls) are allowed in the MEMBERNO column of the employee table.

Rules for Multiple FOREIGN KEY Constraints

Oracle Database allows a column to be referenced by multiple FOREIGN KEY constraints; there is no limit on the number of dependent keys. This situation might be present if a single column is part of two different composite foreign keys.

Deferring Constraint Checks

When Oracle Database checks a constraint, it signals an error if the constraint is not satisfied. You can use the SET CONSTRAINTS statement to defer checking the validity of constraints until the end of a transaction.

Note: You cannot issue a SET CONSTRAINTS statement inside a trigger.

The SET CONSTRAINTS setting lasts for the duration of the transaction, or until another SET CONSTRAINTS statement resets the mode.

See Also: *Oracle Database SQL Reference*

Guidelines for Deferring Constraint Checks

Consider the following guidelines when deferring constraint checks.

Select Appropriate Data You may wish to defer constraint checks on UNIQUE and FOREIGN keys if the data you are working with has any of the following characteristics:

- Tables are snapshots.
- Some tables contain a large amount of data being manipulated by another application, which may or may not return the data in the same order.
- Update cascade operations on foreign keys.

Ensure Constraints Are Created Deferrable After you have identified and selected the appropriate tables, make sure their FOREIGN, UNIQUE and PRIMARY key constraints are created deferrable. You can do so by issuing statements similar to the following:

```
CREATE TABLE dept (
     deptno NUMBER PRIMARY KEY,
     dname VARCHAR2 (30)
     );
CREATE TABLE emp (
     empno NUMBER,
     ename VARCHAR2 (30),
     deptno NUMBER REFERENCES (dept),
     CONSTRAINT epk PRIMARY KEY (empno) DEFERRABLE,
     CONSTRAINT efk FOREIGN KEY (deptno)
     REFERENCES (dept.deptno) DEFERRABLE);
INSERT INTO dept VALUES (10, 'Accounting');
INSERT INTO dept VALUES (20, 'SALES');
INSERT INTO emp VALUES (1, 'Corleone', 10);
INSERT INTO emp VALUES (2, 'Costanza', 20);
COMMIT;
```

```
SET CONSTRAINT efk DEFERRED;
UPDATE dept SET deptno = deptno + 10
     WHERE deptno = 20;

SELECT * from emp ORDER BY deptno;
EMPNO   ENAME          DEPTNO
-----   -------------- -------
   1    Corleone       10
   2    Costanza       20
UPDATE emp SET deptno = deptno + 10
     WHERE deptno = 20;
SELECT * FROM emp ORDER BY deptno;

EMPNO   ENAME          DEPTNO
-----   -------------- -------
   1    Corleone       10
   2    Costanza       30
COMMIT;
```

Set All Constraints Deferred Within the application that manipulates the data, you must set all constraints deferred before you begin processing any data. Use the following DML statement to set all constraints deferred:

```
SET CONSTRAINTS ALL DEFERRED;
```

> **Note:** The `SET CONSTRAINTS` statement applies only to the current transaction. The defaults specified when you create a constraint remain as long as the constraint exists. The `ALTER SESSION SET CONSTRAINTS` statement applies for the current session only.

Check the Commit (Optional) You can check for constraint violations before committing by issuing the `SET CONSTRAINTS ALL IMMEDIATE` statement just before issuing the `COMMIT`. If there are any problems with a constraint, this statement will fail and the constraint causing the error will be identified. If you commit while constraints are violated, the transaction will be rolled back and you will receive an error message.

Managing Constraints That Have Associated Indexes

When you create a `UNIQUE` or `PRIMARY` key, Oracle Database checks to see if an existing index can be used to enforce uniqueness for the constraint. If there is no such index, the database creates one.

Minimizing Space and Time Overhead for Indexes Associated with Constraints

When Oracle Database uses a unique index to enforce a constraint, and constraints associated with the unique index are dropped or disabled, the index is dropped. To preserve the statistics associated with the index (because, for example, it would take a long time to re-create it), you can specify the `KEEP INDEX` clause on the `DROP` command for the constraint.

While enabled foreign keys reference a `PRIMARY` or `UNIQUE` key, you cannot disable or drop the `PRIMARY` or `UNIQUE` key constraint or the index.

> **Note:** `UNIQUE` and `PRIMARY` keys with deferrable constraints must all use non-unique indexes.

To reuse existing indexes when creating unique and primary key constraints, you can include USING INDEX in the constraint clause. For example:

```
CREATE TABLE b
(
    b1 INTEGER,
    b2 INTEGER,
    CONSTRAINT unique1 (b1, b2) USING INDEX (CREATE UNIQUE INDEX b_index on b(b1,
b2),
    CONSTRAINT unique2 (b1, b2) USING INDEX b_index
);
```

Guidelines for Indexing Foreign Keys

You should almost always index foreign keys. The only exception is when the matching unique or primary key is never updated or deleted.

> **See Also:** *Oracle Database Concepts* for information on locking mechanisms involving indexes and keys

About Referential Integrity in a Distributed Database

The declaration of a referential integrity constraint cannot specify a foreign key that references a primary or unique key of a remote table.

However, you can maintain parent/child table relationships across nodes using triggers.

> **See Also:** Chapter 9, "Coding Triggers" for more information about triggers that enforce referential integrity

---

Note: If you decide to define referential integrity across the nodes of a distributed database using triggers, be aware that network failures can make both the parent table and the child table inaccessible.

For example, assume that the child table is in the SALES database, and the parent table is in the HQ database.

If the network connection between the two databases fails, then some DML statements against the child table (those that insert rows or update a foreign key value) cannot proceed, because the referential integrity triggers must have access to the parent table in the HQ database.

When to Use CHECK Integrity Constraints

Use CHECK constraints when you need to enforce integrity rules based on logical expressions, such as comparisons. Never use CHECK constraints when any of the other types of integrity constraints can provide the necessary checking.

> **See Also:** "Choosing Between CHECK and NOT NULL Integrity Constraints" on page 6-13

Examples of CHECK constraints include the following:

- A CHECK constraint on employee salaries so that no salary value is greater than 10000.

- A CHECK constraint on department locations so that only the locations "BOSTON", "NEW YORK", and "DALLAS" are allowed.
- A CHECK constraint on the salary and commissions columns to prevent the commission from being larger than the salary.

Restrictions on CHECK Constraints

A CHECK integrity constraint requires that a condition be true or unknown for every row of the table. If a statement causes the condition to evaluate to false, then the statement is rolled back. The condition of a CHECK constraint has the following limitations:

- The condition must be a boolean expression that can be evaluated using the values in the row being inserted or updated.
- The condition cannot contain subqueries or sequences.
- The condition cannot include the SYSDATE, UID, USER, or USERENV SQL functions.
- The condition cannot contain the pseudocolumns LEVEL, PRIOR, or ROWNUM.

  See Also: *Oracle Database SQL Reference* for an explanation of these pseudocolumns

- The condition cannot contain a user-defined SQL function.

Designing CHECK Constraints

When using CHECK constraints, remember that a CHECK constraint is violated only if the condition evaluates to false; true and unknown values (such as comparisons with nulls) do not violate a check condition. Make sure that any CHECK constraint that you define is specific enough to enforce the rule.

For example, consider the following CHECK constraint:

```
CHECK (Sal > 0 OR Comm >= 0)
```

At first glance, this rule may be interpreted as "do not allow a row in the employee table unless the employee salary is greater than zero or the employee commission is greater than or equal to zero." But if a row is inserted with a null salary, that row does not violate the CHECK constraint, regardless of whether or not the commission value is valid, because the entire check condition is evaluated as unknown. In this case, you can prevent such violations by placing NOT NULL integrity constraints on both the SAL and COMM columns.

Note: If you are not sure when unknown values result in NULL conditions, review the truth tables for the logical operators AND and OR in *Oracle Database SQL Reference*

Rules for Multiple CHECK Constraints

A single column can have multiple CHECK constraints that reference the column in its definition. There is no limit to the number of CHECK constraints that can be defined that reference a column.

The order in which the constraints are evaluated is not defined, so be careful not to rely on the order or to define multiple constraints that conflict with each other.

Choosing Between CHECK and NOT NULL Integrity Constraints

According to the ANSI/ISO standard, a NOT NULL integrity constraint is an example of a CHECK integrity constraint, where the condition is the following:

```
CHECK (Column_name IS NOT NULL)
```

Therefore, NOT NULL integrity constraints for a single column can, in practice, be written in two forms: using the NOT NULL constraint or a CHECK constraint. For ease of use, you should always choose to define NOT NULL integrity constraints, instead of CHECK constraints with the IS NOT NULL condition.

In the case where a composite key can allow only all nulls or all values, you must use a CHECK integrity constraint. For example, the following expression of a CHECK integrity constraint allows a key value in the composite key made up of columns C1 and C2 to contain either all nulls or all values:

```
CHECK ((C1 IS NULL AND C2 IS NULL) OR
    (C1 IS NOT NULL AND C2 IS NOT NULL))
```

Examples of Defining Integrity Constraints

Here are some examples showing how to create simple constraints during the prototype phase of your database design.

Each constraint is given a name in these examples. Naming the constraints prevents the database from creating multiple copies of the same constraint, with different system-generated names, if the DDL is run multiple times.

> **See Also:** *Oracle Database Administrator's Guide* for information on creating and maintaining constraints for a large production database

Example: Defining Integrity Constraints with the CREATE TABLE Command

The following examples of CREATE TABLE statements show the definition of several integrity constraints:

```
CREATE TABLE Dept_tab (
    Deptno  NUMBER(3) CONSTRAINT Dept_pkey PRIMARY KEY,
    Dname   VARCHAR2(15),
    Loc     VARCHAR2(15),
                CONSTRAINT Dname_ukey UNIQUE (Dname, Loc),
                CONSTRAINT Loc_check1
                    CHECK (loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')));

CREATE TABLE Emp_tab (
    Empno    NUMBER(5) CONSTRAINT Emp_pkey PRIMARY KEY,
    Ename    VARCHAR2(15) NOT NULL,
    Job      VARCHAR2(10),
    Mgr      NUMBER(5) CONSTRAINT Mgr_fkey REFERENCES Emp_tab,
    Hiredate DATE,
    Sal      NUMBER(7,2),
    Comm     NUMBER(5,2),
    Deptno   NUMBER(3) NOT NULL
             CONSTRAINT dept_fkey REFERENCES Dept_tab ON DELETE CASCADE);
```

Example: Defining Constraints with the ALTER TABLE Command

You can also define integrity constraints using the constraint clause of the ALTER TABLE command. For example:

```
CREATE UNIQUE INDEX I_dept ON Dept_tab(deptno);
ALTER TABLE Dept_tab
    ADD CONSTRAINT Dept_pkey PRIMARY KEY (deptno);

ALTER TABLE Emp_tab
    ADD CONSTRAINT Dept_fkey FOREIGN KEY (Deptno) REFERENCES Dept_tab;
ALTER TABLE Emp_tab MODIFY (Ename VARCHAR2(15) NOT NULL);
```

You cannot create a validated constraint on a table if the table already contains any rows that would violate the constraint.

Privileges Required to Create Constraints

The creator of a constraint must have the ability to create tables (the CREATE TABLE or CREATE ANY TABLE system privilege), or the ability to alter the table (the ALTER object privilege for the table or the ALTER ANY TABLE system privilege) with the constraint. Additionally, UNIQUE and PRIMARY KEY integrity constraints require that the owner of the table have either a quota for the tablespace that contains the associated index or the UNLIMITED TABLESPACE system privilege. FOREIGN KEY integrity constraints also require some additional privileges.

> **See Also:** "Privileges Required to Create FOREIGN KEY Integrity Constraints" on page 6-20

Naming Integrity Constraints

Assign names to constraints NOT NULL, UNIQUE KEY, PRIMARY KEY, FOREIGN KEY, and CHECK using the CONSTRAINT option of the constraint clause. This name must be unique with respect to other constraints that you own. If you do not specify a constraint name, one is assigned automatically by Oracle Database.

Picking your own name makes error messages for constraint violations more understandable, and prevents the creation of duplicate constraints with different names if the SQL statements are run more than once.

See the previous examples of the CREATE TABLE and ALTER TABLE statements for examples of the CONSTRAINT option of the constraint clause. Note that the name of each constraint is included with other information about the constraint in the data dictionary.

> **See Also:** "Viewing Definitions of Integrity Constraints" on page 6-21 for examples of data dictionary views

Enabling and Disabling Integrity Constraints

This section explains the mechanisms and procedures for manually enabling and disabling integrity constraints.

enabled constraint. When a constraint is enabled, the corresponding rule is enforced on the data values in the associated columns. The definition of the constraint is stored in the data dictionary.

disabled constraint. When a constraint is disabled, the corresponding rule is not enforced. The definition of the constraint is still stored in the data dictionary.

An integrity constraint represents an assertion about the data in a database. This assertion is always true when the constraint is enabled. The assertion may or may not be true when the constraint is disabled, because data that violates the integrity constraint can be in the database.

Why Disable Constraints?

During day-to-day operations, constraints should always be enabled. In certain situations, temporarily disabling the integrity constraints of a table makes sense for performance reasons. For example:

- When loading large amounts of data into a table using SQL*Loader
- When performing batch operations that make massive changes to a table (such as changing each employee number by adding 1000 to the existing number)
- When importing or exporting one table at a time

Temporarily turning off integrity constraints can speed up these operations.

About Exceptions to Integrity Constraints

If a row of a table disobeys an integrity constraint, then this row is in violation of the constraint and is called an **exception** to the constraint. If any exceptions exist, then the constraint *cannot* be enabled. The rows that violate the constraint must be updated or deleted before the constraint can be enabled.

You can identify exceptions for a specific integrity constraint as you try to enable the constraint.

> **See Also:** "Fixing Constraint Exceptions" on page 6-17 for more information on this procedure

Enabling Constraints

When you define an integrity constraint in a `CREATE TABLE` or `ALTER TABLE` statement, Oracle Database automatically enables the constraint by default. For code clarity, you can explicitly enable the constraint by including the `ENABLE` clause in its definition.

Use this technique when creating tables that start off empty, and are populated a row at a time by individual transactions. In such cases, you want to ensure that data is consistent at all times, and the performance overhead of each DML operation is small.

The following `CREATE TABLE` and `ALTER TABLE` statements both define and enable integrity constraints:

```
CREATE TABLE Emp_tab (
    Empno NUMBER(5) PRIMARY KEY);
 ALTER TABLE Emp_tab
    ADD PRIMARY KEY (Empno);
```

An `ALTER TABLE` statement that tries to enable an integrity constraint will fail if any existing rows of the table violate the integrity constraint. The statement is rolled back and the constraint definition is not stored and not enabled.

> **See Also:** "Fixing Constraint Exceptions" on page 6-17 for more information about rows that violate integrity constraints

Creating Disabled Constraints

The following CREATE TABLE and ALTER TABLE statements both define and disable integrity constraints:

```
CREATE TABLE Emp_tab (
    Empno NUMBER(5) PRIMARY KEY DISABLE);

ALTER TABLE Emp_tab
    ADD PRIMARY KEY (Empno) DISABLE;
```

Use this technique when creating tables that will be loaded with large amounts of data before anybody else accesses them, particularly if you need to cleanse data after loading it, or need to fill empty columns with sequence numbers or parent/child relationships.

An ALTER TABLE statement that defines and disables an integrity constraints never fails, because its rule is not enforced.

Enabling and Disabling Existing Integrity Constraints

Use the ALTER TABLE command to:

- Enable a disabled constraint, using the ENABLE clause.
- Disable an enabled constraint, using the DISABLE clause.

Enabling Existing Constraints

Once you have finished cleansing data and filling empty columns, you can enable constraints that were disabled during data loading.

The following statements are examples of statements that enable disabled integrity constraints:

```
ALTER TABLE Dept_tab
    ENABLE CONSTRAINT Dname_ukey;

ALTER TABLE Dept_tab
    ENABLE PRIMARY KEY
    ENABLE UNIQUE (Dname)
    ENABLE UNIQUE (Loc);
```

An ALTER TABLE statement that attempts to enable an integrity constraint fails if any of the table rows violate the integrity constraint. The statement is rolled back and the constraint is not enabled.

> **See Also:** "Fixing Constraint Exceptions" on page 6-17 for more information about rows that violate integrity constraints

Disabling Existing Constraints

If you need to perform a large load or update when a table already contains data, you can temporarily disable constraints to improve performance of the bulk operation.

The following statements are examples of statements that disable enabled integrity constraints:

```
ALTER TABLE Dept_tab
    DISABLE CONSTRAINT Dname_ukey;

ALTER TABLE Dept_tab
```

```
DISABLE PRIMARY KEY
DISABLE UNIQUE (Dname)
DISABLE UNIQUE (Loc);
```

Tip: Using the Data Dictionary to Find Constraints

The preceding examples require that you know the relevant constraint names and which columns they affect. To find this information, you can query one of the data dictionary views defined for constraints, USER_CONSTRAINTS or USER_CONS_COLUMNS. For more information about these views, refer to "Viewing Definitions of Integrity Constraints" on page 6-21 and *Oracle Database Reference.*

Guidelines for Enabling and Disabling Key Integrity Constraints

When enabling or disabling UNIQUE, PRIMARY KEY, and FOREIGN KEY integrity constraints, you should be aware of several important issues and prerequisites. UNIQUE key and PRIMARY KEY constraints are usually managed by the database administrator.

> **See Also:** *Oracle Database Administrator's Guide* and "Managing FOREIGN KEY Integrity Constraints" on page 6-19

Fixing Constraint Exceptions

When you try to create or enable a constraint, and the statement fails because integrity constraint exceptions exist, the statement is rolled back. You cannot enable the constraint until all exceptions are either updated or deleted. To determine which rows violate the integrity constraint, include the EXCEPTIONS option in the ENABLE clause of a CREATE TABLE or ALTER TABLE statement.

> **See Also:** *Oracle Database Administrator's Guide* for more information about responding to constraint exceptions

Altering Integrity Constraints

Starting with Oracle8*i*, you can alter the state of an existing constraint with the MODIFY CONSTRAINT clause.

> **See Also:** *Oracle Database SQL Reference* for information on the parameters you can modify

MODIFY CONSTRAINT Example #1

The following commands show several alternatives for whether the CHECK constraint is enforced, and when the constraint checking is done:

```
CREATE TABLE X1_tab (a1 NUMBER CONSTRAINT y CHECK (a1>3) DEFERRABLE DISABLE);

ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt ENABLE;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt RELY;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt INITIALLY DEFERRED;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt ENABLE NOVALIDATE;
```

MODIFY CONSTRAINT Example #2

The following commands show several alternatives for whether the NOT NULL constraint is enforced, and when the checking is done:

```
CREATE TABLE X1_tab (A1 NUMBER CONSTRAINT Y_cnstrt
NOT NULL DEFERRABLE INITIALLY DEFERRED NORELY DISABLE);

ALTER TABLE X1_tab ADD CONSTRAINT One_cnstrt UNIQUE(A1)
DEFERRABLE INITIALLY IMMEDIATE RELY USING INDEX PCTFREE = 30
ENABLE VALIDATE;

ALTER TABLE X1_tab MODIFY UNIQUE(A1)
INITIALLY DEFERRED NORELY USING INDEX PCTFREE = 40
ENABLE NOVALIDATE;

ALTER TABLE X1_tab MODIFY CONSTRAINT One_cnstrt
INITIALLY IMMEDIATE RELY;
```

Modify Constraint Example #3

The following commands show several alternatives for whether the primary key constraint is enforced, and when the checking is done:

```
CREATE TABLE T1_tab (A1 INT, B1 INT);
ALTER TABLE T1_tab add CONSTRAINT P1_cnstrt PRIMARY KEY(a1) DISABLE;
ALTER TABLE T1_tab MODIFY PRIMARY KEY INITIALLY IMMEDIATE
USING INDEX PCTFREE = 30 ENABLE NOVALIDATE;
ALTER TABLE T1_tab MODIFY PRIMARY KEY
USING INDEX PCTFREE = 35 ENABLE;
ALTER TABLE T1_tab MODIFY PRIMARY KEY ENABLE NOVALIDATE;
```

Renaming Integrity Constraints

Because constraint names must be unique, even across multiple schemas, you can encounter problems when you want to clone a table and all its constraints, because the constraint name for the new table conflicts with the one for the original table. Or, you might create a constraint with a default system-generated name, and later realize that you want to give the constraint a name that is easy to remember, so that you can easily enable and disable it.

One of the properties you can alter for a constraint is its name. The following SQL*Plus script finds the system-generated name for a constraint and changes it:

```
prompt Enter table name to find its primary key:
accept table_name
select constraint_name from user_constraints
  where table_name = upper('&table_name.')
  and constraint_type = 'P';

prompt Enter new name for its primary key:
accept new_constraint

set serveroutput on

declare
-- USER_CONSTRAINTS.CONSTRAINT_NAME is declared as VARCHAR2(30).
-- Using %TYPE here protects us if the length changes in a future release.
  constraint_name user_constraints.constraint_name%type;
begin
  select constraint_name into constraint_name from user_constraints
    where table_name = upper('&table_name.')
    and constraint_type = 'P';
```

```
  dbms_output.put_line('The primary key for ' || upper('&table_name.') || ' is: '
 || constraint_name);

  execute immediate
    'alter table &table_name. rename constraint ' || constraint_name ||
    ' to &new_constraint.';
end;
/
```

Dropping Integrity Constraints

Drop an integrity constraint if the rule that it enforces is no longer true or if the constraint is no longer needed. Drop an integrity constraint using the `ALTER TABLE` command and the `DROP` clause. For example, the following statements drop integrity constraints:

```
ALTER TABLE Dept_tab
    DROP UNIQUE (Dname);
ALTER TABLE Dept_tab
    DROP UNIQUE (Loc);

ALTER TABLE Emp_tab
    DROP PRIMARY KEY,
    DROP CONSTRAINT Dept_fkey;

DROP TABLE Emp_tab CASCADE CONSTRAINTS;
```

When dropping `UNIQUE`, `PRIMARY KEY`, and `FOREIGN KEY` integrity constraints, you should be aware of several important issues and prerequisites. `UNIQUE` and `PRIMARY KEY` constraints are usually managed by the database administrator.

> **See Also:** *Oracle Database Administrator's Guide* and "Managing FOREIGN KEY Integrity Constraints" on page 6-19

Managing FOREIGN KEY Integrity Constraints

General information about defining, enabling, disabling, and dropping all types of integrity constraints is given in section "Dropping Integrity Constraints". The present section supplements this information, focusing specifically on issues regarding `FOREIGN KEY` integrity constraints, which enforce relationships between columns in different tables.

Note: `FOREIGN KEY` integrity constraints cannot be enabled if the constraint of the referenced primary or unique key is not present or not enabled.

Datatypes and Names for Foreign Key Columns

You must use the same datatype for corresponding columns in the dependent and referenced tables. The column names do not need to match.

Limit on Columns in Composite Foreign Keys

Because foreign keys reference primary and unique keys of the parent table, and `PRIMARY KEY` and `UNIQUE` key constraints are enforced using indexes, composite foreign keys are limited to 32 columns.

Foreign Key References Primary Key by Default

If the column list is not included in the REFERENCES option when defining a FOREIGN KEY constraint (single column or composite), then Oracle Database assumes that you intend to reference the primary key of the specified table. Alternatively, you can explicitly specify the column(s) to reference in the parent table within parentheses. Oracle Database automatically checks to verify that this column list references a primary or unique key of the parent table. If it does not, then an informative error is returned.

Privileges Required to Create FOREIGN KEY Integrity Constraints

To create a FOREIGN KEY constraint, the creator of the constraint must have privileged access to the parent and child tables.

- **The Parent Table** The creator of the referential integrity constraint must own the parent table or have REFERENCES object privileges on the columns that constitute the parent key of the parent table.
- **The Child Table** The creator of the referential integrity constraint must have the ability to create tables (that is, the CREATE TABLE or CREATE ANY TABLE system privilege) or the ability to alter the child table (that is, the ALTER object privilege for the child table or the ALTER ANY TABLE system privilege).

In both cases, necessary privileges *cannot* be obtained through a role; they must be explicitly granted to the creator of the constraint.

These restrictions allow:

- The owner of the child table to explicitly decide which constraints are enforced and which other users can create constraints
- The owner of the parent table to explicitly decide if foreign keys can depend on the primary and unique keys in her tables

Choosing How Foreign Keys Enforce Referential Integrity

Oracle Database allows different types of referential integrity actions to be enforced, as specified with the definition of a FOREIGN KEY constraint:

- **Prevent Delete or Update of Parent Key** The default setting prevents the deletion or update of a parent key if there is a row in the child table that references the key. For example:

```
CREATE TABLE Emp_tab (
FOREIGN KEY (Deptno) REFERENCES Dept_tab);
```

- **Delete Child Rows When Parent Key Deleted** The ON DELETE CASCADE action allows parent key data that is referenced from the child table to be deleted, but not updated. When data in the parent key is deleted, all rows in the child table that depend on the deleted parent key values are also deleted. To specify this referential action, include the ON DELETE CASCADE option in the definition of the FOREIGN KEY constraint. For example:

```
CREATE TABLE Emp_tab (
    FOREIGN KEY (Deptno) REFERENCES Dept_tab
        ON DELETE CASCADE);
```

- **Set Foreign Keys to Null When Parent Key Deleted** The ON DELETE SET NULL action allows data that references the parent key to be deleted, but not updated. When referenced data in the parent key is deleted, all rows in the child table that

depend on those parent key values have their foreign keys set to null. To specify this referential action, include the ON DELETE SET NULL option in the definition of the FOREIGN KEY constraint. For example:

```
CREATE TABLE Emp_tab (
    FOREIGN KEY (Deptno) REFERENCES Dept_tab
        ON DELETE SET NULL);
```

Viewing Definitions of Integrity Constraints

The data dictionary contains the following views that relate to integrity constraints:

- ALL_CONSTRAINTS
- ALL_CONS_COLUMNS
- USER_CONSTRAINTS
- USER_CONS_COLUMNS
- DBA_CONSTRAINTS
- DBA_CONS_COLUMNS

You can query these views to find the names of constraints, what columns they affect, and other information to help you manage constraints.

See Also: *Oracle Database Reference* for information on each view

Examples of Defining Integrity Constraints

The following CREATE TABLE statements define a number of integrity constraints:

```
CREATE TABLE
Dept_tab
 (
    Deptno   NUMBER(3) PRIMARY KEY,
    Dname    VARCHAR2(15),
    Loc      VARCHAR2(15),
    CONSTRAINT Dname_ukey UNIQUE (Dname, Loc),
    CONSTRAINT LOC_CHECK1
        CHECK (Loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')));

CREATE TABLE
Emp_tab
 (
    Empno    NUMBER(5) PRIMARY KEY,
    Ename    VARCHAR2(15) NOT NULL,
    Job      VARCHAR2(10),
    Mgr      NUMBER(5) CONSTRAINT Mgr_fkey
         REFERENCES Emp_tab ON DELETE CASCADE,
    Hiredate DATE,
    Sal      NUMBER(7,2),
    Comm     NUMBER(5,2),
    Deptno   NUMBER(3) NOT NULL
    CONSTRAINT Dept_fkey REFERENCES Dept_tab);
```

Example 1: Listing All of Your Accessible Constraints The following query lists all constraints defined on all tables accessible to the user:

```
SELECT Constraint_name, Constraint_type, Table_name,
    R_constraint_name
```

```
    FROM User_constraints;
```

Considering the example statements at the beginning of this section, a list similar to this is returned:

```
CONSTRAINT_NAME  C TABLE_NAME  R_CONSTRAINT_NAME
---------------  - ----------  -----------------
SYS_C00275       P DEPT_TAB
DNAME_UKEY       U DEPT_TAB
LOC_CHECK1       C DEPT_TAB
SYS_C00278       C EMP_TAB
SYS_C00279       C EMP_TAB
SYS_C00280       P EMP_TAB
MGR_FKEY         R EMP_TAB     SYS_C00280
DEPT_FKEY        R EMP_TAB     SYS_C00275
```

Notice the following:

- Some constraint names are user specified (such as DNAME_UKEY), while others are system specified (such as SYS_C00275).
- Each constraint type is denoted with a different character in the CONSTRAINT_TYPE column. The following table summarizes the characters used for each constraint type.

Constraint Type	Character
PRIMARY KEY	P
UNIQUE KEY	U
FOREIGN KEY	R
CHECK, NOT NULL	C

> **Note:** An additional constraint type is indicated by the character "V" in the CONSTRAINT_TYPE column. This constraint type corresponds to constraints created using the WITH CHECK OPTION for views.

Example 2: Distinguishing NOT NULL Constraints from CHECK Constraints In the previous example, several constraints are listed with a constraint type of C. To distinguish which constraints are NOT NULL constraints and which are CHECK constraints in the EMP_TAB and DEPT_TAB tables, submit the following query:

```
SELECT Constraint_name, Search_condition
    FROM User_constraints
    WHERE (Table_name = 'DEPT_TAB' OR Table_name = 'EMP_TAB') AND
        Constraint_type = 'C';
```

Considering the example CREATE TABLE statements at the beginning of this section, a list similar to this is returned:

```
CONSTRAINT_NAME  SEARCH_CONDITION
---------------  ----------------------------------------
LOC_CHECK1       loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')
SYS_C00278       ENAME IS NOT NULL
SYS_C00279       DEPTNO IS NOT NULL
```

Notice that the following are explicitly listed in the SEARCH_CONDITION column:

- NOT NULL constraints
- The conditions for user-defined CHECK constraints

Example 3: Listing Column Names that Constitute an Integrity Constraint The following query lists all columns that constitute the constraints defined on all tables accessible to you, the user:

```
SELECT Constraint_name, Table_name, Column_name
    FROM User_cons_columns;
```

Considering the example statements at the beginning of this section, a list similar to this is returned:

```
CONSTRAINT_NAME  TABLE_NAME  COLUMN_NAME
---------------  ----------- ---------------
DEPT_FKEY        EMP_TAB     DEPTNO
DNAME_UKEY       DEPT_TAB    DNAME
DNAME_UKEY       DEPT_TAB    LOC
LOC_CHECK1       DEPT_TAB    LOC
MGR_FKEY         EMP_TAB     MGR
SYS_C00275       DEPT_TAB    DEPTNO
SYS_C00278       EMP_TAB     ENAME
SYS_C00279       EMP_TAB     DEPTNO
SYS_C00280       EMP_TAB     EMPNO
```

Part II

PL/SQL for Application Developers

This part contains the following chapters:

7

Coding PL/SQL Procedures and Packages

This chapter describes some of the procedural capabilities of Oracle Database for application development, including:

Overview of PL/SQL Program Units

PL/SQL is a modern, block-structured programming language. It provides several features that make developing powerful database applications very convenient. For example, PL/SQL provides procedural constructs, such as loops and conditional statements, that are not available in standard SQL.

You can directly enter SQL data manipulation language (DML) statements inside PL/SQL blocks, and you can use procedures supplied by Oracle to perform data definition language (DDL) statements.

PL/SQL code runs on the server, so using PL/SQL lets you centralize significant parts of your database applications for increased maintainability and security. It also enables you to achieve a significant reduction of network overhead in client/server applications.

Note: Some Oracle tools, such as Oracle Forms, contain a PL/SQL engine that lets you run PL/SQL locally.

You can even use PL/SQL for some database applications in place of 3GL programs that use embedded SQL or Oracle Call Interface (OCI).

PL/SQL program units include:

- Anonymous Blocks
- Stored Program Units (Procedures, Functions, and Packages)
- Triggers

See Also:

- *Oracle Database PL/SQL User's Guide and Reference* for syntax and examples of operations on PL/SQL packages
- *Oracle Database PL/SQL Packages and Types Reference* for information about the PL/SQL packages that come with Oracle Database

Anonymous Blocks

An anonymous block is a PL/SQL program unit that has no name. An anonymous block consists of an optional *declarative* part, an *executable* part, and one or more optional *exception handlers*.

The declarative part declares PL/SQL variables, exceptions, and cursors. The executable part contains PL/SQL code and SQL statements, and can contain nested blocks. Exception handlers contain code that is called when the exception is raised, either as a predefined PL/SQL exception (such as `NO_DATA_FOUND` or `ZERO_DIVIDE`) or as an exception that you define.

The following short example of a PL/SQL anonymous block prints the names of all employees in department 20 in the `hr.employees` table by using the `DBMS_OUTPUT` package:

```
DECLARE
   Last_name    VARCHAR2(10);
   Cursor       c1 IS SELECT last_name
                      FROM employees
                      WHERE department_id = 20;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO Last_name;
      EXIT WHEN c1%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE(Last_name);
   END LOOP;
END;
/
```

Note: If you test this block using SQL*Plus, then enter the statement `SET SERVEROUTPUT ON` so that output using the `DBMS_OUTPUT` procedures (for example, `PUT_LINE`) is activated. Also, end the example with a slash (/) to activate it.

Exceptions let you handle Oracle Database error conditions within PL/SQL program logic. This allows your application to prevent the server from issuing an error that could cause the client application to end. The following anonymous block handles the

predefined Oracle Database exception NO_DATA_FOUND (which would result in an ORA-01403 error if not handled):

```
DECLARE
   Emp_number   INTEGER := 9999;
   Emp_name     VARCHAR2(10);
BEGIN
   SELECT Ename INTO Emp_name FROM Emp_tab
      WHERE Empno = Emp_number;   -- no such number
   DBMS_OUTPUT.PUT_LINE('Employee name is ' || Emp_name);
EXCEPTION
   WHEN NO_DATA_FOUND THEN
      DBMS_OUTPUT.PUT_LINE('No such employee: ' || Emp_number);
END;
```

You can also define your own exceptions, declare them in the declaration part of a block, and define them in the exception part of the block. An example follows:

```
DECLARE
   Emp_name           VARCHAR2(10);
   Emp_number         INTEGER;
   Empno_out_of_range EXCEPTION;
BEGIN
   Emp_number := 10001;
   IF Emp_number > 9999 OR Emp_number < 1000 THEN
      RAISE Empno_out_of_range;
   ELSE
      SELECT Ename INTO Emp_name FROM Emp_tab
         WHERE Empno = Emp_number;
      DBMS_OUTPUT.PUT_LINE('Employee name is ' || Emp_name);
END IF;
EXCEPTION
   WHEN Empno_out_of_range THEN
      DBMS_OUTPUT.PUT_LINE('Employee number ' || Emp_number ||
       ' is out of range.');
END;
```

Anonymous blocks are usually used interactively from a tool, such as SQL*Plus, or in a precompiler, OCI, or SQL*Module application. They are usually used to call stored procedures or to open cursor variables.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference* for complete information about the DBMS_OUTPUT package
- *Oracle Database PL/SQL User's Guide and Reference* and "Handling Run-Time PL/SQL Errors" on page 7-26
- "Cursor Variables" on page 7-22

Stored Program Units (Procedures, Functions, and Packages)

A stored procedure, function, or package is a PL/SQL program unit that:

- Has a name.
- Can take parameters, and can return values.
- Is stored in the data dictionary.
- Can be called by many users.

Note: The term **stored procedure** is sometimes used generically for both stored procedures and stored functions. The only difference between procedures and functions is that functions always return a single value to the caller, while procedures do not return a value to the caller.

Naming Procedures and Functions

Because a procedure or function is stored in the database, it must be named. This distinguishes it from other stored procedures and makes it possible for applications to call it. Each publicly-visible procedure or function in a schema must have a unique name, and the name must be a legal PL/SQL identifier.

Note: If you plan to call a stored procedure using a stub generated by SQL*Module, then the stored procedure name must also be a legal identifier in the calling host 3GL language, such as Ada or C.

Parameters for Procedures and Functions

Stored procedures and functions can take parameters. The following example shows a stored procedure that is similar to the anonymous block in "Anonymous Blocks" on page 7-2.

Caution: To execute the following, use `CREATE OR REPLACE PROCEDURE...`

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER) IS
   Emp_name       VARCHAR2(10);
   CURSOR         c1 (Depno NUMBER) IS
                     SELECT Ename FROM Emp_tab
                        WHERE deptno = Depno;
BEGIN
   OPEN c1(Dept_num);
   LOOP
      FETCH c1 INTO Emp_name;
      EXIT WHEN C1%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE(Emp_name);
   END LOOP;
   CLOSE c1;
END;
```

In this stored procedure example, the department number is an input parameter which is used when the parameterized cursor `c1` is opened.

The formal parameters of a procedure have three major attributes, described in Table 7–1.

Table 7–1 Attributes of Procedure Parameters

Parameter Attribute	Description
Name	This must be a legal PL/SQL identifier.
Mode	This indicates whether the parameter is an input-only parameter (`IN`), an output-only parameter (`OUT`), or is both an input and an output parameter (`IN OUT`). If the mode is not specified, then `IN` is assumed.

Table 7–1 (Cont.) Attributes of Procedure Parameters

Parameter Attribute	Description
Datatype	This is a standard PL/SQL datatype.

Parameter Modes Parameter modes define the behavior of formal parameters. The three parameter modes, `IN` (the default), `OUT`, and `IN OUT`, can be used with any subprogram. However, avoid using the `OUT` and `IN OUT` modes with functions. The purpose of a function is to take no arguments and return a single value. It is poor programming practice to have a function return multiple values. Also, functions should be free from side effects, which change the values of variables not local to the subprogram.

Table 7–2 summarizes the information about parameter modes.

Table 7–2 Parameter Modes

IN	OUT	IN OUT
The default.	Must be specified.	Must be specified.
Passes values to a subprogram.	Returns values to the caller.	Passes initial values to a subprogram; returns updated values to the caller.
Formal parameter acts like a constant.	Formal parameter acts like an uninitialized variable.	Formal parameter acts like an initialized variable.
Formal parameter cannot be assigned a value.	Formal parameter cannot be used in an expression; must be assigned a value.	Formal parameter should be assigned a value.
Actual parameter can be a constant, initialized variable, literal, or expression.	Actual parameter must be a variable.	Actual parameter must be a variable.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference* for details about parameter modes

Parameter Datatypes The datatype of a formal parameter consists of one of the following:

- An *unconstrained* type name, such as `NUMBER` or `VARCHAR2`.
- A type that is *constrained* using the `%TYPE` or `%ROWTYPE` attributes.

> **Note:** Numerically constrained types such as `NUMBER(2)` or `VARCHAR2(20)` are not allowed in a parameter list.

%TYPE and %ROWTYPE Attributes Use the type attributes `%TYPE` and `%ROWTYPE` to constrain the parameter. For example, the `Get_emp_names` procedure specification in "Parameters for Procedures and Functions" on page 7-4 could be written as the following:

```
PROCEDURE Get_emp_names(Dept_num IN Emp_tab.Deptno%TYPE)
```

This has the `Dept_num` parameter take the same datatype as the `Deptno` column in the `Emp_tab` table. The column and table must be available when a declaration using `%TYPE` (or `%ROWTYPE`) is elaborated.

Using %TYPE is recommended, because if the type of the column in the table changes, then it is not necessary to change the application code.

If the Get_emp_names procedure is part of a package, then you can use previously-declared public (package) variables to constrain a parameter datatype. For example:

```
Dept_number    number(2);
...
PROCEDURE Get_emp_names(Dept_num IN Dept_number%TYPE);
```

Use the %ROWTYPE attribute to create a record that contains all the columns of the specified table. The following example defines the Get_emp_rec procedure, which returns all the columns of the Emp_tab table in a PL/SQL record for the given empno:

> **Caution:** To execute the following, use CREATE OR REPLACE PROCEDURE...

```
PROCEDURE Get_emp_rec (Emp_number  IN  Emp_tab.Empno%TYPE,
                       Emp_ret     OUT Emp_tab%ROWTYPE) IS
BEGIN
   SELECT Empno, Ename, Job, Mgr, Hiredate, Sal, Comm, Deptno
      INTO Emp_ret
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
```

You could call this procedure from a PL/SQL block as follows:

```
DECLARE
   Emp_row      Emp_tab%ROWTYPE;     -- declare a record matching a
                                     -- row in the Emp_tab table
BEGIN
   Get_emp_rec(7499, Emp_row);   -- call for Emp_tab# 7499
   DBMS_OUTPUT.PUT(Emp_row.Ename || ' '                || Emp_row.Empno);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Job || ' ' || Emp_row.Mgr);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Hiredate   || ' ' || Emp_row.Sal);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Comm || ' '|| Emp_row.Deptno);
   DBMS_OUTPUT.NEW_LINE;
END;
```

Stored functions can also return values that are declared using %ROWTYPE. For example:

```
FUNCTION Get_emp_rec (Dept_num IN Emp_tab.Deptno%TYPE)
   RETURN Emp_tab%ROWTYPE IS ...
```

Tables and Records You can pass PL/SQL tables as parameters to stored procedures and functions. You can also pass tables of records as parameters.

> **Note:** When passing a user defined type, such as a PL/SQL table or record to a remote procedure, to make PL/SQL use the same definition so that the type checker can verify the source, you must create a redundant loop back DBLINK so that when the PL/SQL compiles, both sources pull from the same location.

Default Parameter Values Parameters can take default values. Use the DEFAULT keyword or the assignment operator to give a parameter a default value. For example, the specification for the Get_emp_names procedure could be written as the following:

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER DEFAULT 20) IS ...
```

or

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER := 20) IS ...
```

When a parameter takes a default value, it can be omitted from the actual parameter list when you call the procedure. When you do specify the parameter value on the call, it overrides the default value.

> **Note:** Unlike in an anonymous PL/SQL block, you do not use the keyword DECLARE before the declarations of variables, cursors, and exceptions in a stored procedure. In fact, it is an error to use it.

Creating Stored Procedures and Functions

Use a text editor to write the procedure or function. At the beginning of the procedure, place the following statement:

```
CREATE PROCEDURE Procedure_name AS   ...
```

For example, to use the example in "%TYPE and %ROWTYPE Attributes" on page 7-5, create a text (source) file called get_emp.sql containing the following code:

```
CREATE PROCEDURE Get_emp_rec (Emp_number  IN  Emp_tab.Empno%TYPE,
                              Emp_ret     OUT Emp_tab%ROWTYPE) AS
BEGIN
   SELECT Empno, Ename, Job, Mgr, Hiredate, Sal, Comm, Deptno
      INTO Emp_ret
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
/
```

Then, using an interactive tool such as SQL*Plus, load the text file containing the procedure by entering the following statement:

```
SQL> @get_emp
```

This loads the procedure into the current schema from the get_emp.sql file (.sql is the default file extension). Note the slash (/) at the end of the code. This is not part of the code; it just activates the loading of the procedure.

Use the CREATE [OR REPLACE] FUNCTION... statement to store functions.

> **Caution:** When developing a new procedure, it is usually much more convenient to use the CREATE OR REPLACE PROCEDURE statement. This replaces any previous version of that procedure in the same schema with the newer version, but note that this is done without warning.

You can use either the keyword IS or AS after the procedure parameter list.

> **See Also:** *Oracle Database Reference* for the complete syntax of the CREATE PROCEDURE and CREATE FUNCTION statements

Privileges to Create Procedures and Functions To create a standalone procedure or function, or package specification or body, you must meet the following prerequisites:

- You must have the CREATE PROCEDURE system privilege to create a procedure or package in your schema, or the CREATE ANY PROCEDURE system privilege to create a procedure or package in another user's schema.

> **Note:** To create without errors (to compile the procedure or package successfully) requires the following additional privileges:
>
> - The owner of the procedure or package must be explicitly granted the necessary object privileges for all objects referenced within the body of the code.
> - The owner cannot obtain required privileges through roles.

If the privileges of the owner of a procedure or package change, then the procedure must be reauthenticated before it is run. If a necessary privilege to a referenced object is revoked from the owner of the procedure or package, then the procedure cannot be run.

The EXECUTE privilege on a procedure gives a user the right to run a procedure owned by another user. Privileged users run the procedure under the security domain of the owner of the procedure. Therefore, users never need to be granted the privileges to the objects referenced by a procedure. This allows for more disciplined and efficient security strategies with database applications and their users. Furthermore, all procedures and packages are stored in the data dictionary (in the SYSTEM tablespace). No quota controls the amount of space available to a user who creates procedures and packages.

> **Note:** Package creation requires a sort. So the user creating the package should be able to create a sort segment in the temporary tablespace with which the user is associated.

> **See Also:** "Privileges Required to Execute a Procedure" on page 7-33

Altering Stored Procedures and Functions

To alter a stored procedure or function, you must first drop it using the DROP PROCEDURE or DROP FUNCTION statement, then re-create it using the CREATE PROCEDURE or CREATE FUNCTION statement. Alternatively, use the CREATE OR REPLACE PROCEDURE or CREATE OR REPLACE FUNCTION statement, which first drops the procedure or function if it exists, then re-creates it as specified.

> **Caution:** The procedure or function is dropped without any warning.

Dropping Procedures and Functions

A standalone procedure, a standalone function, a package body, or an entire package can be dropped using the SQL statements DROP PROCEDURE, DROP FUNCTION, DROP

PACKAGE BODY, and DROP PACKAGE, respectively. A DROP PACKAGE statement drops both the specification and body of a package.

The following statement drops the Old_sal_raise procedure in your schema:

```
DROP PROCEDURE Old_sal_raise;
```

Privileges to Drop Procedures and Functions To drop a procedure, function, or package, the procedure or package must be in your schema, or you must have the DROP ANY PROCEDURE privilege. An individual procedure within a package cannot be dropped; the containing package specification and body must be re-created without the procedures to be dropped.

External Procedures

A PL/SQL procedure executing on an Oracle Database instance can call an external procedure written in a 3GL. The 3GL procedure runs in a separate address space from that of the database.

> **See Also:** Chapter 14, "Calling External Procedures" for information about external procedures

PL/SQL Packages

A *package* is an encapsulated collection of related program objects (for example, procedures, functions, variables, constants, cursors, and exceptions) stored together in the database.

Using packages is an alternative to creating procedures and functions as standalone schema objects. Packages have many advantages over standalone procedures and functions. For example, they:

- Let you organize your application development more efficiently.
- Let you grant privileges more efficiently.
- Let you modify package objects without recompiling dependent schema objects.
- Enable Oracle Database to read multiple package objects into memory at once.
- Can contain global variables and cursors that are available to all procedures and functions in the package.
- Let you **overload** procedures or functions. Overloading a procedure means creating multiple procedures with the same name in the same package, each taking arguments of different number or datatype.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference* for more information about subprogram name overloading

The **specification** part of a package *declares* the public types, variables, constants, and subprograms that are visible outside the immediate scope of the package. The **body** of a package *defines* the objects declared in the specification, as well as private objects that are not visible to applications outside the package.

Example of a PL/SQL Package Specification and Body The following example shows a package specification for a package named Employee_management. The package contains one stored function and two stored procedures. The body for this package defines the function and the procedures:

```
CREATE PACKAGE BODY Employee_management AS
   FUNCTION Hire_emp (Name VARCHAR2, Job VARCHAR2,
```

```
      Mgr NUMBER, Hiredate DATE, Sal NUMBER, Comm NUMBER,
      Deptno NUMBER) RETURN NUMBER IS
       New_empno    NUMBER(10);

-- This function accepts all arguments for the fields in
-- the employee table except for the employee number.
-- A value for this field is supplied by a sequence.
-- The function returns the sequence number generated
-- by the call to this function.

   BEGIN
      SELECT Emp_sequence.NEXTVAL INTO New_empno FROM dual;
      INSERT INTO Emp_tab VALUES (New_empno, Name, Job, Mgr,
         Hiredate, Sal, Comm, Deptno);
      RETURN (New_empno);
   END Hire_emp;

   PROCEDURE fire_emp(emp_id IN NUMBER) AS

-- This procedure deletes the employee with an employee
-- number that corresponds to the argument Emp_id. If
-- no employee is found, then an exception is raised.

   BEGIN
      DELETE FROM Emp_tab WHERE Empno = Emp_id;
      IF SQL%NOTFOUND THEN
      Raise_application_error(-20011, 'Invalid Employee
         Number: ' || TO_CHAR(Emp_id));
   END IF;
END fire_emp;

PROCEDURE Sal_raise (Emp_id IN NUMBER, Sal_incr IN NUMBER) AS

-- This procedure accepts two arguments. Emp_id is a
-- number that corresponds to an employee number.
-- SAL_INCR is the amount by which to increase the
-- employee's salary. If employee exists, then update
-- salary with increase.

   BEGIN
      UPDATE Emp_tab
         SET Sal = Sal + Sal_incr
         WHERE Empno = Emp_id;
      IF SQL%NOTFOUND THEN
         Raise_application_error(-20011, 'Invalid Employee
            Number: ' || TO_CHAR(Emp_id));
      END IF;
   END Sal_raise;
END Employee_management;
```

Note: If you want to try this example, then first create the sequence number `Emp_sequence`. Do this with the following SQL*Plus statement:

```
SQL> CREATE SEQUENCE Emp_sequence
   > START WITH 8000 INCREMENT BY 10;
```

PL/SQL Object Size Limitation

The size limitation for PL/SQL stored database objects such as procedures, functions, triggers, and packages is the size of the DIANA (Descriptive Intermediate Attributed Notation for Ada) code in the shared pool in bytes. The UNIX limit on the size of the flattened DIANA/pcode size is 64K but the limit may be 32K on desktop platforms.

The most closely related number that a user can access is the PARSED_SIZE in the data dictionary view USER_OBJECT_SIZE. That gives the size of the DIANA in bytes as stored in the SYS.IDL_xxx$ tables. This is not the size in the shared pool. The size of the DIANA part of PL/SQL code (used during compilation) is significantly larger in the shared pool than it is in the system table.

Creating Packages

Each part of a package is created with a different statement. Create the package specification using the CREATE PACKAGE statement. The CREATE PACKAGE statement declares public package objects.

To create a package body, use the CREATE PACKAGE BODY statement. The CREATE PACKAGE BODY statement defines the procedural code of the public procedures and functions declared in the package specification.

You can also define private, or local, package procedures, functions, and variables in a package body. These objects can only be accessed by other procedures and functions in the body of the same package. They are not visible to external users, regardless of the privileges they hold.

It is often more convenient to add the OR REPLACE clause in the CREATE PACKAGE or CREATE PACKAGE BODY statements when you are first developing your application. The effect of this option is to drop the package or the package body without warning. The CREATE statements would then be the following:

```
CREATE OR REPLACE PACKAGE Package_name AS ...
```

and

```
CREATE OR REPLACE PACKAGE BODY Package_name AS ...
```

Creating Packaged Objects The body of a package can contain:

- Procedures and functions declared in the package specification.
- Definitions of cursors declared in the package specification.
- Local procedures and functions, not declared in the package specification.
- Local variables.

Procedures, functions, cursors, and variables that are declared in the package specification are **global**. They can be called, or used, by external users that have EXECUTE permission for the package or that have EXECUTE ANY PROCEDURE privileges.

When you create the package body, make sure that each procedure that you define in the body has the same parameters, *by name, datatype, and mode*, as the declaration in the package specification. For functions in the package body, the parameters *and* the return type must agree in name and type.

Privileges to Create or Drop Packages The privileges required to create or drop a package specification or package body are the same as those required to create or drop a standalone procedure or function.

See Also:

- "Privileges to Create Procedures and Functions" on page 7-8
- "Privileges to Drop Procedures and Functions" on page 7-9

Naming Packages and Package Objects

The names of a package and all public objects in the package must be unique within a given schema. The package specification and its body must have the same name. All package constructs must have unique names within the scope of the package, unless overloading of procedure names is desired.

Package Invalidations and Session State

Each session that references a package object has its own instance of the corresponding package, including persistent state for any public and private variables, cursors, and constants. If any of the session's instantiated packages (specification or body) are invalidated, then all package instances in the session are invalidated and recompiled. As a result, the session state is lost for all package instances in the session.

When a package in a given session is invalidated, the session receives the following error the first time it attempts to use any object of the invalid package instance:

```
ORA-04068: existing state of packages has been discarded
```

The second time a session makes such a package call, the package is reinstantiated for the session without error.

Note: For optimal performance, Oracle Database returns this error message only once—each time the package state is discarded.

If you handle this error in your application, ensure that your error handling strategy can accurately handle this error. For example, when a procedure in one package calls a procedure in another package, your application should be aware that the session state is lost for both packages.

In most production environments, DDL operations that can cause invalidations are usually performed during inactive working hours; therefore, this situation might not be a problem for end-user applications. However, if package invalidations are common in your system during working hours, then you might want to code your applications to handle this error when package calls are made.

Packages Supplied With Oracle Database

There are many packages provided with Oracle Database, either to extend the functionality of the database or to give PL/SQL access to SQL features. You can call these packages from your application.

See Also: *Oracle Database PL/SQL Packages and Types Reference* for an overview of these Oracle Database packages

Overview of Bulk Binds

Oracle Database uses two engines to run PL/SQL blocks and subprograms. The PL/SQL engine runs procedural statements, while the SQL engine runs SQL statements. During execution, every SQL statement causes a context switch between the two engines, resulting in performance overhead.

Performance can be improved substantially by minimizing the number of context switches required to run a particular block or subprogram. When a SQL statement runs inside a loop that uses collection elements as bind variables, the large number of context switches required by the block can cause poor performance. Collections include the following:

- Varrays
- Nested tables
- Index-by tables
- Host arrays

Binding is the assignment of values to PL/SQL variables in SQL statements. **Bulk binding** is binding an entire collection at once. Bulk binds pass the entire collection back and forth between the two engines in a single operation.

Typically, using bulk binds improves performance for SQL statements that affect four or more database rows. The more rows affected by a SQL statement, the greater the performance gain from bulk binds.

> **Note:** This section provides an overview of bulk binds to help you decide if you should use them in your PL/SQL applications. For detailed information about using bulk binds, including ways to handle exceptions that occur in the middle of a bulk bind operation, refer to the *Oracle Database PL/SQL User's Guide and Reference.*

When to Use Bulk Binds

If you have scenarios like these in your applications, consider using bulk binds to improve performance.

DML Statements that Reference Collections The `FORALL` keyword can improve the performance of `INSERT`, `UPDATE`, or `DELETE` statements that reference collection elements.

For example, the following PL/SQL block increases the salary for employees whose manager's ID number is 7902, 7698, or 7839, both with and without using bulk binds:

```
DECLARE
   TYPE Numlist IS VARRAY (100) OF NUMBER;
   Id NUMLIST := NUMLIST(7902, 7698, 7839);
BEGIN

-- Efficient method, using a bulk bind
   FORALL i IN Id.FIRST..Id.LAST   -- bulk-bind the VARRAY
      UPDATE Emp_tab SET Sal = 1.1 * Sal
      WHERE Mgr = Id(i);

-- Slower method, running the UPDATE statements within a regular loop
   FOR i IN Id.FIRST..Id.LAST LOOP
      UPDATE Emp_tab SET Sal = 1.1 * Sal
      WHERE Mgr = Id(i);
   END LOOP;
END;
```

Without the bulk bind, PL/SQL sends a SQL statement to the SQL engine for each employee that is updated, leading to context switches that hurt performance.

If you have a set of rows prepared in a PL/SQL table, you can bulk-insert or bulk-update the data using a loop like:

```
FORALL i in Emp_Data.FIRST..Emp_Data.LAST
    INSERT INTO Emp_tab VALUES(Emp_Data(i));
```

SELECT Statements that Reference Collections The `BULK COLLECT INTO` clause can improve the performance of queries that reference collections.

For example, the following PL/SQL block queries multiple values into PL/SQL tables, both with and without bulk binds:

```
-- Find all employees whose manager's ID number is 7698.
DECLARE
   TYPE Var_tab IS TABLE OF VARCHAR2(20) INDEX BY BINARY_INTEGER;
   Empno VAR_TAB;
   Ename VAR_TAB;
   Counter NUMBER;
   CURSOR C IS
      SELECT Empno, Ename FROM Emp_tab WHERE Mgr = 7698;
BEGIN

-- Efficient method, using a bulk bind
    SELECT Empno, Ename BULK COLLECT INTO Empno, Ename
        FROM Emp_Tab WHERE Mgr = 7698;

-- Slower method, assigning each collection element within a loop.

   counter := 1;
   FOR rec IN C LOOP
      Empno(Counter) := rec.Empno;
      Ename(Counter) := rec.Ename;
      Counter := Counter + 1;
   END LOOP;
END;
```

You can use `BULK COLLECT INTO` with tables of scalar values, or tables of `%TYPE` values.

Without the bulk bind, PL/SQL sends a SQL statement to the SQL engine for each employee that is selected, leading to context switches that hurt performance.

FOR Loops that Reference Collections and the Returning Into Clause You can use the `FORALL` keyword along with the `BULK COLLECT INTO` keywords to improve the performance of `FOR` loops that reference collections and return DML.

For example, the following PL/SQL block updates the `Emp_tab` table by computing bonuses for a collection of employees; then it returns the bonuses in a column called `Bonlist`. The actions are performed both with and without using bulk binds:

```
DECLARE
   TYPE Emplist IS VARRAY(100) OF NUMBER;
   Empids EMPLIST := EMPLIST(7369, 7499, 7521, 7566, 7654, 7698);
   TYPE Bonlist IS TABLE OF Emp_tab.sal%TYPE;
   Bonlist_inst BONLIST;
BEGIN
   Bonlist_inst := BONLIST(1,2,3,4,5);

   FORALL i IN Empids.FIRST..empIDs.LAST
```

```
      UPDATE Emp_tab SET Bonus = 0.1 * Sal
      WHERE Empno = Empids(i)
      RETURNING Sal BULK COLLECT INTO Bonlist;

   FOR i IN Empids.FIRST..Empids.LAST LOOP
      UPDATE Emp_tab Set Bonus = 0.1 * sal
         WHERE Empno = Empids(i)
       RETURNING Sal INTO BONLIST(i);
   END LOOP;
END;
```

Without the bulk bind, PL/SQL sends a SQL statement to the SQL engine for each employee that is updated, leading to context switches that hurt performance.

Triggers

A trigger is a special kind of PL/SQL anonymous block. You can define triggers to fire before or after SQL statements, either on a statement level or for each row that is affected. You can also define `INSTEAD OF` triggers or system triggers (triggers on `DATABASE` and `SCHEMA`).

See Also: Chapter 9, "Coding Triggers"

Compiling PL/SQL Procedures for Native Execution

You can speed up PL/SQL procedures by compiling them into native code residing in shared libraries. The procedures are translated into C code, then compiled with your usual C compiler and linked into the Oracle Database process.

You can use this technique with both the supplied Oracle Database PL/SQL packages, and procedures you write yourself. You can use the `ALTER SYSTEM` or `ALTER SESSION` command, or update your initialization file, to set the parameter `PLSQL_CODE_TYPE` to the value `NATIVE` (the default setting is the value `INTERPRETED`).

Because this technique cannot do much to speed up SQL statements called from these procedures, it is most effective for compute-intensive procedures that do not spend much time executing SQL.

With Java, you can use the `ncomp` tool to compile your own packages and classes.

See Also:

- *Oracle Database PL/SQL User's Guide and Reference* for details on PL/SQL native compilation
- *Oracle Database Java Developer's Guide* for details on Java native compilation

Remote Dependencies

Dependencies among PL/SQL program units can be handled in two ways:

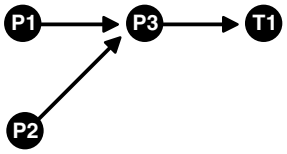
- Timestamps
- Signatures

Timestamps

If timestamps are used to handle dependencies among PL/SQL program units, then whenever you alter a program unit or a relevant schema object, all of its dependent units are marked as invalid and must be recompiled before they can be run.

Each program unit carries a timestamp that is set by the server when the unit is created or recompiled. Figure 7–1 demonstrates this graphically. Procedures `P1` and `P2` call stored procedure `P3`. Stored procedure `P3` references table `T1`. In this example, each of the procedures is dependent on table `T1`. `P3` depends upon `T1` directly, while `P1` and `P2` depend upon `T1` indirectly.

Figure 7–1 Dependency Relationships



If `P3` is altered, then `P1` and `P2` are marked as invalid immediately, if they are on the same server as `P3`. The compiled states of `P1` and `P2` contain records of the timestamp of `P3`. Therefore, if the procedure `P3` is altered and recompiled, then the timestamp on `P3` no longer matches the value that was recorded for `P3` during the compilation of `P1` and `P2`.

If `P1` and `P2` are on a client system, or on another Oracle Database instance in a distributed environment, then the timestamp information is used to mark them as invalid at runtime.

Disadvantages of the Timestamp Model

The disadvantage of this dependency model is that it is unnecessarily restrictive. Recompilation of dependent objects across the network are often performed when not strictly necessary, leading to performance degradation.

Furthermore, on the client side, the timestamp model can lead to situations that block an application from running at all, if the client-side application is built using PL/SQL version 2. Earlier releases of tools, such as Oracle Forms, that used PL/SQL version 1 on the client side did not use this dependency model, because PL/SQL version 1 had no support for stored procedures.

For releases of Oracle Forms that are integrated with PL/SQL version 2 on the client side, the timestamp model can present problems. For example, during the installation of the application, the application is rendered invalid unless the client-side PL/SQL procedures that it uses are recompiled at the client site. Also, if a client-side procedure depends on a server procedure, and if the server procedure is changed or automatically recompiled, then the client-side PL/SQL procedure must then be recompiled. Yet in many application environments (such as Forms runtime applications), there is no PL/SQL compiler available on the client. This blocks the application from running at all. The client application developer must then redistribute new versions of the application to all customers.

Signatures

To alleviate some of the problems with the timestamp-only dependency model, Oracle Database provides the additional capability of remote dependencies using signatures.

The signature capability affects only remote dependencies. Local (same server) dependencies are not affected, as recompilation is always possible in this environment.

A signature is associated with each compiled stored program unit. It identifies the unit using the following criteria:

- The name of the unit (the package, procedure, or function name).
- The types of each of the parameters of the subprogram.
- The modes of the parameters (`IN`, `OUT`, `IN OUT`).
- The number of parameters.
- The type of the return value for a function.

The user has control over whether signatures or timestamps govern remote dependencies.

> **See Also:** "Controlling Remote Dependencies" on page 7-20

When the signature dependency model is used, a dependency on a remote program unit causes an invalidation of the dependent unit if the dependent unit contains a call to a subprogram in the parent unit, and if the signature of this subprogram has been changed in an incompatible manner.

For example, consider a procedure `get_emp_name` stored on a server in Boston (`BOSTON_SERVER`). The procedure is defined as the following:

> **Note:** You may need to set up data structures, similar to the following, for certain examples to work:
>
> ```
> CONNECT system/manager
> CREATE PUBLIC DATABASE LINK boston_server USING 'inst1_alias';
> CONNECT scott/tiger
> ```

```
CREATE OR REPLACE PROCEDURE get_emp_name (
   emp_number   IN  NUMBER,
   hire_date    OUT VARCHAR2,
   emp_name     OUT VARCHAR2) AS
BEGIN
   SELECT ename, to_char(hiredate, 'DD-MON-YY')
      INTO emp_name, hire_date
      FROM emp
      WHERE empno = emp_number;
END;
```

When `get_emp_name` is compiled on `BOSTON_SERVER`, its signature, as well as its timestamp, is recorded.

Suppose that on another server in California, some PL/SQL code calls `get_emp_name` identifying it using a DBlink called `BOSTON_SERVER`, as follows:

```
CREATE OR REPLACE PROCEDURE print_ename (emp_number IN NUMBER) AS
   hire_date    VARCHAR2(12);
   ename        VARCHAR2(10);
BEGIN
   get_emp_name@BOSTON_SERVER(emp_number, hire_date, ename);
   dbms_output.put_line(ename);
   dbms_output.put_line(hire_date);
END;
```

When this California server code is compiled, the following actions take place:

- A connection is made to the Boston server.
- The signature of `get_emp_name` is transferred to the California server.
- The signature is recorded in the compiled state of `print_ename`.

At runtime, during the remote procedure call from the California server to the Boston server, the recorded signature of `get_emp_name` that was saved in the compiled state of `print_ename` gets sent to the Boston server, regardless of whether or not there were any changes.

If the timestamp dependency mode is in effect, then a mismatch in timestamps causes an error status to be returned to the calling procedure.

However, if the signature mode is in effect, then any mismatch in timestamps is ignored, and the recorded signature of `get_emp_name` in the compiled state of `Print_ename` on the California server is compared with the current signature of `get_emp_name` on the Boston server. If they match, then the call succeeds. If they do not match, then an error status is returned to the `print_name` procedure.

Note that the `get_emp_name` procedure on the Boston server could have been changed. Or, its timestamp could be different from that recorded in the `print_name` procedure on the California server, possibly due to the installation of a new release of the server. As long as the signature remote dependency mode is in effect on the California server, a timestamp mismatch does not cause an error when `get_emp_name` is called.

Note: `DETERMINISTIC`, `PARALLEL_ENABLE`, and purity information do not show in the signature mode. Optimizations based on these settings are not automatically reconsidered if a function on a remote system is redefined with different settings. This may lead to incorrect query results when calls to the remote function occur, even indirectly, in a SQL statement, or if the remote function is used, even indirectly, in a function-based index.

When Does a Signature Change?

Here is information on when a signature changes.

Switching Datatype Classes

A signature changes when you switch from one class of datatype to another. Within each datatype class, there can be several types. Changing a parameter datatype from one type to another within a class does not cause the signature to change. Datatypes that are not listed in the following table, such as `NCHAR` or `TIMESTAMP`, are not part of any class; changing their type always causes a signature mismatch.

VARCHAR types: `VARCHAR2, VARCHAR, STRING, LONG, ROWID`

Character types: `CHARACTER, CHAR`

Raw types: `RAW, LONG RAW`

Integer types: `BINARY_INTEGER, PLS_INTEGER, BOOLEAN, NATURAL, POSITIVE, POSITIVEN, NATURALN`

Number types: `NUMBER, INTEGER, INT, SMALLINT, DECIMAL, DEC, REAL, FLOAT, NUMERIC, DOUBLE PRECISION, DOUBLE PRECISION, NUMERIC`

Date types: DATE, TIMESTAMP, TIMESTAMP WITH TIME ZONE, TIMESTAMP WITH LOCAL TIME ZONE, INTERVAL YEAR TO MONTH, INTERVAL DAY TO SECOND

Modes Changing to or from an explicit specification of the default parameter mode IN does not change the signature of a subprogram. For example, changing between:

```
PROCEDURE P1 (Param1 NUMBER);
PROCEDURE P1 (Param1 IN NUMBER);
```

does not change the signature. Any other change of parameter mode *does* change the signature.

Default Parameter Values Changing the specification of a default parameter value does not change the signature. For example, procedure P1 has the same signature in the following two examples:

```
PROCEDURE P1 (Param1 IN NUMBER := 100);
PROCEDURE P1 (Param1 IN NUMBER := 200);
```

An application developer who requires that callers get the new default value must recompile the called procedure, but no signature-based invalidation occurs when a default parameter value assignment is changed.

Examples of Changing Procedure Signatures

Using the Get_emp_names procedure defined in "Parameters for Procedures and Functions" on page 7-4, if the procedure body is changed to the following:

```
DECLARE
   Emp_number  NUMBER;
   Hire_date   DATE;
BEGIN
-- date format model changes

   SELECT Ename, To_char(Hiredate, 'DD/MON/YYYY')
      INTO Emp_name, Hire_date
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
```

The specification of the procedure has not changed, so its signature has not changed.

But if the procedure specification is changed to the following:

```
CREATE OR REPLACE PROCEDURE Get_emp_name (
   Emp_number  IN  NUMBER,
   Hire_date   OUT DATE,
   Emp_name    OUT VARCHAR2) AS
```

And if the body is changed accordingly, then the signature changes, because the parameter Hire_date has a different datatype.

However, if the name of that parameter changes to When_hired, and the datatype remains VARCHAR2, and the mode remains OUT, the signature does *not* change. Changing the *name* of a formal parameter does not change the signature of the unit.

Consider the following example:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_type IS RECORD (
        Emp_number NUMBER,
```

```
        Hire_date  VARCHAR2(12),
        Emp_name   VARCHAR2(10));
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type);
END;

CREATE OR REPLACE PACKAGE BODY Emp_package AS
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type) IS
   BEGIN
       SELECT Empno, Ename, TO_CHAR(Hiredate, 'DD/MON/YY')
           INTO Emp_data
           FROM Emp_tab
           WHERE Empno = Emp_data.Emp_number;
   END;
END;
```

If the package specification is changed so that the record's field names are changed, but the types remain the same, then this does not affect the signature. For example, the following package specification has the same signature as the previous package specification example:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_type IS RECORD (
        Emp_num    NUMBER,         -- was Emp_number
        Hire_dat   VARCHAR2(12),   -- was Hire_date
        Empname    VARCHAR2(10));  -- was Emp_name
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type);
END;
```

Changing the name of the type of a parameter does not cause a change in the signature if the type remains the same as before. For example, the following package specification for `Emp_package` is the same as the first one:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_record_type IS RECORD (
        Emp_number NUMBER,
        Hire_date  VARCHAR2(12),
        Emp_name   VARCHAR2(10));
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_record_type);
END;
```

Controlling Remote Dependencies

The dynamic initialization parameter `REMOTE_DEPENDENCIES_MODE` controls whether the timestamp or the signature dependency model is in effect.

- If the initialization parameter file contains the following specification:

  ```
  REMOTE_DEPENDENCIES_MODE = TIMESTAMP
  ```

  Then only timestamps are used to resolve dependencies (if this is not explicitly overridden dynamically).

- If the initialization parameter file contains the following parameter specification:

  ```
  REMOTE_DEPENDENCIES_MODE = SIGNATURE
  ```

  Then signatures are used to resolve dependencies (if this not explicitly overridden dynamically).

- You can alter the mode dynamically by using the DDL statements. For example, this example alters the dependency model for the current session:

```
ALTER SESSION SET REMOTE_DEPENDENCIES_MODE =
    {SIGNATURE | TIMESTAMP}


Thise example alters the dependency model systemwide after startup:
ALTER SYSTEM SET REMOTE_DEPENDENCIES_MODE =
    {SIGNATURE | TIMESTAMP}
```

If the REMOTE_DEPENDENCIES_MODE parameter is not specified, either in the init.ora parameter file or using the ALTER SESSION or ALTER SYSTEM DDL statements, then timestamp is the default value. Therefore, unless you explicitly use the REMOTE_DEPENDENCIES_MODE parameter, or the appropriate DDL statement, your server is operating using the timestamp dependency model.

When you use REMOTE_DEPENDENCIES_MODE=SIGNATURE:

- If you change the default value of a parameter of a remote procedure, then the local procedure calling the remote procedure is not invalidated. If the call to the remote procedure does not supply the parameter, then the default value is used. In this case, because invalidation/recompilation does not automatically occur, the old default value is used. If you want to see the new default values, then you must recompile the calling procedure manually.
- If you add a new overloaded procedure in a package (a new procedure with the same name as an existing one), then local procedures that call the remote procedure are not invalidated. If it turns out that this overloading results in a rebinding of existing calls from the local procedure under the timestamp mode, then this rebinding does not happen under the signature mode, because the local procedure does not get invalidated. You must recompile the local procedure manually to achieve the new rebinding.
- If the types of parameters of an existing packaged procedure are changed so that the new types have the same shape as the old ones, then the local calling procedure is not invalidated or recompiled automatically. You must recompile the calling procedure manually to get the semantics of the new type.

Dependency Resolution

When REMOTE_DEPENDENCIES_MODE = TIMESTAMP (the default value), dependencies among program units are handled by comparing timestamps at runtime. If the timestamp of a called remote procedure does not match the timestamp of the called procedure, then the calling (dependent) unit is invalidated and must be recompiled. In this case, if there is no local PL/SQL compiler, then the calling application cannot proceed.

In the timestamp dependency mode, signatures are not compared. If there is a local PL/SQL compiler, then recompilation happens automatically when the calling procedure is run.

When REMOTE_DEPENDENCIES_MODE = SIGNATURE, the recorded timestamp in the calling unit is first compared to the current timestamp in the called remote unit. If they match, then the call proceeds. If the timestamps do not match, then the signature of the called remote subprogram, as recorded in the calling subprogram, is compared with the current signature of the called subprogram. If they do not match (using the criteria described in the section "When Does a Signature Change?" on page 7-18), then an error is returned to the calling session.

Suggestions for Managing Dependencies

Follow these guidelines for setting the REMOTE_DEPENDENCIES_MODE parameter:

- Server-side PL/SQL users can set the parameter to TIMESTAMP (or let it default to that) to get the timestamp dependency mode.
- Server-side PL/SQL users can choose to use the signature dependency mode if they have a distributed system and they want to avoid possible unnecessary recompilations.
- Client-side PL/SQL users should set the parameter to SIGNATURE. This allows:
  - Installation of new applications at client sites, without the need to recompile procedures.
  - Ability to upgrade the server, without encountering timestamp mismatches.
- When using signature mode on the server side, add new procedures to the end of the procedure (or function) declarations in a package specification. Adding a new procedure in the middle of the list of declarations can cause unnecessary invalidation and recompilation of dependent procedures.

Cursor Variables

A cursor is a static object; a cursor variable is a pointer to a cursor. Because cursor variables are pointers, they can be passed and returned as parameters to procedures and functions. A cursor variable can also refer to different cursors in its lifetime.

Some additional advantages of cursor variables include:

- *Encapsulation* Queries are centralized in the stored procedure that opens the cursor variable.
- *Ease of maintenance* If you need to change the cursor, then you only need to make the change in one place: the stored procedure. There is no need to change each application.
- *Convenient security* The user of the application is the username used when the application connects to the server. The user must have EXECUTE permission on the stored procedure that opens the cursor. But, the user does not need to have READ permission on the tables used in the query. This capability can be used to limit access to the columns in the table, as well as access to other stored procedures.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference* for details on cursor variables

Declaring and Opening Cursor Variables

Memory is usually allocated for a cursor variable in the client application using the appropriate ALLOCATE statement. In Pro*C, use the EXEC SQL ALLOCATE <cursor_name> statement. In OCI, use the Cursor Data Area.

You can also use cursor variables in applications that run entirely in a single server session. You can declare cursor variables in PL/SQL subprograms, open them, and use them as parameters for other PL/SQL subprograms.

Examples of Cursor Variables

This section includes several examples of cursor variable usage in PL/SQL. For additional cursor variable examples that use the programmatic interfaces, refer to the following manuals:

- *Pro*C/C++ Programmer's Guide*
- *Pro*COBOL Programmer's Guide*
- *Oracle Call Interface Programmer's Guide*
- *Oracle SQL*Module for Ada Programmer's Guide*

Fetching Data

The following package defines a PL/SQL cursor variable type `Emp_val_cv_type`, and two procedures. The first procedure, `Open_emp_cv`, opens the cursor variable using a bind variable in the `WHERE` clause. The second procedure, `Fetch_emp_data`, fetches rows from the `Emp_tab` table using the cursor variable.

```
CREATE OR REPLACE PACKAGE Emp_data AS
  TYPE Emp_val_cv_type IS REF CURSOR RETURN Emp_tab%ROWTYPE;
  PROCEDURE Open_emp_cv (Emp_cv          IN OUT Emp_val_cv_type,
                         Dept_number     IN     INTEGER);
  PROCEDURE Fetch_emp_data (emp_cv       IN     Emp_val_cv_type,
                            emp_row      OUT    Emp_tab%ROWTYPE);
END Emp_data;

CREATE OR REPLACE PACKAGE BODY Emp_data AS
  PROCEDURE Open_emp_cv (Emp_cv      IN OUT Emp_val_cv_type,
                         Dept_number IN     INTEGER) IS
  BEGIN
    OPEN emp_cv FOR SELECT * FROM Emp_tab WHERE deptno = dept_number;
  END open_emp_cv;
  PROCEDURE Fetch_emp_data (Emp_cv      IN  Emp_val_cv_type,
                            Emp_row     OUT Emp_tab%ROWTYPE) IS
  BEGIN
    FETCH Emp_cv INTO Emp_row;
  END Fetch_emp_data;
END Emp_data;
```

The following example shows how to call the `Emp_data` package procedures from a PL/SQL block:

```
DECLARE
-- declare a cursor variable
   Emp_curs Emp_data.Emp_val_cv_type;
   Dept_number Dept_tab.Deptno%TYPE;
   Emp_row Emp_tab%ROWTYPE;

BEGIN
   Dept_number := 20;
-- open the cursor using a variable
   Emp_data.Open_emp_cv(Emp_curs, Dept_number);
-- fetch the data and display it
   LOOP
     Emp_data.Fetch_emp_data(Emp_curs, Emp_row);
     EXIT WHEN Emp_curs%NOTFOUND;
     DBMS_OUTPUT.PUT(Emp_row.Ename || '  ');
     DBMS_OUTPUT.PUT_LINE(Emp_row.Sal);
   END LOOP;
```

```
END;
```

Implementing Variant Records

The power of cursor variables comes from their ability to point to different cursors. In the following package example, a discriminant is used to open a cursor variable to point to one of two different cursors:

```
CREATE OR REPLACE PACKAGE Emp_dept_data AS
  TYPE Cv_type IS REF CURSOR;
  PROCEDURE Open_cv (Cv          IN OUT cv_type,
                     Discrim     IN     POSITIVE);
END Emp_dept_data;

CREATE OR REPLACE PACKAGE BODY Emp_dept_data AS
  PROCEDURE Open_cv (Cv      IN OUT cv_type,
                     Discrim IN     POSITIVE) IS
  BEGIN
    IF Discrim = 1 THEN
      OPEN Cv FOR SELECT * FROM Emp_tab WHERE Sal > 2000;
    ELSIF Discrim = 2 THEN
      OPEN Cv FOR SELECT * FROM Dept_tab;
    END IF;
  END Open_cv;
END Emp_dept_data;
```

You can call the `Open_cv` procedure to open the cursor variable and point it to either a query on the `Emp_tab` table or the `Dept_tab` table. The following PL/SQL block shows how to fetch using the cursor variable, and then use the `ROWTYPE_MISMATCH` predefined exception to handle either fetch:

```
DECLARE
  Emp_rec  Emp_tab%ROWTYPE;
  Dept_rec Dept_tab%ROWTYPE;
  Cv       Emp_dept_data.CV_TYPE;

BEGIN
  Emp_dept_data.open_cv(Cv, 1); -- Open Cv For Emp_tab Fetch
  Fetch cv INTO Dept_rec;       -- but fetch into Dept_tab record
                                -- which raises ROWTYPE_MISMATCH
  DBMS_OUTPUT.PUT(Dept_rec.Deptno);
  DBMS_OUTPUT.PUT_LINE('  ' || Dept_rec.Loc);

EXCEPTION
  WHEN ROWTYPE_MISMATCH THEN
    BEGIN
      DBMS_OUTPUT.PUT_LINE
           ('Row type mismatch, fetching Emp_tab data...');
      FETCH Cv INTO Emp_rec;
      DBMS_OUTPUT.PUT(Emp_rec.Deptno);
      DBMS_OUTPUT.PUT_LINE('  ' || Emp_rec.Ename);
    END;
```

Handling PL/SQL Compile-Time Errors

When you use SQL*Plus to submit PL/SQL code, and when the code contains errors, you receive notification that compilation errors have occurred, but there is no immediate indication of what the errors are. For example, if you submit a standalone (or stored) procedure `PROC1` in the file `proc1.sql` as follows:

```
SQL> @proc1
```

And, if there are one or more errors in the code, then you receive a notice such as the following:

```
MGR-00072: Warning: Procedure proc1 created with compilation errors
```

In this case, use the SHOW ERRORS statement in SQL*Plus to get a list of the errors that were found. SHOW ERRORS with no argument lists the errors from the most recent compilation. You can qualify SHOW ERRORS using the name of a procedure, function, package, or package body:

```
SQL> SHOW ERRORS PROC1
SQL> SHOW ERRORS PROCEDURE PROC1
```

> **See Also:** *SQL*Plus User's Guide and Reference* for complete information about the SHOW ERRORS statement

> **Note:** Before issuing the SHOW ERRORS statement, use the SET LINESIZE statement to get long lines on output. The value 132 is usually a good choice. For example:
>
> ```
> SET LINESIZE 132
> ```

Assume that you want to create a simple procedure that deletes records from the employee table using SQL*Plus:

```
CREATE OR REPLACE PROCEDURE Fire_emp(Emp_id NUMBER) AS
   BEGIN
      DELETE FROM Emp_tab WHER Empno = Emp_id;
   END
/
```

Notice that the CREATE PROCEDURE statement has two errors: the DELETE statement has an error (the E is absent from WHERE), and the semicolon is missing after END.

After the CREATE PROCEDURE statement is entered and an error is returned, a SHOW ERRORS statement returns the following lines:

```
SHOW ERRORS;

ERRORS FOR PROCEDURE Fire_emp:
LINE/COL       ERROR
-------------- -----------------------------------------
3/27           PL/SQL-00103: Encountered the symbol "EMPNO" wh. . .
5/0            PL/SQL-00103: Encountered the symbol "END" when . . .
2 rows selected.
```

Notice that each line and column number where errors were found is listed by the SHOW ERRORS statement.

Alternatively, you can query the following data dictionary views to list errors when using any tool or application:

- USER_ERRORS
- ALL_ERRORS
- DBA_ERRORS

The error text associated with the compilation of a procedure is updated when the procedure is replaced, and it is deleted when the procedure is dropped.

Original source code can be retrieved from the data dictionary using the following views: ALL_SOURCE, USER_SOURCE, and DBA_SOURCE.

> **See Also:** *Oracle Database Reference* for more information about these data dictionary views

Handling Run-Time PL/SQL Errors

Oracle Database allows user-defined errors in PL/SQL code to be handled so that user-specified error numbers and messages are returned to the client application. After received, the client application can handle the error based on the user-specified error number and message returned by Oracle Database.

User-specified error messages are returned using the RAISE_APPLICATION_ERROR procedure. For example:

```
RAISE_APPLICATION_ERROR(Error_number, 'text', Keep_error_stack)
```

This procedure stops procedure execution, rolls back any effects of the procedure, and returns a user-specified error number and message (unless the error is trapped by an exception handler). ERROR_NUMBER must be in the range of -20000 to -20999.

Error number -20000 should be used as a generic number for messages where it is important to relay information to the user, but having a unique error number is not required. Text must be a character expression, 2 Kbytes or less (longer messages are ignored). Keep_error_stack can be TRUE if you want to add the error to any already on the stack, or FALSE if you want to replace the existing errors. By default, this option is FALSE.

> **Note:** Some of the Oracle Database packages, such as DBMS_OUTPUT, DBMS_DESCRIBE, and DBMS_ALERT, use application error numbers in the range -20000 to -20005. Refer to the descriptions of these packages for more information.

The RAISE_APPLICATION_ERROR procedure is often used in exception handlers or in the logic of PL/SQL code. For example, the following exception handler selects the string for the associated user-defined error message and calls the RAISE_APPLICATION_ERROR procedure:

```
...
WHEN NO_DATA_FOUND THEN
   SELECT Error_string INTO Message
   FROM Error_table,
   V$NLS_PARAMETERS V
   WHERE Error_number = -20101 AND Lang = v.value AND
      v.parameter = "NLS_LANGUAGE";
   Raise_application_error(-20101, Message);
...
```

> **See Also:** "Handling Errors in Remote Procedures" on page 7-28 for information on exception handling when calling remote procedures

The following section includes an example of passing a user-specified error number from a trigger to a procedure.

Declaring Exceptions and Exception Handling Routines

User-defined exceptions are explicitly defined and signaled within the PL/SQL block to control processing of errors specific to the application. When an exception is *raised* (signaled), the usual execution of the PL/SQL block stops, and a routine called an exception handler is called. Specific exception handlers can be written to handle any internal or user-defined exception.

Application code can check for a condition that requires special attention using an `IF` statement. If there is an error condition, then two options are available:

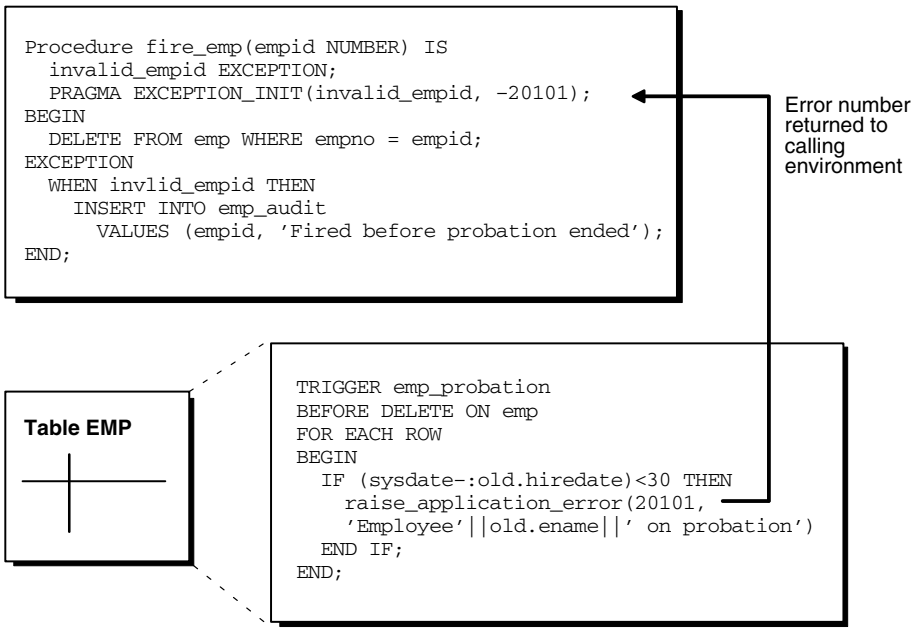
- Enter a `RAISE` statement that names the appropriate exception. A `RAISE` statement stops the execution of the procedure, and control passes to an exception handler (if any).
- Call the `RAISE_APPLICATION_ERROR` procedure to return a user-specified error number and message.

You can also define an exception handler to handle user-specified error messages. For example, Figure 7–2 on page 7-27 illustrates the following:

- An exception and associated exception handler in a procedure
- A conditional statement that checks for an error (such as transferring funds not available) and enters a user-specified error number and message within a trigger
- How user-specified error numbers are returned to the calling environment (in this case, a procedure), and how that application can define an exception that corresponds to the user-specified error number

Declare a user-defined exception in a procedure or package body (private exceptions), or in the specification of a package (public exceptions). *Define* an exception handler in the body of a procedure (standalone or package).

Figure 7–2 Exceptions and User-Defined Errors



Unhandled Exceptions

In database PL/SQL program units, an unhandled user-error condition or internal error condition that is not trapped by an appropriate exception handler causes the implicit rollback of the program unit. If the program unit includes a `COMMIT` statement before the point at which the unhandled exception is observed, then the implicit rollback of the program unit can only be completed back to the previous `COMMIT`.

Additionally, unhandled exceptions in database-stored PL/SQL program units propagate back to client-side applications that call the containing program unit. In such an application, only the application program unit call is rolled back (not the entire application program unit), because it is submitted to the database as a SQL statement.

If unhandled exceptions in database PL/SQL program units are propagated back to database applications, then the database PL/SQL code should be modified to handle the exceptions. Your application can also trap for unhandled exceptions when calling database program units and handle such errors appropriately.

Handling Errors in Distributed Queries

You can use a trigger or a stored procedure to create a distributed query. This distributed query is decomposed by the local Oracle Database instance into a corresponding number of remote queries, which are sent to the remote nodes for execution. The remote nodes run the queries and send the results back to the local node. The local node then performs any necessary post-processing and returns the results to the user or application.

If a portion of a distributed statement fails, possibly due to an integrity constraint violation, then Oracle Database returns error number `ORA-02055`. Subsequent statements, or procedure calls, return error number `ORA-02067` until a rollback or a rollback to savepoint is entered.

You should design your application to check for any returned error messages that indicates that a portion of the distributed update has failed. If you detect a failure, then you should rollback the entire transaction (or rollback to a savepoint) before allowing the application to proceed.

Handling Errors in Remote Procedures

When a procedure is run locally or at a remote location, four types of exceptions can occur:

- PL/SQL user-defined exceptions, which must be declared using the keyword `EXCEPTION`.
- PL/SQL predefined exceptions, such as `NO_DATA_FOUND`.
- SQL errors, such as `ORA-00900` and `ORA-02015`.
- Application exceptions, which are generated using the `RAISE_APPLICATION_ERROR`() procedure.

When using local procedures, all of these messages can be trapped by writing an exception handler, such as shown in the following example:

```
EXCEPTION
    WHEN ZERO_DIVIDE THEN
    /* ...handle the exception */
```

Notice that the WHEN clause requires an exception name. If the exception that is raised does not have a name, such as those generated with RAISE_APPLICATION_ERROR, then one can be assigned using PRAGMA_EXCEPTION_INIT, as shown in the following example:

```
DECLARE
    ...
    Null_salary EXCEPTION;
    PRAGMA EXCEPTION_INIT(Null_salary, -20101);
BEGIN
    ...
    RAISE_APPLICATION_ERROR(-20101, 'salary is missing');
    ...
EXCEPTION
    WHEN Null_salary THEN
        ...
```

When calling a remote procedure, exceptions are also handled by creating a local exception handler. The remote procedure must return an error number to the local calling procedure, which then handles the exception, as shown in the previous example. Because PL/SQL user-defined exceptions always return ORA-06510 to the local procedure, these exceptions cannot be handled. All other remote exceptions can be handled in the same manner as local exceptions.

Debugging Stored Procedures

Compiling a stored procedure involves fixing any syntax errors in the code. You might need to do additional debugging to make sure that the procedure works correctly, performs well, and recovers from errors. Such debugging might involve:

- Adding extra output statements to verify execution progress and check data values at certain points within the procedure.
- Running a separate debugger to analyze execution in greater detail.

Oracle JDeveloper

Recent releases of Oracle JDeveloper have extensive features for debugging PL/SQL, Java, and multi-language programs. You can get Oracle JDeveloper as part of various Oracle product suites. Often, a more recent release is available as a download at http://www.oracle.com/technology/.

Oracle Procedure Builder and TEXT_IO Package

Oracle Procedure Builder is an advanced client/server debugger that transparently debugs your database applications. It lets you run PL/SQL procedures and triggers in a controlled debugging environment, and you can set breakpoints, list the values of variables, and perform other debugging tasks. Oracle Procedure Builder is part of the Oracle Developer tool set. It also provides the TEXT_IO package that is useful for printing debug information.

DBMS_OUTPUT Package

You can also debug stored procedures and triggers using the DBMS_OUTPUT supplied package. Put PUT and PUT_LINE statements in your code to output the value of variables and expressions to your terminal.

Privileges for Debugging PL/SQL and Java Stored Procedures

Starting with Oracle Database 10*g*, a new privilege model applies to debugging PL/SQL and Java code running within the database. This model applies whether you are using Oracle JDeveloper, Oracle Developer, or any of the various third-party PL/SQL or Java development environments, and it affects both the DBMS_DEBUG and DBMS_DEBUG_JDWP APIs.

For a session to connect to a debugger, the effective user at the time of the connect operation must have the DEBUG CONNECT SESSION system privilege. This effective user may be the owner of a definer's rights routine involved in making the connect call.

When a debugger becomes connected to a session, the session login user and the currently enabled session-level roles are fixed as the privilege environment for that debugging connection. Any DEBUG or EXECUTE privileges needed for debugging must be granted to that combination of user and roles.

- To be able to display and change Java public variables or variables declared in a PL/SQL package specification, the debugging connection must be granted either EXECUTE or DEBUG privilege on the relevant code.
- To be able to either display and change private variables or breakpoint and execute code lines step by step, the debugging connection must be granted DEBUG privilege on the relevant code

> **Caution:** The DEBUG privilege effectively allows a debugging session to do anything that the procedure being debugged could have done if that action had been included in its code.

In addition to these privilege requirements, the ability to stop on individual code lines and debugger access to variables are allowed only in code compiled with debug information generated. The PLSQL_DEBUG parameter and the DEBUG keyword on commands such as ALTER PACKAGE can be used to control whether the PL/SQL compiler includes debug information in its results. If it does not, variables will not be accessible, and neither stepping nor breakpoints will stop on code lines. The PL/SQL compiler will never generate debug information for code that has been obfuscated using the PL/SQL wrap utility.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference*, "Obfuscating PL/SQL Source Code"

The DEBUG ANY PROCEDURE system privilege is equivalent to the DEBUG privilege granted on *all* objects in the database. Objects owned by SYS are included if the value of the O7_DICTIONARY_ACCESSIBILITY parameter is TRUE.

A debug role mechanism is available to carry privileges needed for debugging that are not normally enabled in the session. Refer to the documentation on the DBMS_DEBUG and DBMS_DEBUG_JDWP packages for details on how to specify a debug role and any necessary related password.

The JAVADEBUGPRIV role carries the DEBUG CONNECT SESSION and DEBUG ANY PROCEDURE privileges. Grant it only with the care those privileges warrant.

> **Caution:** Granting DEBUG ANY PROCEDURE privilege, or granting DEBUG privilege on any object owned by SYS, means granting *complete rights to the database*.

Writing Low-Level Debugging Code

If you are actually writing code that will be part of a debugger, you might need to use packages such as DBMS_DEBUG_JDWP or DBMS_DEBUG.

DBMS_DEBUG_JDWP Package

The DBMS_DEBUG_JDWP package, provided starting with Oracle9*i* Release 2, provides a framework for multi-language debugging that is expected to supersede the DBMS_DEBUG package over time. It is especially useful for programs that combine PL/SQL and Java.

DBMS_DEBUG Package

The DBMS_DEBUG package, provided starting with Oracle8*i*, implements server-side debuggers and provides a way to debug server-side PL/SQL program units. Several of the debuggers available, such as Oracle Procedure Builder and various third-party vendor solutions, use this API.

See Also:

- *Oracle Procedure Builder Developer's Guide*
- *Oracle Database PL/SQL Packages and Types Reference* for more information about the DBMS_DEBUG and DBMS_OUTPUT packages and associated privileges
- The Oracle JDeveloper documentation for information on using package DBMS_DEBUG_JDWP
- *Oracle Database SQL Reference* for more details on privileges
- The PL/SQL page at http://www.oracle.com/technology/ for information about writing low-level debug code

Calling Stored Procedures

Note: You may need to set up data structures, similar to the following, for certain examples to work:

```
CREATE TABLE Emp_tab (
   Empno    NUMBER(4) NOT NULL,
   Ename    VARCHAR2(10),
   Job      VARCHAR2(9),
   Mgr      NUMBER(4),
   Hiredate DATE,
   Sal      NUMBER(7,2),
   Comm     NUMBER(7,2),
   Deptno   NUMBER(2));

CREATE OR REPLACE PROCEDURE fire_emp1(Emp_id NUMBER) AS
   BEGIN
      DELETE FROM Emp_tab WHERE Empno = Emp_id;
   END;
VARIABLE Empnum NUMBER;
```

Procedures can be called from many different environments. For example:

- A procedure can be called within the body of another procedure or a trigger.

- A procedure can be interactively called by a user using an Oracle Database tool.
- A procedure can be explicitly called within an application, such as a SQL*Forms or a precompiler application.
- A stored function can be called from a SQL statement in a manner similar to calling a built-in SQL function, such as `LENGTH` or `ROUND`.

This section includes some common examples of calling procedures from within these environments.

> **See Also:** "Calling Stored Functions from SQL Expressions" on page 7-36

A Procedure or Trigger Calling Another Procedure

A procedure or trigger can call another stored procedure. For example, included in the body of one procedure might be the following line:

```
. . .
Sal_raise(Emp_id, 200);
. . .
```

This line calls the `Sal_raise` procedure. `Emp_id` is a variable within the context of the procedure. Recursive procedure calls are allowed within PL/SQL: A procedure can call itself.

Interactively Calling Procedures From Oracle Database Tools

A procedure can be called interactively from an Oracle Database tool, such as SQL*Plus. For example, to call a procedure named `SAL_RAISE`, owned by you, you can use an anonymous PL/SQL block, as follows:

```
BEGIN
    Sal_raise(7369, 200);
END;
```

> **Note:** Interactive tools, such as SQL*Plus, require you to follow these lines with a slash (/) to run the PL/SQL block.

An easier way to run a block is to use the SQL*Plus statement `EXECUTE`, which wraps `BEGIN` and `END` statements around the code you enter. For example:

```
EXECUTE Sal_raise(7369, 200);
```

Some interactive tools allow session variables to be created. For example, when using SQL*Plus, the following statement creates a session variable:

```
VARIABLE Assigned_empno NUMBER
```

After defined, any session variable can be used for the duration of the session. For example, you might run a function and capture the return value using a session variable:

```
EXECUTE :Assigned_empno := Hire_emp('JSMITH', 'President',
   1032, SYSDATE, 5000, NULL, 10);
PRINT Assigned_empno;
ASSIGNED_EMPNO
--------------
          2893
```

See Also:

- *SQL*Plus User's Guide and Reference*
- Your tools documentation for information about performing similar operations using your development tool

Calling Procedures within 3GL Applications

A 3GL database application, such as a precompiler or an OCI application, can include a call to a procedure within the code of the application.

To run a procedure within a PL/SQL block in an application, simply call the procedure. The following line within a PL/SQL block calls the `Fire_emp` procedure:

```
Fire_emp1(:Empnun);
```

In this case, `:Empno` is a host (bind) variable within the context of the application.

To run a procedure within the code of a precompiler application, you must use the `EXEC` call interface. For example, the following statement calls the `Fire_emp` procedure in the code of a precompiler application:

```
EXEC SQL EXECUTE
   BEGIN
      Fire_emp1(:Empnum);
   END;
END-EXEC;
```

See Also: For information about calling PL/SQL procedures from within 3GL applications:

- *Oracle Call Interface Programmer's Guide*
- *Pro*C/C++ Programmer's Guide*
- *Oracle SQL*Module for Ada Programmer's Guide*

Name Resolution When Calling Procedures

References to procedures and packages are resolved according to the algorithm described in the "Rules for Name Resolution in SQL Statements" section of Chapter 2, "Designing Schema Objects".

Privileges Required to Execute a Procedure

If you are the owner of a standalone procedure or package, then you can run the standalone procedure or packaged procedure, or any public procedure or packaged procedure at any time, as described in the previous sections. If you want to run a standalone or packaged procedure owned by another user, then the following conditions apply:

- You must have the `EXECUTE` privilege for the standalone procedure or package containing the procedure, or you must have the `EXECUTE ANY PROCEDURE` system privilege. If you are executing a remote procedure, then you must be granted the `EXECUTE` privilege or `EXECUTE ANY PROCEDURE` system privilege directly, *not* through a role.
- You must include the name of the owner in the call. For example:[1]

```
EXECUTE Jward.Fire_emp (1043);
EXECUTE Jward.Hire_fire.Fire_emp (1043);
```

- If the procedure is a **definer's-rights procedure**, then it runs with the privileges of the procedure *owner*. The owner must have all the necessary object privileges for any referenced objects.
- If the procedure is an **invoker's-rights procedure**, then it runs with your privileges (as the invoker). In this case, you also need privileges on all referenced objects; that is, all objects accessed by the procedure through external references that are resolved in your schema. You may hold these privileges directly or through a role. Roles are enabled unless an invoker's-rights procedure is called directly or indirectly by a definer's-rights procedure.

Specifying Values for Procedure Arguments

When you call a procedure, specify a value or parameter for each of the procedure's arguments. Identify the argument values using either of the following methods, or a combination of both:

- List the values in the order the arguments appear in the procedure declaration.
- Specify the argument names and corresponding values, in any order.

For example, these statements each call the procedure `Sal_raise` to increase the salary of employee number 7369 by 500:

```
Sal_raise(7369, 500);

Sal_raise(Sal_incr=>500, Emp_id=>7369);

Sal_raise(7369, Sal_incr=>500);
```

The first statement identifies the argument values by listing them in the order in which they appear in the procedure specification.

The second statement identifies the argument values by name and in an order different from that of the procedure specification. If you use argument names, then you can list the arguments in any order.

The third statement identifies the argument values using a combination of these methods. If you use a combination of order and argument names, then values identified in order must precede values identified by name.

If you used the `DEFAULT` option to define default values for `IN` parameters to a subprogram (see the *Oracle Database PL/SQL User's Guide and Reference*),then you can pass different numbers of actual parameters to the first subprogram, accepting or overriding the default values as you please. If an actual value is not passed, then the corresponding default value is used. If you want to assign a value to an argument that occurs after an omitted argument (for which the corresponding default is used), then you must explicitly designate the name of the argument, as well as its value.

Calling Remote Procedures

Call remote procedures using an appropriate database link and the procedure name. The following SQL*Plus statement runs the procedure `Fire_emp` located in the database and pointed to by the local database link named `BOSTON_SERVER`:

[1] You may need to set up the following data structures for certain examples to work: *CONNECT SYS/password AS SYSDBA;*CREATE USER Jward IDENTIFIED BY Jward;GRANT CREATE ANY PACKAGE TO Jward;GRANT CREATE SESSION TO Jward;GRANT EXECUTE ANY PROCEDURE TO Jward;CONNECT Scott/Tiger

```
EXECUTE fire_emp1@boston_server(1043);
```

> **See Also:** "Handling Errors in Remote Procedures" on page 7-28 for information on exception handling when calling remote procedures

Remote Procedure Calls and Parameter Values

You must explicitly pass values to all remote procedure parameters, even if there are defaults. You cannot access remote package variables and constants.

Referencing Remote Objects

Remote objects can be referenced within the body of a locally defined procedure. The following procedure deletes a row from the remote employee table:

```
CREATE OR REPLACE PROCEDURE fire_emp(emp_id NUMBER) IS
BEGIN
    DELETE FROM emp@boston_server WHERE empno = emp_id;
END;
```

The following list explains how to properly call remote procedures, depending on the calling environment.

- Remote procedures (standalone and packaged) can be called from within a procedure, an OCI application, or a precompiler application by specifying the remote procedure name, a database link, and the arguments for the remote procedure.

  ```
  CREATE OR REPLACE PROCEDURE local_procedure(arg IN NUMBER) AS
  BEGIN
    fire_emp1@boston_server(arg);
  END;
  ```

- In the previous example, you could create a synonym for `FIRE_EMP1@BOSTON_SERVER`. This would enable you to call the remote procedure from an Oracle Database tool application, such as a SQL*Forms application, as well from within a procedure, OCI application, or precompiler application.

  ```
  CREATE SYNONYM synonym1 for  fire_emp1@boston_server;
  CREATE OR REPLACE PROCEDURE local_procedure(arg IN NUMBER) AS
  BEGIN
    synonym1(arg);
  END;
  ```

- If you do not want to use a synonym, then you could write a local cover procedure to call the remote procedure.

  ```
  DECLARE
     arg NUMBER;
  BEGIN
     local_procedure(arg);
  END;
  ```

  Here, `local_procedure` is defined as in the first item of this list.

> **See Also:** "Synonyms for Procedures and Packages" on page 7-36

> **Caution:** Unlike stored procedures, which use compile-time binding, runtime binding is used when referencing remote procedures. The user account to which you connect depends on the database link.

All calls to remotely stored procedures are assumed to perform updates; therefore, this type of referencing always requires two-phase commit of that transaction (even if the remote procedure is read-only). Furthermore, if a transaction that includes a remote procedure call is rolled back, then the work done by the remote procedure is also rolled back.

A procedure called remotely can usually execute a `COMMIT`, `ROLLBACK`, or `SAVEPOINT` statement, the same as a local procedure. However, there are some differences in behavior:

- If the transaction was originated by a non-Oracle database, as may be the case in XA applications, these operations are not allowed in the remote procedure.
- After doing one of these operations, the remote procedure cannot start any distributed transactions of its own.
- If the remote procedure does not commit or roll back its work, the commit is done implicitly when the database link is closed. In the meantime, further calls to the remote procedure are not allowed because it is still considered to be performing a transaction.

A **distributed update** modifies data on two or more databases. A distributed update is possible using a procedure that includes two or more remote updates that access data on different databases. Statements in the construct are sent to the remote databases, and the execution of the construct succeeds or fails as a unit. If part of a distributed update fails and part succeeds, then a rollback (of the entire transaction or to a savepoint) is required to proceed. Consider this when creating procedures that perform distributed updates.

Pay special attention when using a local procedure that calls a remote procedure. If a timestamp mismatch is found during execution of the local procedure, then the remote procedure is not run, and the local procedure is invalidated.

Synonyms for Procedures and Packages

Synonyms can be created for standalone procedures and packages to do the following:

- Hide the identity of the name and owner of a procedure or package.
- Provide location transparency for remotely stored procedures (standalone or within a package).

When a privileged user needs to call a procedure, an associated synonym can be used. Because the procedures defined within a package are not individual objects (the package is the object), synonyms cannot be created for individual procedures within a package.

Calling Stored Functions from SQL Expressions

You can include user-written PL/SQL functions in SQL expressions. (You must be using PL/SQL release 2.1 or higher.) By using PL/SQL functions in SQL statements, you can do the following:

- Increase user productivity by extending SQL. Expressiveness of the SQL statement increases where activities are too complex, too awkward, or unavailable with SQL.
- Increase query efficiency. Functions used in the `WHERE` clause of a query can filter data using criteria that would otherwise need to be evaluated by the application.
- Manipulate character strings to represent special datatypes (for example, latitude, longitude, or temperature).
- Provide parallel query execution: If the query is parallelized, then SQL statements in your PL/SQL function may also be run in parallel (using the parallel query option).

Using PL/SQL Functions

PL/SQL functions must be created as top-level functions or declared within a package specification before they can be named within a SQL statement. Stored PL/SQL functions are used in the same manner as built-in Oracle functions (such as `SUBSTR` or `ABS`).

PL/SQL functions can be placed wherever an Oracle function can be placed within a SQL statement, or, wherever expressions can occur in SQL. For example, they can be called from the following:

- The select list of the `SELECT` statement.
- The condition of the `WHERE` and `HAVING` clause.
- The `CONNECT BY`, `START WITH`, `ORDER BY`, and `GROUP BY` clauses.
- The `VALUES` clause of the `INSERT` statement.
- The `SET` clause of the `UPDATE` statement.

You cannot call stored PL/SQL functions from a `CHECK` constraint clause of a `CREATE` or `ALTER TABLE` statement or use them to specify a default value for a column. These situations require an unchanging definition.

Note: Unlike functions, which are called as part of an expression, procedures are called as statements. Therefore, PL/SQL procedures are *not* directly callable from SQL statements. However, functions called from a PL/SQL statement or referenced in a SQL expression can call a PL/SQL procedure.

Syntax for SQL Calling a PL/SQL Function

Use the following syntax to reference a PL/SQL function from SQL:

```
[[schema.]package.]function_name[@dblink][(param_1...param_n)]
```

For example, to reference a function you created that is called `My_func`, in the `My_funcs_pkg` package, in the `Scott` schema, that takes two numeric parameters, you could call the following:

```
SELECT Scott.My_funcs_pkg.My_func(10,20) FROM dual;
```

Naming Conventions

If only one of the optional schema or package names is given, then the first identifier can be either a schema name or a package name. For example, to determine whether

Payroll in the reference Payroll.Tax_rate is a schema or package name, Oracle Database proceeds as follows:

- Oracle Database first checks for the Payroll package in the current schema.
- If the PAYROLL package is found in the current schema, then Oracle Database looks for a Tax_rate function in the Payroll package. If a Tax_rate function is not found in the Payroll package, then an error message is returned.
- If a Payroll package is not found, then Oracle Database looks for a schema named Payroll that contains a top-level Tax_rate function. If the Tax_rate function is not found in the Payroll schema, then an error message is returned.

You can also refer to a stored top-level function using any synonym that you have defined for it.

Name Precedence

In SQL statements, the names of database columns take precedence over the names of functions with no parameters. For example, if schema Scott creates the following two objects:

```
CREATE TABLE Emp_tab(New_sal NUMBER ...);
CREATE FUNCTION New_sal RETURN NUMBER IS ...;
```

Then, in the following two statements, the reference to New_sal refers to the column Emp_tab.New_sal:

```
SELECT New_sal FROM Emp_tab;
SELECT Emp_tab.New_sal FROM Emp_tab;
```

To access the function new_sal, enter the following:

```
SELECT Scott.New_sal FROM Emp_tab;
```

Example of Calling a PL/SQL Function from SQL For example, to call the Tax_rate PL/SQL function from schema Scott, run it against the Ss_no and sal columns in Tax_table, and place the results in the variable Income_tax, specify the following:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CREATE TABLE Tax_table (
   Ss_no  NUMBER,
   Sal    NUMBER);

CREATE OR REPLACE FUNCTION tax_rate (ssn IN NUMBER, salary IN
NUMBER) RETURN NUMBER IS
   sal_out NUMBER;
   BEGIN
      sal_out := salary * 1.1;
   END;
```

```
DECLARE
   Tax_id     NUMBER;
   Income_tax NUMBER;
BEGIN
   SELECT scott.tax_rate (Ss_no, Sal)
      INTO Income_tax
      FROM Tax_table
```

```
      WHERE Ss_no = Tax_id;
END;
```

These sample calls to PL/SQL functions are allowed in SQL expressions:

```
Circle_area(Radius)
Payroll.Tax_rate(Empno)
scott.Payroll.Tax_rate@boston_server(Dependents, Empno)
```

Arguments

To pass any number of arguments to a function, supply the arguments within the parentheses. You must use positional notation; named notation is not supported. For functions that do not accept arguments, use `()`.

Using Default Values

The stored function `Gross_pay` initializes two of its formal parameters to default values using the `DEFAULT` clause. For example:

```
CREATE OR REPLACE FUNCTION Gross_pay
    (Emp_id  IN NUMBER,
     St_hrs  IN NUMBER DEFAULT 40,
     Ot_hrs  IN NUMBER DEFAULT 0) RETURN NUMBER AS
  ...
```

When calling `Gross_pay` from a procedural statement, you can always accept the default value of `St_hrs`. This is because you can use named notation, which lets you skip parameters. For example:

```
IF Gross_pay(Eenum, Ot_hrs => Otime) > Pay_limit
THEN ...
```

However, when calling `Gross_pay` from a SQL expression, you cannot accept the default value of `St_hrs`, unless you accept the default value of `Ot_hrs`. This is because you cannot use named notation.

Privileges

To call a PL/SQL function from SQL, you must either own or have `EXECUTE` privileges on the function. To select from a view defined with a PL/SQL function, you must have `SELECT` privileges on the view. No separate `EXECUTE` privileges are necessary to select from the view.

Requirements for Calling PL/SQL Functions from SQL Expressions

To be callable from SQL expressions, a user-defined PL/SQL function must meet the following basic requirements:

- It must be a stored function, *not* a function defined within a PL/SQL block or subprogram.
- It must be a row function, *not* a column (group) function; in other words, it cannot take an entire column of data as its argument.
- All its formal parameters must be `IN` parameters; none can be an `OUT` or `IN OUT` parameter.
- The datatypes of its formal parameters must be Oracle built-in types, such as `CHAR`, `DATE`, or `NUMBER`, *not* PL/SQL types, such as `BOOLEAN`, `RECORD`, or `TABLE`.
- Its return type (the datatype of its result value) must be an Oracle built-in type.

For example, the following stored function meets the basic requirements:

> **Note:** You may need to set up the following data structures for certain examples to work:
>
> ```
> CREATE TABLE Payroll(
>  Srate             NUMBER,
>  Orate             NUMBER,
>  Acctno            NUMBER);
> ```

```
CREATE FUNCTION Gross_pay
      (Emp_id IN NUMBER,
       St_hrs IN NUMBER DEFAULT 40,
       Ot_hrs IN NUMBER DEFAULT 0) RETURN NUMBER AS
   St_rate  NUMBER;
   Ot_rate  NUMBER;

BEGIN
   SELECT Srate, Orate INTO St_rate, Ot_rate FROM Payroll
      WHERE Acctno = Emp_id;
   RETURN St_hrs * St_rate + Ot_hrs * Ot_rate;
END Gross_pay;
```

Controlling Side Effects

The **purity** of a stored subprogram (function or procedure) refers to the side effects of that subprogram on database tables or package variables. Side effects can prevent the parallelization of a query, yield order-dependent (and therefore, indeterminate) results, or require that package state be maintained across user sessions. Various side effects are not allowed when a subprogram is called from a SQL query or DML statement.

In releases prior to Oracle8*i*, Oracle Database leveraged the PL/SQL compiler to enforce restrictions during the compilation of a stored subprogram or a SQL statement. Starting with Oracle8*i*, the compile-time restrictions were relaxed, and a smaller set of restrictions are enforced during execution.

This change provides uniform support for stored subprograms written in PL/SQL, Java, and C, and it allows programmers the most flexibility possible.

Restrictions

When a SQL statement is run, checks are made to see if it is logically embedded within the execution of an already running SQL statement. This occurs if the statement is run from a trigger or from a subprogram that was in turn called from the already running SQL statement. In these cases, further checks occur to determine if the new SQL statement is safe in the specific context.

The following restrictions are enforced on subprograms:

- A subprogram called from a query or DML statement may not end the current transaction, create or rollback to a savepoint, or `ALTER` the system or session.
- A subprogram called from a query (`SELECT`) statement or from a parallelized DML statement may not execute a DML statement or otherwise modify the database.
- A subprogram called from a DML statement may not read or modify the particular table being modified by that DML statement.

These restrictions apply regardless of what mechanism is used to run the SQL statement inside the subprogram or trigger. For example:

- They apply to a SQL statement called from PL/SQL, whether embedded directly in a subprogram or trigger body, run using the native dynamic mechanism (`EXECUTE IMMEDIATE`), or run using the `DBMS_SQL` package.
- They apply to statements embedded in Java with SQLJ syntax or run using JDBC.
- They apply to statements run with OCI using the callback context from within an "external" C function.

You can avoid these restrictions if the execution of the new SQL statement is not logically embedded in the context of the already running statement. PL/SQL's autonomous transactions provide one escape (see "Autonomous Transactions" on page 2-20). Another escape is available using Oracle Call Interface (OCI) from an external C function, if you create a new connection rather than using the handle available from the `OCIExtProcContext` argument.

Declaring a Function

You can use the keywords `DETERMINISTIC` and `PARALLEL_ENABLE` in the syntax for declaring a function. These are optimization hints that inform the query optimizer and other software components about the following:

- Functions that need not be called redundantly
- Functions permitted within a parallelized query or parallelized DML statement

Only functions that are `DETERMINISTIC` are allowed in function-based indexes and in certain snapshots and materialized views.

A deterministic function depends solely on the values passed into it as arguments and does not reference or modify the contents of package variables or the database or have other side-effects. Such a function produces the same result value for any combination of argument values passed into it.

You place the `DETERMINISTIC` keyword after the return value type in a declaration of the function. For example:

```
CREATE FUNCTION F1 (P1 NUMBER) RETURN NUMBER DETERMINISTIC IS
BEGIN
  RETURN P1 * 2;
END;
```

You may place this keyword in the following places:

- On a function defined in a `CREATE FUNCTION` statement
- In a function declaration in a `CREATE PACKAGE` statement
- On a method declaration in a `CREATE TYPE` statement

You should not repeat the keyword on the function or method body in a `CREATE PACKAGE BODY` or `CREATE TYPE BODY` statement.

Certain performance optimizations occur on calls to functions that are marked `DETERMINISTIC` without any other action being required. The following features require that any function used with them be declared `DETERMINISTIC`:

- Any user-defined function used in a function-based index.
- Any function used in a materialized view, if that view is to qualify for Fast Refresh or is marked `ENABLE QUERY REWRITE`.

The preceding functions features attempt to use previously calculated results rather than calling the function when it is possible to do so.

Functions that fall in the following categories should typically be DETERMINISTIC:

- Functions used in a WHERE, ORDER BY, or GROUP BY clause
- Functions that MAP or ORDER methods of a SQL type
- Functions that in any other way help determine whether or where a row should appear in a result set

Oracle Database cannot require that you should explicitly declare functions in the preceding categories as DETERMINISTIC without breaking existing applications, but the use of the keyword might be a wise choice of style within your application.

Keep the following points in mind when you create DETERMINISTIC functions:

- The database cannot recognize if the behavior of the function is indeed deterministic. If the DETERMINISTIC keyword is applied to a function whose behavior is not truly deterministic, then the result of queries involving that function is unpredictable.
- If you change the semantics of a DETERMINISTIC function and recompile it, then existing function-based indexes and materialized views report results for the prior version of the function. Thus, if you change the semantics of a function, you must manually rebuild any dependent function-based indexes and materialized views.

> **See Also:** *Oracle Database SQL Reference* for an account of CREATE FUNCTION restrictions

Parallel Query and Parallel DML

Oracle Database's parallel execution feature divides the work of executing a SQL statement across multiple processes. Functions called from a SQL statement which is run in parallel may have a separate copy run in each of these processes, with each copy called for only the subset of rows that are handled by that process.

Each process has its own copy of package variables. When parallel execution begins, these are initialized based on the information in the package specification and body as if a new user is logging into the system; the values in package variables are not copied from the original login session. And changes made to package variables are not automatically propagated between the various sessions or back to the original session. Java STATIC class attributes are similarly initialized and modified independently in each process. Because a function can use package (or Java STATIC) variables to accumulate some value across the various rows it encounters, Oracle Database cannot assume that it is safe to parallelize the execution of all user-defined functions.

For query (SELECT) statements in Oracle Database versions prior to 8.1.5, the parallel query optimization looked to see if a function was noted as RNPS and WNPS in a PRAGMA RESTRICT_REFERENCES declaration; those functions that were marked as both RNPS and WNPS could be run in parallel. Functions defined with a CREATE FUNCTION statement had their code implicitly examined to determine if they were pure enough; parallelized execution might occur even though a pragma cannot be specified on these functions.

> **See Also:** "PRAGMA RESTRICT_REFERENCES – for Backward Compatibility" on page 7-43

For DML statements in Oracle Database versions prior to 8.1.5, the parallelization optimization looked to see if a function was noted as having all four of RNDS, WNDS,

RNPS and WNPS specified in a PRAGMA RESTRICT_REFERENCES declaration; those functions that were marked as neither reading nor writing to either the database or package variables could run in parallel. Again, those functions defined with a CREATE FUNCTION statement had their code implicitly examined to determine if they were actually pure enough; parallelized execution might occur even though a pragma cannot be specified on these functions.

Oracle Database versions 8.1.5 and later continue to parallelize those functions that earlier versions recognize as parallelizable. The PARALLEL_ENABLE keyword is the preferred way to mark your code as safe for parallel execution. This keyword is syntactically similar to DETERMINISTIC as described in "Declaring a Function" on page 7-41; it is placed after the return value type in a declaration of the function, as in:

```
CREATE FUNCTION F1 (P1 NUMBER) RETURN NUMBER PARALLEL_ENABLE IS
BEGIN
  RETURN P1 * 2;
END;
```

A PL/SQL function defined with CREATE FUNCTION may still be run in parallel without any explicit declaration that it is safe to do so, if the system can determine that it neither reads nor writes package variables nor calls any function that might do so. A Java method or C function is never seen by the system as safe to run in parallel, unless the programmer explicitly indicates PARALLEL_ENABLE on the "call specification", or provides a PRAGMA RESTRICT_REFERENCES indicating that the function is sufficiently pure.

An additional runtime restriction is imposed on functions run in parallel as part of a parallelized DML statement. Such a function is not permitted to in turn execute a DML statement; it is subject to the same restrictions that are enforced on functions that are run inside a query (SELECT) statement.

> **See Also:** "Restrictions" on page 7-40

PRAGMA RESTRICT_REFERENCES – for Backward Compatibility

In Oracle Database versions prior to 8.1.5 (Oracle8*i*), programmers used the pragma RESTRICT_REFERENCES to assert the purity level of a subprogram. In subsequent versions, use the hints parallel-enable and deterministic, instead, to communicate subprogram purity to Oracle Database.

You can remove RESTRICT_REFERENCES from your code. However, this pragma remains available for *backward compatibility* in situations where one of the following is true:

- It is impossible or impractical to edit existing code to remove RESTRICT_REFERENCES completely. If you do not remove it from a subprogram *S1* that depends on another subprogram *S2*, then RESTRICT_REFERENCES might also be needed in *S2*, so that *S1* will compile.
- Replacing RESTRICT_REFERENCES in existing code with hints parallel-enable and deterministic would negatively affect the behavior of new, dependent code. Use RESTRICT_REFERENCES to preserve the behavior of the existing code.

An existing PL/SQL application can thus continue using the pragma even on new functionality, to ease integration with the existing code. Do not use the pragma in a wholly new application.

If you use the pragma RESTRICT_REFERENCES, place it in a package specification, not in a package body. It must follow the declaration of a subprogram (function or

procedure), but it need not follow immediately. Only one pragma can reference a given subprogram declaration.

> **Note:** The pragma RESTRICT_REFERENCES applies to both functions and procedures. Purity levels are important for functions, but also for procedures that are called by functions.

To code the pragma RESTRICT_REFERENCES, use the following syntax:

```
PRAGMA RESTRICT_REFERENCES (
    Function_name, WNDS [, WNPS] [, RNDS] [, RNPS] [, TRUST] );
```

Where:

Keyword	Description
WNDS	The subprogram writes no database state (does not modify database tables).
RNDS	The subprogram reads no database state (does not query database tables).
WNPS	The subprogram writes no package state (does not change the values of packaged variables).
RNPS	The subprogram reads no package state (does not reference the values of packaged variables).
TRUST	The other restrictions listed in the pragma are not enforced; they are simply assumed to be true. This allows easy calling from functions that have RESTRICT_REFERENCES declarations to those that do not.

You can pass the arguments in any order. If any SQL statement inside the subprogram body violates a rule, then you get an error when the statement is parsed.

In the following example, the function compound neither reads nor writes database or package state; therefore, you can assert the maximum purity level. Always assert the highest purity level that a subprogram allows. That way, the PL/SQL compiler never rejects the subprogram unnecessarily.

> **Note:** You may need to set up the following data structures for certain examples here to work:
>
> ```
> CREATE TABLE Accts (
>  Yrs      NUMBER,
>  Amt      NUMBER,
>  Acctno   NUMBER,
>  Rte      NUMBER);
> ```

```
CREATE PACKAGE Finance AS  -- package specification
   FUNCTION Compound
         (Years  IN NUMBER,
          Amount IN NUMBER,
          Rate   IN NUMBER) RETURN NUMBER;
   PRAGMA RESTRICT_REFERENCES (Compound, WNDS, WNPS, RNDS, RNPS);
END Finance;

CREATE PACKAGE BODY Finance AS  --package body
   FUNCTION Compound
         (Years  IN NUMBER,
          Amount IN NUMBER,
```

```
         Rate   IN NUMBER) RETURN NUMBER IS
   BEGIN
      RETURN Amount * POWER((Rate / 100) + 1, Years);
   END Compound;
                  -- no pragma in package body
END Finance;
```

Later, you might call `compound` from a PL/SQL block, as follows:

```
DECLARE
   Interest NUMBER;
   Acct_id NUMBER;
BEGIN
   SELECT Finance.Compound(Yrs, Amt, Rte)  -- function call
   INTO   Interest
   FROM   Accounts
   WHERE  Acctno = Acct_id;
```

Using the Keyword TRUST The keyword `TRUST` in the `RESTRICT_REFERENCES` syntax allows easy calling from functions that have `RESTRICT_REFERENCES` declarations to those that do not. When `TRUST` is present, the restrictions listed in the pragma are not actually enforced, but rather are simply assumed to be true.

When calling from a section of code that is using pragmas to one that is not, there are two likely usage styles. One is to place a pragma on the routine to be called, for example on a "call specification" for a Java method. Then, calls from PL/SQL to this method will complain if the method is less restricted than the calling subprogram. For example:

```
CREATE OR REPLACE PACKAGE P1 IS
   FUNCTION F1 (P1 NUMBER) RETURN NUMBER IS
      LANGUAGE JAVA NAME 'CLASS1.METHODNAME(int) return int';
      PRAGMA RESTRICT_REFERENCES(F1,WNDS,TRUST);
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER;

   PRAGMA RESTRICT_REFERENCES(F2,WNDS);
END;

CREATE OR REPLACE PACKAGE BODY P1 IS
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER IS
   BEGIN
      RETURN F1(P1);
   END;
END;
```

Here, `F2` can call `F1`, as `F1` has been declared to be `WNDS`.

The other approach is to mark only the caller, which may then make a call to any subprogram without complaint. For example:

```
CREATE OR REPLACE PACKAGE P1a IS
   FUNCTION F1 (P1 NUMBER) RETURN NUMBER IS
      LANGUAGE JAVA NAME 'CLASS1.METHODNAME(int) return int';
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER;
   PRAGMA RESTRICT_REFERENCES(F2,WNDS,TRUST);
END;

CREATE OR REPLACE PACKAGE BODY P1a IS
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER IS
   BEGIN
      RETURN F1(P1);
```

```
   END;
END;
```

Here, F2 can call F1 because while F2 is promised to be WNDS (because TRUST is specified), the body of F2 is not actually examined to determine if it truly satisfies the WNDS restriction. Because F2 is not examined, its call to F1 is allowed, even though there is no PRAGMA RESTRICT_REFERENCES for F1.

Differences between Static and Dynamic SQL Statements. Static INSERT, UPDATE, and DELETE statements do not violate RNDS if these statements do not explicitly read any database states, such as columns of a table. However, dynamic INSERT, UPDATE, and DELETE statements *always* violate RNDS, regardless of whether or not the statements explicitly read database states.

The following INSERT violates RNDS if it is executed dynamically, but it does *not* violate RNDS if it is executed statically.

```
INSERT INTO my_table values(3, 'SCOTT');
```

The following UPDATE always violates RNDS statically and dynamically, because it explicitly reads the column name of my_table.

```
UPDATE my_table SET id=777 WHERE name='SCOTT';
```

Overloading Packaged PL/SQL Functions PL/SQL lets you **overload** packaged (but not standalone) functions: You can use the same name for different functions if their formal parameters differ in number, order, or datatype family.

However, a RESTRICT_REFERENCES pragma can apply to only one function declaration. Therefore, a pragma that references the name of overloaded functions always applies to the nearest preceding function declaration.

In this example, the pragma applies to the second declaration of valid:

```
CREATE PACKAGE Tests AS
    FUNCTION Valid (x NUMBER) RETURN CHAR;
    FUNCTION Valid (x DATE) RETURN CHAR;
    PRAGMA RESTRICT_REFERENCES (valid, WNDS);
 END;
```

Serially Reusable PL/SQL Packages

PL/SQL packages usually consume user global area (UGA) memory corresponding to the number of package variables and cursors in the package. This limits scalability, because the memory increases linearly with the number of users. The solution is to allow some packages to be marked as SERIALLY_REUSABLE (using pragma syntax).

For serially reusable packages, the package global memory is not kept in the UGA for each user; rather, it is kept in a small pool and reused for different users. This means that the global memory for such a package is only used within a unit of work. At the end of that unit of work, the memory can therefore be released to the pool to be reused by another user (after running the initialization code for all the global variables).

The unit of work for serially reusable packages is implicitly a call to the server; for example, an OCI call to the server, or a PL/SQL RPC call from a client to a server, or an RPC call from a server to another server.

Package States

The state of a nonreusable package (one not marked SERIALLY_REUSABLE) persists for the lifetime of a session. A package **state** includes global variables, cursors, and so on.

The state of a serially reusable package persists only for the lifetime of a call to the server. On a subsequent call to the server, if a reference is made to the serially reusable package, then Oracle Database creates a new *instantiation* of the serially reusable package and initializes all the global variables to NULL or to the default values provided. Any changes made to the serially reusable package state in the previous calls to the server are not visible.

Note: Creating a new instantiation of a serially reusable package on a call to the server does not necessarily imply that Oracle Database allocates memory or configures the instantiation object. Oracle Database looks for an available instantiation work area (which is allocated and configured) for this package in a least-recently used (LRU) pool in the SGA.

At the end of the call to the server, this work area is returned back to the LRU pool. The reason for keeping the pool in the SGA is that the work area can be reused across users who have requests for the same package.

Why Serially Reusable Packages?

Because the state of a non-reusable package persists for the lifetime of the session, this locks up UGA memory for the whole session. In applications, such as Oracle Office, a log-on session can typically exist for days together. Applications often need to use certain packages only for certain localized periods in the session and would ideally like to de-instantiate the package state in the middle of the session, after they are done using the package.

With SERIALLY_REUSABLE packages, application developers have a way of modelling their applications to manage their memory better for scalability. Package state that they care about only for the duration of a call to the server should be captured in SERIALLY_REUSABLE packages.

Syntax of Serially Reusable Packages

A package can be marked serially reusable by a pragma. The syntax of the pragma is:

```
PRAGMA SERIALLY_REUSABLE;
```

A package specification can be marked serially reusable, whether or not it has a corresponding package body. If the package has a body, then the body must have the serially reusable pragma, if its corresponding specification has the pragma; it cannot have the serially reusable pragma unless the specification also has the pragma.

Semantics of Serially Reusable Packages

A package that is marked SERIALLY_REUSABLE has the following properties:

- Its package variables are meant for use only within the work boundaries, which correspond to calls to the server (either OCI call boundaries or PL/SQL RPC calls to the server).

> **Note:** If the application programmer makes a mistake and depends on a package variable that is set in a previous unit of work, then the application program can fail. PL/SQL cannot check for such cases.

- A pool of package instantiations is kept, and whenever a "unit of work" needs this package, one of the instantiations is "reused", as follows:
  - The package variables are reinitialized (for example, if the package variables have default values, then those values are reinitialized).
  - The initialization code in the package body is run again.
- At the "end work" boundary, cleanup is done.
  - If any cursors were left open, then they are silently closed.
  - Some non-reusable secondary memory is freed (such as memory for collection variables or long `VARCHAR2`s).
  - This package instantiation is returned back to the pool of reusable instantiations kept for this package.
- Serially reusable packages cannot be accessed from database triggers or other PL/SQL subprograms that are called from SQL statements. If you try, then Oracle Database generates an error.

Examples of Serially Reusable Packages

This section presents a few examples of serially reusable packages.

Example 1: How Package Variables Act Across Call Boundaries This example has a serially reusable package specification (there is no body).

```
CONNECT Scott/Tiger

CREATE OR REPLACE PACKAGE Sr_pkg IS
  PRAGMA SERIALLY_REUSABLE;
  N NUMBER := 5;                -- default initialization
END Sr_pkg;
```

Suppose your Enterprise Manager (or SQL*Plus) application issues the following:

```
CONNECT Scott/Tiger

# first CALL to server
BEGIN
   Sr_pkg.N := 10;
END;

# second CALL to server
BEGIN
   DBMS_OUTPUT.PUT_LINE(Sr_pkg.N);
END;
```

This program prints:

```
5
```

Note: If the package had not had the pragma SERIALLY_REUSABLE, the program would have printed '10'.

Example 2: How Package Variables Act Across Call Boundaries This example has both a package specification and package body, which are serially reusable.

```
CONNECT Scott/Tiger

DROP PACKAGE Sr_pkg;
CREATE OR REPLACE PACKAGE Sr_pkg IS
   PRAGMA SERIALLY_REUSABLE;
   TYPE Str_table_type IS TABLE OF VARCHAR2(200) INDEX BY BINARY_INTEGER;
   Num     NUMBER        := 10;
   Str     VARCHAR2(200) := 'default-init-str';
   Str_tab STR_TABLE_TYPE;

    PROCEDURE Print_pkg;
    PROCEDURE Init_and_print_pkg(N NUMBER, V VARCHAR2);
END Sr_pkg;
CREATE OR REPLACE PACKAGE BODY Sr_pkg IS
   -- the body is required to have the pragma because the
  -- specification of this package has the pragma
  PRAGMA SERIALLY_REUSABLE;
   PROCEDURE Print_pkg IS
   BEGIN
      DBMS_OUTPUT.PUT_LINE('num: ' || Sr_pkg.Num);
      DBMS_OUTPUT.PUT_LINE('str: ' || Sr_pkg.Str);
      DBMS_OUTPUT.PUT_LINE('number of table elems: ' || Sr_pkg.Str_tab.Count);
      FOR i IN 1..Sr_pkg.Str_tab.Count LOOP
         DBMS_OUTPUT.PUT_LINE(Sr_pkg.Str_tab(i));
      END LOOP;
   END;
   PROCEDURE Init_and_print_pkg(N NUMBER, V VARCHAR2) IS
   BEGIN
   -- init the package globals
      Sr_pkg.Num := N;
      Sr_pkg.Str := V;
      FOR i IN 1..n LOOP
         Sr_pkg.Str_tab(i) := V || ' ' || i;
   END LOOP;
   -- print the package
   Print_pkg;
   END;
 END Sr_pkg;

SET SERVEROUTPUT ON;

Rem SR package access in a CALL:

BEGIN
   -- initialize and print the package
   DBMS_OUTPUT.PUT_LINE('Initing and printing pkg state..');
   Sr_pkg.Init_and_print_pkg(4, 'abracadabra');
   -- print it in the same call to the server.
   -- we should see the initialized values.
   DBMS_OUTPUT.PUT_LINE('Printing package state in the same CALL...');
   Sr_pkg.Print_pkg;
END;
```

```
Initing and printing pkg state..
num: 4
str: abracadabra
number of table elems: 4
abracadabra 1
abracadabra 2
abracadabra 3
abracadabra 4
Printing package state in the same CALL...
num: 4
str: abracadabra
number of table elems: 4
abracadabra 1
abracadabra 2
abracadabra 3
abracadabra 4

REM SR package access in subsequent CALL:
BEGIN
   -- print the package in the next call to the server.
   -- We should that the package state is reset to the initial (default) values.
   DBMS_OUTPUT.PUT_LINE('Printing package state in the next CALL...');
   Sr_pkg.Print_pkg;
END;
Statement processed.
Printing package state in the next CALL...
num: 10
str: default-init-str
number of table elems: 0
```

Example 3: Open Cursors in Serially Reusable Packages at Call Boundaries This example demonstrates that any open cursors in serially reusable packages get closed automatically at the end of a work boundary (which is a call). Also, in a new call, these cursors need to be opened again.

```
REM  For serially reusable pkg: At the end work boundaries
REM  (which is currently the OCI call boundary) all open
REM  cursors will be closed.
REM
REM  Because the cursor is closed - every time we fetch we
REM  will start at the first row again.

CONNECT Scott/Tiger
DROP PACKAGE  Sr_pkg;
DROP TABLE People;
CREATE TABLE People (Name VARCHAR2(20));
INSERT INTO  People  VALUES ('ET');
INSERT INTO  People  VALUES ('RAMBO');
CREATE OR REPLACE PACKAGE Sr_pkg IS
   PRAGMA SERIALLY_REUSABLE;
   CURSOR C IS SELECT Name FROM People;
END Sr_pkg;
SQL> SET SERVEROUTPUT ON;
SQL>
CREATE OR REPLACE PROCEDURE Fetch_from_cursor IS
Name VARCHAR2(200);
BEGIN
   IF (Sr_pkg.C%ISOPEN) THEN
      DBMS_OUTPUT.PUT_LINE('cursor is already open.');
   ELSE
```

```
      DBMS_OUTPUT.PUT_LINE('cursor is closed; opening now.');
      OPEN Sr_pkg.C;
   END IF;
   -- fetching from cursor.
   FETCH sr_pkg.C INTO name;
   DBMS_OUTPUT.PUT_LINE('fetched: ' || Name);
   FETCH Sr_pkg.C INTO name;
   DBMS_OUTPUT.PUT_LINE('fetched: ' || Name);
   -- Oops forgot to close the cursor (Sr_pkg.C).
   -- But, because it is a Serially Reusable pkg's cursor,
   -- it will be closed at the end of this CALL to the server.
END;
EXECUTE fetch_from_cursor;
cursor is closed; opening now.
fetched: ET
fetched: RAMBO
```

Returning Large Amounts of Data from a Function

In a data warehousing environment, you might use a PL/SQL function to transform large amounts of data. Perhaps the data is passed through a series of transformations, each performed by a different function. PL/SQL table functions let you perform such transformations without significant memory overhead or the need to store the data in tables between each transformation stage. These functions can accept and return multiple rows, can return rows as they are ready rather than all at once, and can be parallelized.

In this technique:

- The producer function uses the `PIPELINED` keyword in its declaration.
- The producer function uses an `OUT` parameter that is a record, corresponding to a row in the result set.
- As each output record is completed, it is sent to the consumer function using the `PIPE ROW` keyword.
- The producer function ends with a `RETURN` statement that does not specify any return value.
- The consumer function or SQL statement uses the `TABLE` keyword to treat the resulting rows like a regular table.

For example:

```
CREATE FUNCTION StockPivot(p refcur_pkg.refcur_t) RETURN TickerTypeSet PIPELINED
IS
  out_rec TickerType := TickerType(NULL,NULL,NULL);
  in_rec p%ROWTYPE;
BEGIN
  LOOP
-- Function accepts multiple rows through a REF CURSOR argument.
    FETCH p INTO in_rec;
    EXIT WHEN p%NOTFOUND;
-- Return value is a record type that matches the table definition.
    out_rec.ticker := in_rec.Ticker;
    out_rec.PriceType := 'O';
    out_rec.price := in_rec.OpenPrice;
-- Once a result row is ready, we send it back to the calling program,
-- and continue processing.
    PIPE ROW(out_rec);
```

```
-- This function outputs twice as many rows as it receives as input.
    out_rec.PriceType := 'C';
    out_rec.Price := in_rec.ClosePrice;
    PIPE ROW(out_rec);
  END LOOP;
  CLOSE p;
-- The function ends with a RETURN statement that does not specify any value.
  RETURN;
END;
/

-- Here we use the result of this function in a SQL query.
SELECT * FROM TABLE(StockPivot(CURSOR(SELECT * FROM StockTable)));

-- Here we use the result of this function in a PL/SQL block.
DECLARE
  total NUMBER := 0;
  price_type VARCHAR2(1);
BEGIN
  FOR item IN (SELECT * FROM TABLE(StockPivot(CURSOR(SELECT * FROM StockTable))))
  LOOP
-- Access the values of each output row.
-- We know the column names based on the declaration of the output type.
-- This computation is just for illustration.
    total := total + item.price;
    price_type := item.price_type;
  END LOOP;
END;
/
```

Coding Your Own Aggregate Functions

To analyze a set of rows and compute a result value, you can code your own aggregate function that works the same as a built-in aggregate like `SUM`:

- Define a SQL object type that defines these member functions:
  - `ODCIAggregateInitialize`
  - `ODCIAggregateIterate`
  - `ODCIAggregateMerge`
  - `ODCIAggregateTerminate`
- Code the member functions. In particular, `ODCIAggregateIterate` accumulates the result as it is called once for each row that is processed. Store any intermediate results using the attributes of the object type.
- Create the aggregate function, and associate it with the new object type.
- Call the aggregate function from SQL queries, DML statements, or other places that you might use the built-in aggregates. You can include typical options such as `DISTINCT` and `ALL` in the calls to the aggregate function.

> **See Also:** *Oracle Database Data Cartridge Developer's Guide* for details of this process and the requirements for the member functions

8

Coding Dynamic SQL

This chapter covers the following topics:

What Is Dynamic SQL?

Unlike static SQL, which remains the same in each execution, dynamic SQL enables you to build SQL statements as character strings at runtime. The strings contain the text of a SQL statement or PL/SQL block and can also contain placeholders for bind arguments.

You can create general purpose, flexible applications with dynamic SQL because the full text of a SQL statement may be unknown at compilation. You can use dynamic SQL in several different development environments, including PL/SQL, Pro*C/C++, and Java.

For an example of an application that uses dynamic SQL, suppose that a reporting application in a data warehouse environment does not know a table name until runtime. These tables are named according to the starting month and year of the quarter, for example, `inv_01_2003`, `inv_04_2003`, `inv_07_2003`, `inv_10_2003`, `inv_01_2004`, and so on. You can use dynamic SQL in your reporting application to specify the table name at runtime.

In a different example, suppose that you want to run a complex query with a user-selectable sort order. Instead of coding the query twice with a different `ORDER BY` clause in each query, you can construct the query dynamically to include a specified `ORDER BY` clause.

Programming with Dynamic SQL

For the sake of consistency, this chapter discusses dynamic SQL mainly from the perspective of PL/SQL. To process most dynamic SQL statements, you use the `EXECUTE IMMEDIATE` statement. To process a multi-row query in a PL/SQL procedure, you use the `OPEN-FOR`, `FETCH`, and `CLOSE` statements.

Oracle Database enables you to implement dynamic SQL in a PL/SQL application in the following ways:

- Using native dynamic SQL, which involves placing dynamic SQL statements directly into PL/SQL blocks
- Calling procedures in the `DBMS_SQL` package

Although this chapter discusses PL/SQL support for dynamic SQL, you can call dynamic SQL from other languages:

- If you use C/C++, you can call dynamic SQL with the Oracle Call Interface (OCI), or you can use the Pro*C/C++ precompiler to add dynamic SQL extensions to your C code.
- If you use COBOL, you can use the Pro*COBOL precompiler to add dynamic SQL extensions to your COBOL code.
- If you use Java, you can develop applications that use dynamic SQL with JDBC.

If you have a program that uses OCI, Pro*C/C++, or Pro*COBOL to execute dynamic SQL, consider switching to native dynamic SQL inside PL/SQL stored procedures and functions. The network round-trips required to perform dynamic SQL operations from client-side applications might hurt performance. Stored procedures can reside on the server, eliminating network overhead. You can call the PL/SQL stored procedures and stored functions from the OCI, Pro*C/C++, or Pro*COBOL application.

> **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for details about the `DBMS_SQL` package. To learn about calling Oracle Database stored procedures and stored functions from languages other than PL/SQL, consult the following resources:
>
> - *Oracle Call Interface Programmer's Guide*
> - *Pro*C/C++ Programmer's Guide*
> - *Pro*COBOL Programmer's Guide*

Why Use Dynamic SQL?

Dynamic SQL and static SQL both have advantages and disadvantages. The full text of static SQL statements is known at compilation, which provides the following benefits:

- Successful compilation verifies that the SQL statements reference valid database objects and that the necessary privileges are in place to access the objects.
- Performance of static SQL is generally better than dynamic SQL.

Despite these advantages, static SQL has limitations that can be overcome with dynamic SQL, as in the following cases:

- You do not know the full text of the SQL statements that must be executed in a PL/SQL procedure. These SQL statements may depend on user input or on processing work performed by the program.
- You want to execute DDL statements and other SQL statements that are not supported in purely static SQL programs.
- You want to write a program that can handle changes in data definitions without the need to recompile. Dynamic SQL is more flexible than static SQL because it enables you to write reusable code that can be adapted for different environments.

As a general rule you should use dynamic SQL only if you cannot use static SQL to accomplish your goals, or if using static SQL is too cumbersome. The following sections describe typical situations in which you should use dynamic SQL:

- Executing DDL and SCL Statements in PL/SQL
- Executing Dynamic Queries
- Referencing Database Objects that Do Not Exist at Compilation
- Optimizing Execution Dynamically
- Executing Dynamic PL/SQL Blocks
- Performing Dynamic Operations Using Invoker's Rights

Executing DDL and SCL Statements in PL/SQL

Only dynamic SQL can execute the following types of statements within PL/SQL program units:

- Data definition language (DDL) statements such as `CREATE`, `DROP`, `GRANT`, and `REVOKE`
- Session control language (SCL) statements such as `ALTER SESSION` and `SET ROLE`
- The `TABLE` clause in the `SELECT` statement

The following native dynamic SQL example uses a `SELECT` statement with the `TABLE` clause.

Example 8–1 Using SELECT . . . TABLE in Dynamic SQL

```
-- Create an object t_emp and a datatype t_emplist as a table of type t_emp
CREATE TYPE t_emp AS OBJECT (id NUMBER, name VARCHAR2(20))
/
CREATE TYPE t_emplist AS TABLE OF t_emp
/
-- Create a table with a nested table of type t_emplist
CREATE TABLE dept_new (id NUMBER, emps t_emplist)
  NESTED TABLE emps STORE AS emp_table;
-- Populate the dept_new table with data
INSERT INTO dept_new VALUES
(
  10,
  t_emplist
  (
    t_emp(1, 'SCOTT'),
    t_emp(2, 'BRUCE')
  )
);
-- Write a PL/SQL block that queries table dept_new and nested table emps
-- SELECT ... FROM ... TABLE is not allowed in static SQL in PL/SQL
DECLARE
  v_deptid  NUMBER;
  v_ename   VARCHAR2(20);
BEGIN
  EXECUTE IMMEDIATE 'SELECT d.id, e.name
                     FROM dept_new d, TABLE(d.emps) e
                     WHERE e.id = 1'
  INTO v_deptid, v_ename;
END;
/
```

See Also: *Oracle Database SQL Reference* for information about DDL and SCL statements

Executing Dynamic Queries

You can use dynamic SQL to create applications that execute dynamic queries whose full text is not available until runtime. Many types of applications need to use dynamic queries, including applications that do the following:

- Allow users to input or choose query search or sorting criteria at runtime
- Allow users to input or choose optimizer hints at run time
- Query a database where the data definitions of tables are constantly changing
- Query a database where new tables are created often

See Also: "Querying with Dynamic SQL: Example" on page 8-14 and "Developing with Native Dynamic SQL: Scenario" on page 8-7

Referencing Database Objects that Do Not Exist at Compilation

Many applications must interact with data that is generated periodically. For example, an application knows the table definitions at compile time, but not the table names. Dynamic SQL enables you to specify table names at runtime.

In the sample data warehouse application discussed in "What Is Dynamic SQL?" on page 8-1, the system generates new tables every quarter. You could allow a user to specify the name of the table at runtime with a dynamic SQL query similar to the following sample procedure.

Example 8–2 Dynamically Specifying a Table Name

```
CREATE OR REPLACE PROCEDURE query_invoice
  (p_month VARCHAR2, p_year VARCHAR2)
IS
  TYPE cur_typ IS REF CURSOR;
  v_inv_cursor cur_typ; -- Declare a cursor variable
  v_inv_query  VARCHAR2(200);
  v_inv_num    NUMBER;
  v_inv_cust   VARCHAR2(20);
  v_inv_amt    NUMBER;
BEGIN
  -- Write dynamic query receiving month and year as parameters
  -- and using these values to form the table name, for example, inv_APR_2004
  v_inv_query := 'SELECT num, cust, amt FROM inv_'
                 || p_month
                 || '_'
                 || p_year
                 || ' WHERE v_inv_num = :g_id';
  -- Open a cursor variable
  OPEN v_inv_cursor FOR v_inv_query USING v_inv_num;
  -- Fetch row into variables
    LOOP
      FETCH v_inv_cursor
        INTO v_inv_num, v_inv_cust, v_inv_amt;
      EXIT WHEN v_inv_cursor%NOTFOUND;
      -- process row here
    END LOOP;
  CLOSE v_inv_cursor;
END;
```

```
/
```

Optimizing Execution Dynamically

You can use dynamic SQL to build a SQL statement that optimizes execution by concatenating hints into a dynamic SQL statement. This technique enables you change the hints based on your current database statistics without recompiling. The following sample procedure uses a variable called `p_hint` to allow users to pass a hint option to the `SELECT` statement.

Example 8–3 Concatenating Hints

```
CREATE OR REPLACE PROCEDURE query_emp
  (p_hint VARCHAR2)
IS
  TYPE cur_typ IS REF CURSOR;
  v_emp_cursor cur_typ;
BEGIN
  OPEN v_emp_cursor FOR 'SELECT '
                        || p_hint
                        ||' empno, ename, sal, job FROM emp WHERE empno = 7566';
  -- process ...
  CLOSE v_emp_cursor;
END;
/
```

In Example 8–3, the user can pass values such as the following for `p_hint`:

```
p_hint = '/*+ ALL_ROWS */'
p_hint = '/*+ FIRST_ROWS */'
p_hint = '/*+ CHOOSE */'
```

> **See Also:** *Oracle Database Performance Tuning Guide* to learn more about using hints

Executing Dynamic PL/SQL Blocks

You can use the `EXECUTE IMMEDIATE` statement to execute anonymous PL/SQL blocks. In this way you can add flexibility by constructing the contents of the block at runtime.

For example, suppose that you want to write an application that takes an event number and dispatches it to a handler for the event. The name of the handler is in the form `EVENT_HANDLER_`*event_num*, where *event_num* is the number of the event. One approach is to implement the dispatcher as a switch statement, where the code handles each event by making a static call to its appropriate handler. This code is not very extensible because the dispatcher code must be updated whenever a handler for a new event is added.

Example 8–4 Event Dispatching with Static SQL

```
CREATE OR REPLACE PROCEDURE event_handler_1
  (p_handle NUMBER)
IS
BEGIN
  -- process event 1
  RETURN;
END;
/
```

```
CREATE OR REPLACE PROCEDURE event_handler_2
  (p_handle NUMBER)
IS
BEGIN
  -- process event 2
  RETURN;
END;
/

CREATE OR REPLACE PROCEDURE event_handler_3
  (p_handle NUMBER)
IS
BEGIN
  -- process event 3
  RETURN;
END;
/

CREATE OR REPLACE PROCEDURE event_dispatcher
  (p_event_num NUMBER, p_handle NUMBER)
IS
BEGIN
  IF (p_event_num = 1) THEN
    EVENT_HANDLER_1(p_handle);
  ELSIF (p_event_num = 2) THEN
    EVENT_HANDLER_2(p_handle);
  ELSIF (p_event_num = 3) THEN
    EVENT_HANDLER_3(p_handle);
  END IF;
END;
/
```

By using native dynamic SQL, you can write a smaller, more flexible event dispatcher as shown in the following example.

Example 8–5 Event Dispatching with Native Dynamic SQL

```
CREATE OR REPLACE PROCEDURE event_dispatcher
   (p_event_num NUMBER, p_handle NUMBER)
IS
BEGIN
  EXECUTE IMMEDIATE
    'BEGIN
       EVENT_HANDLER_' || TO_CHAR(p_event_num) || '(:1);
     END;'
  USING p_handle;
END;
/
```

Performing Dynamic Operations Using Invoker's Rights

By using the invoker's rights feature with dynamic SQL, you can build applications that issue dynamic SQL statements under the privileges and schema of the invoker. These two features—invoker's rights and dynamic SQL—enable you to build reusable application subcomponents that can operate on and access the invoker's data and modules.

> **See Also:** *Oracle Database PL/SQL User's Guide and Reference* to learn about invoker's rights and native dynamic SQL

Developing with Native Dynamic SQL: Scenario

This scenario shows you how to perform the following operations with native dynamic SQL:

- Execute DDL and DML operations.
- Execute single row and multiple row queries.

The database in this scenario is used for human resources. A master table named `offices` contains the list of all company locations. The `offices` table has the following definition:

```
Column_Name             Null?           Type
LOCATION                NOT_NULL        VARCHAR2(200)
```

Multiple `emp_`*location* tables contain the employee information, where *location* is the name of city where the office is located. For example, a table named `emp_houston` contains employee information for the company's Houston office, whereas a table named `emp_boston` contains employee information for the company's Boston office.

Each `emp_`*location* table has the following definition:

```
Column_Name             Null?           Type
EMPNO                   NOT_NULL        NUMBER(4)
ENAME                   NOT_NULL        VARCHAR2(10)
JOB                     NOT_NULL        VARCHAR2(9)
SAL                     NOT_NULL        NUMBER(7,2)
DEPTNO                  NOT_NULL        NUMBER(2)
```

The following sections describe various native dynamic SQL operations that can be performed on the data in the `hr` database.

Sample DML Operation Using Native Dynamic SQL

The following native dynamic SQL procedure gives a raise to all employees with a particular job title.

Example 8–6 Performing DML in Native Dynamic SQL

```
CREATE OR REPLACE PROCEDURE salary_raise
  (p_raise_percent NUMBER, p_job VARCHAR2)
IS
  TYPE loc_array_type IS TABLE OF VARCHAR2(40)
    INDEX BY binary_integer;
  v_dml_str VARCHAR2(200);
  v_loc_array loc_array_type;
BEGIN
  -- bulk fetch the list of office locations
  SELECT location BULK COLLECT
    INTO v_loc_array
  FROM offices;
  -- for each location, give a raise to employees with the given 'job'
  FOR i IN v_loc_array.first..v_loc_array.last LOOP
    v_dml_str := 'UPDATE emp_'
                 || v_loc_array(i)
                 || ' SET sal = sal * (1+(:p_raise_percent/100))'
                 || ' WHERE p_job = :g_job_title';
    EXECUTE IMMEDIATE v_dml_str USING p_raise_percent, p_job;
  END LOOP;
END;
/
```

```
SHOW ERRORS;
```

Sample DDL Operation Using Native Dynamic SQL

The EXECUTE IMMEDIATE statement can perform DDL operations. For example, the following procedure adds an office location.

Example 8–7 Creating a Table with Native Dynamic SQL

```
CREATE OR REPLACE PROCEDURE add_location
  (p_loc VARCHAR2)
IS
BEGIN
  -- Insert new location in master table, for example, detroit
  INSERT INTO offices VALUES (p_loc);
  -- Create an employee information table
  EXECUTE IMMEDIATE
  -- Use the parameter value to concatenate the table name, as in emp_detroit
    'CREATE TABLE emp_'
    || p_loc
    || '(
           empno   NUMBER(4) NOT NULL,
           ename   VARCHAR2(10),
           job     VARCHAR2(9),
           sal     NUMBER(7,2),
           deptno  NUMBER(2)
       )';
END;
/
SHOW ERRORS;
```

The following procedure uses the same concatenation technique to drop a table.

Example 8–8 Dropping a Table with Native Dynamic SQL

```
CREATE OR REPLACE PROCEDURE drop_location
  (p_loc VARCHAR2)
IS
BEGIN
  -- Drop the employee table for location 'p_loc', for example, emp_detroit
  EXECUTE IMMEDIATE 'DROP TABLE ' || 'emp_' || p_loc;
  -- Remove location from master table
  DELETE FROM offices WHERE location = p_loc;
END;
/
SHOW ERRORS;
```

Sample Single-Row Query Using Native Dynamic SQL

The EXECUTE IMMEDIATE statement can perform dynamic single-row queries. You can specify bind variables in the USING clause and fetch the resulting row into the target specified in the INTO clause of the statement. The following function retrieves the number of employees at a particular location performing a specified job.

Example 8–9 Performing Single-Row Queries in Native Dynamic SQL

```
CREATE OR REPLACE FUNCTION get_num_of_employees
  (p_loc VARCHAR2, p_job VARCHAR2)
RETURN NUMBER
IS
  v_query_str VARCHAR2(1000);
```

```
  v_num_of_employees NUMBER;
BEGIN
  -- Use concatenation to form the table name in the SELECT statement
  v_query_str := 'SELECT COUNT(*) FROM emp_'
                 || p_loc
                 || ' WHERE job = :1';
  -- Execute the query and put the result row in a variable
  EXECUTE IMMEDIATE v_query_str
    INTO v_num_of_employees
    USING p_job;
  RETURN v_num_of_employees;
END;
/
SHOW ERRORS;
```

Sample Multiple-Row Query with Native Dynamic SQL

The OPEN-FOR, FETCH, and CLOSE statements can perform dynamic multiple-row queries. For example, the following procedure lists all of the employees with a particular job at a specified location.

Example 8–10 Performing Multiple-Row Queries with Dynamic SQL

```
CREATE OR REPLACE PROCEDURE list_employees
  (p_loc VARCHAR2, p_job VARCHAR2)
IS
  TYPE cur_typ IS REF CURSOR;
  -- Define a cursor variable
  v_emp_cursor  cur_typ;
  v_query_str   VARCHAR2(1000);
  v_emp_name    VARCHAR2(20);
  v_emp_num     NUMBER;
BEGIN
  -- Use concatenation to form the SELECT statement
  v_query_str := 'SELECT ename, empno FROM emp_'
                 || p_loc
                 || ' WHERE job = :g_job_title';
  -- Open a cursor variable for the query
  OPEN v_emp_cursor FOR v_query_str USING p_job;
    -- Loop through each row to find employees who perform the specified job
    LOOP
      -- Fetch the employee name and ID into variables
      FETCH v_emp_cursor INTO v_emp_name, v_emp_num;
      EXIT WHEN v_emp_cursor%NOTFOUND;
      -- Process row here
    END LOOP;
  CLOSE v_emp_cursor;
END;
/
SHOW ERRORS;
```

Choosing Between Native Dynamic SQL and the DBMS_SQL Package

Oracle Database provides two methods for using dynamic SQL within PL/SQL: native dynamic SQL and the DBMS_SQL package. Each method has advantages and disadvantages. The following sections provide detailed information about the advantages of both methods.

Native dynamic SQL enables you to place dynamic SQL statements directly into PL/SQL code. These dynamic statements include the following:

- Queries and DML statements
- PL/SQL anonymous blocks
- DDL statements
- Transaction control statements
- Session control statements

To process most native dynamic SQL statements, use the `EXECUTE IMMEDIATE` statement. To process a multi-row `SELECT` statement, use `OPEN-FOR`, `FETCH`, and `CLOSE` statements.

Note: To use native dynamic SQL, you must set the `COMPATIBLE` initialization parameter to 8.1.0 or higher.

As an alternative to native dynamic SQL, the `DBMS_SQL` package offers a PL/SQL API to execute dynamic SQL statements. For example, the `DBMS_SQL` package contains procedures to do the following:

- Open a cursor
- Parse a cursor
- Supply binds

Programs that use the `DBMS_SQL` package make calls to this package to perform dynamic SQL operations.

See Also:

- *Oracle Database PL/SQL User's Guide and Reference* to learn about native dynamic SQL
- *Oracle Database PL/SQL Packages and Types Reference* to learn about the `DBMS_SQL` package
- *Oracle Database Upgrade Guide* to learn about the `COMPATIBLE` initialization parameter

Advantages of Native Dynamic SQL

Native dynamic SQL provides the following advantages over the `DBMS_SQL` package:

- Native Dynamic SQL is Easy to Use
- Native Dynamic SQL is Faster than DBMS_SQL
- Native Dynamic SQL Supports User-Defined Types
- Native Dynamic SQL Supports Fetching into Records

Native Dynamic SQL is Easy to Use

Because native dynamic SQL is integrated with SQL, you can use it in the same way that you use static SQL within PL/SQL code. Native dynamic SQL code is typically more compact and readable than equivalent code that uses the `DBMS_SQL` package.

With the DBMS_SQL package you must call many procedures and functions in a strict sequence, which means that even simple operations require extensive code. You can avoid this complexity by using native dynamic SQL instead.

Table 8–1 illustrates the difference in the amount of code required to perform the same operation with the DBMS_SQL package and native dynamic SQL.

Table 8–1 Code Comparison of DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL Package	Native Dynamic SQL

CREATE OR REPLACE PROCEDURE insert_into_table
  (p_table_name VARCHAR2, p_deptnumber NUMBER,
  p_deptname VARCHAR2, p_location VARCHAR2)
IS
  v_cur_hdl INTEGER;
  v_stmt_str VARCHAR2(200);
  v_rows_processed BINARY_INTEGER;
 	
BEGIN
  v_stmt_str := 'INSERT INTO '
  || p_table_name
  || ' VALUES (:g_deptno, :g_dname, :g_loc)';
  v_cur_hdl := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(v_cur_hdl, v_stmt_str,
  DBMS_SQL.NATIVE);
  DBMS_SQL.BIND_VARIABLE (v_cur_hdl,':g_deptno',
  p_deptnumber);
  DBMS_SQL.BIND_VARIABLE (v_cur_hdl, ':g_dname',
  p_deptname);
  DBMS_SQL.BIND_VARIABLE (v_cur_hdl, ':g_loc',
  p_location);
  v_rows_processed := DBMS_SQL.EXECUTE(v_cur_hdl);
  DBMS_SQL.CLOSE_CURSOR(v_cur_hdl);
END;
/
	CREATE OR REPLACE PROCEDURE insert_into_table
	 (p_table_name VARCHAR2, p_deptnumber NUMBER,
	  p_deptname VARCHAR2, p_location VARCHAR2)
	IS
	  v_stmt_str VARCHAR2(200);
	
	BEGIN
	  v_stmt_str := 'INSERT INTO '
	  || p_table_name
	  || ' VALUES (:g_deptno, :g_dname, :g_loc)';
	  EXECUTE IMMEDIATE v_stmt_str
	  USING p_deptnumber, p_deptname,
	  p_location;
	
	END;
	/

Native Dynamic SQL is Faster than DBMS_SQL

Native dynamic SQL in PL/SQL performs comparably to static SQL because the PL/SQL interpreter has built-in support. Programs that use native dynamic SQL are much faster than programs that use the DBMS_SQL package. Typically, native dynamic SQL statements perform 1.5 to 3 times better than equivalent DBMS_SQL calls. Of course, performance gains may vary depending on your application.

Native dynamic SQL bundles the statement preparation, binding, and execution steps into a single operation, which minimizes the data copying and procedure call overhead and improves performance.

The DBMS_SQL package is based on a procedural API and incurs high procedure call and data copy overhead. Each time you bind a variable, the DBMS_SQL package copies the PL/SQL bind variable into its space for use during execution. Each time you execute a fetch, the data is copied into the space managed by the DBMS_SQL package and then the fetched data is copied, one column at a time, into the appropriate PL/SQL variables, resulting in substantial overhead.

Improving Performance Through Bind Variables When using either native dynamic SQL or the DBMS_SQL package, you can improve performance by using bind variables because bind variables allow Oracle Database to share a single cursor for multiple SQL statements.

In Example 8–11 the native dynamic SQL code uses a parameter instead of a bind variable to construct the SQL statement.

Example 8–11 Using Native Dynamic SQL Without Bind Variables

```
CREATE OR REPLACE PROCEDURE del_dept
  (p_department_id  departments.department_id%TYPE)
IS
BEGIN
  EXECUTE IMMEDIATE 'DELETE FROM departments WHERE department_id = '
  || TO_CHAR(p_department_id);
END;
/
SHOW ERRORS;
```

For each distinct `p_department_id` parameter, the procedure creates a new cursor, which causes resource contention and poor performance. Instead, you can construct the SQL statement by using a bind variable, as shown in Example 8–12.

Example 8–12 Using Native Dynamic SQL with Bind Variables

```
CREATE OR REPLACE PROCEDURE del_dept
  (p_department_id  departments.department_id%TYPE)
IS
BEGIN
  EXECUTE IMMEDIATE 'DELETE FROM departments WHERE department_id = :1'
    USING p_department_id;
END;
/
SHOW ERRORS;
```

In Example 8–12 the same cursor is reused for different values of the bind `my_deptno`, which improves performance and scalability.

Native Dynamic SQL Supports User-Defined Types

Native dynamic SQL supports all of the types supported by static SQL in PL/SQL, including user-defined types such as user-defined objects, collections, and `REF`s. The `DBMS_SQL` package does not support these user-defined types.

> **Note:** The `DBMS_SQL` package provides limited support for arrays. Refer to the *Oracle Database PL/SQL Packages and Types Reference* for information.

Native Dynamic SQL Supports Fetching into Records

Native dynamic SQL and static SQL both support fetching into records, but the `DBMS_SQL` package does not. With native dynamic SQL, the rows resulting from a query can be directly fetched into PL/SQL records. In Example 8–13 the rows from a query are fetched into the `v_emp_rec` variable.

Example 8–13 Using Native Dynamic SQL to Fetch into Records

```
DECLARE
  TYPE EmpCurTyp  IS REF CURSOR;
  v_emp_cursor    EmpCurTyp;
  emp_record      emp%ROWTYPE;
  v_stmt_str      VARCHAR2(200);
  v_e_job         emp.job%TYPE;
```

```
BEGIN
  v_stmt_str := 'SELECT * FROM emp WHERE job = :1';
  -- in a multi-row query
  OPEN v_emp_cursor FOR v_stmt_str USING 'MANAGER';
    LOOP
      FETCH v_emp_cursor INTO emp_record;
      EXIT WHEN v_emp_cursor%NOTFOUND;
    END LOOP;
  CLOSE v_emp_cursor;
  -- in a single-row query
  EXECUTE IMMEDIATE v_stmt_str INTO emp_record USING 'PRESIDENT';
END;
/
```

Advantages of the DBMS_SQL Package

The DBMS_SQL package provides the following advantages over native dynamic SQL:

- DBMS_SQL is Supported in Client-Side Programs
- DBMS_SQL Supports Statements with Unknown Number of Inputs or Outputs
- DBMS_SQL Supports SQL Statements Larger than 32 KB
- DBMS_SQL Lets You Reuse SQL Statements

DBMS_SQL is Supported in Client-Side Programs

The DBMS_SQL package is supported in client-side programs, but native dynamic SQL is not. Every call to the DBMS_SQL package from the client-side program translates to a PL/SQL remote procedure call (RPC). These calls occur when you need to do any of the following:

- Bind a variable
- Define a variable
- Execute a statement

DBMS_SQL Supports Statements with Unknown Number of Inputs or Outputs

Native dynamic SQL does not support statements with an unknown number of inputs or outputs. The DBMS_SQL package does not have this limitation. One consequence is that you can use the DESCRIBE_COLUMNS procedure in the DBMS_SQL package to describe columns for a cursor opened and parsed through DBMS_SQL. This feature is similar to the DESCRIBE command in SQL*Plus. Native dynamic SQL does not have a DESCRIBE facility.

> **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for an example of using DESCRIBE_COLUMNS to create a query in a situation where the SELECT list is not known until runtime

DBMS_SQL Supports SQL Statements Larger than 32 KB

The DBMS_SQL package supports SQL statements larger than 32 KB. Native dynamic SQL does not.

DBMS_SQL Lets You Reuse SQL Statements

The PARSE procedure in the DBMS_SQL package parses a SQL statement once. After the initial parsing, you can use the statement multiple times with different sets of bind arguments.

Native dynamic SQL prepares a SQL statement each time the statement is used, which typically involves parsing, optimization, and plan generation. Although the extra prepare operations incur a small performance penalty, the decrease in speed is typically outweighed by the performance benefits of native dynamic SQL.

Examples of DBMS_SQL Package Code and Native Dynamic SQL Code

The following examples illustrate the code differences necessary to complete operations with the `DBMS_SQL` package and native dynamic SQL. Specifically, the following types of examples are presented:

- Query
- DML operation
- DML returning operation

In general, the native dynamic SQL code is more readable and compact, which can improve developer productivity.

Querying with Dynamic SQL: Example

The following example includes a dynamic query statement with one bind variable (`:g_jobname`) and two select columns (`ename` and `sal`):

```
v_stmt_str := 'SELECT ename, sal
               FROM emp
               WHERE job = :g_jobname';
```

This example queries for employees with the job description `SALESMAN` in the `job` column of the `emp` table. Table 8–2 shows sample code that accomplishes this query using the `DBMS_SQL` package and native dynamic SQL.

Table 8–2 Querying Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL Query Operation	Native Dynamic SQL Query Operation

DECLARE
  v_stmt_str VARCHAR2(200);
  v_cur_hdl INT;
  v_rows_processed INT;
  v_name VARCHAR2(10);
  v_salary INT;
BEGIN
  v_cur_hdl := DBMS_SQL.OPEN_CURSOR; -- open cursor
  v_stmt_str := 'SELECT ename, sal
  FROM emp
  WHERE job = :g_jobname';
 DBMS_SQL.PARSE(v_cur_hdl,v_stmt_str,DBMS_SQL.NATIVE);
  -- Supply binds (bind by name)
  DBMS_SQL.BIND_VARIABLE(v_cur_hdl, 'g_jobname',
  'SALESMAN');
  -- Describe defines
  DBMS_SQL.DEFINE_COLUMN(v_cur_hdl, 1, v_name, 200);
  DBMS_SQL.DEFINE_COLUMN(v_cur_hdl, 2, v_salary);
  -- Execute
  v_rows_processed := DBMS_SQL.EXECUTE(v_cur_hdl);
  LOOP
  -- Fetch a row
  IF DBMS_SQL.FETCH_ROWS(v_cur_hdl) > 0 THEN
  -- Fetch columns from the row
  DBMS_SQL.COLUMN_VALUE(v_cur_hdl, 1, v_name);
  DBMS_SQL.COLUMN_VALUE(v_cur_hdl, 2, v_salary);
  -- Process
  ELSE
  EXIT;
  END IF;
  END LOOP;
  DBMS_SQL.CLOSE_CURSOR(v_cur_hdl); -- close cursor
END;
/
	DECLARE
	  TYPE EmpCurTyp IS REF CURSOR;
	  v_emp_cursor EmpCurTyp;
	  v_stmt_str VARCHAR2(200);
	  v_name VARCHAR2(20);
	  v_salary NUMBER;
	BEGIN
	  v_stmt_str := 'SELECT ename, sal
	  FROM emp
	  WHERE job = :1';
	  OPEN v_emp_cursor FOR v_stmt_str
	  USING 'SALESMAN';
	  LOOP
	  FETCH v_emp_cursor
	  INTO v_name, v_salary;
	  EXIT WHEN v_emp_cursor%NOTFOUND;
	  -- Process data
	  END LOOP;
	  CLOSE v_emp_cursor;
	
	END;
	/

Performing DML with Dynamic SQL: Example

The following example includes a dynamic `INSERT` statement for a table with three columns.

```
v_stmt_str := 'INSERT INTO dept_new VALUES (:g_deptno, :g_dname, :g_loc)';
```

This example inserts a new row for which the column values are in the PL/SQL variables `deptnumber`, `deptname`, and `location`. Table 8–3 shows sample code that accomplishes this task with the `DBMS_SQL` package and native dynamic SQL.

Table 8–3 DML Operation Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL DML Operation	Native Dynamic SQL DML Operation

DECLARE
  v_stmt_str VARCHAR2(200);
  v_cur_hdl NUMBER;
  v_deptnumber NUMBER := 99;
  v_deptname VARCHAR2(20);
  v_location VARCHAR2(10);
  v_rows_processed NUMBER;
BEGIN
  v_stmt_str := 'INSERT INTO dept
  VALUES (:g_deptno, :g_dname, :g_loc)';
  v_cur_hdl := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(v_cur_hdl, v_stmt_str,
  DBMS_SQL.NATIVE);
  -- Supply binds
  DBMS_SQL.BIND_VARIABLE
  (v_cur_hdl, ':g_deptno', v_deptnumber);
  DBMS_SQL.BIND_VARIABLE
  (v_cur_hdl, ':g_dname', v_deptname);
  DBMS_SQL.BIND_VARIABLE
  (v_cur_hdl, ':g_loc', v_location);
 v_rows_processed := DBMS_SQL.EXECUTE(v_cur_hdl);
  DBMS_SQL.CLOSE_CURSOR(v_cur_hdl);
END;
/
	DECLARE
	  v_stmt_str VARCHAR2(200);
	  v_deptnumber NUMBER := 99;
	  v_deptname VARCHAR2(20);
	  v_location VARCHAR2(10);
	
	BEGIN
	  v_stmt_str := 'INSERT INTO dept
	  VALUES (:g_deptno, :g_dname, :g_loc)';
	  EXECUTE IMMEDIATE v_stmt_str
	  USING v_deptnumber, v_deptname,
	  v_location;
	
	END;
	/

Performing DML with RETURNING Clause Using Dynamic SQL: Example

The following example uses a dynamic `UPDATE` statement to update the location of a department, then returns the name of the department:

```
v_stmt_str := 'UPDATE dept_new
               SET loc = :g_newloc
               WHERE deptno = :g_deptno
               RETURNING dname INTO :g_dname';
```

Table 8–4 shows sample code that accomplishes this operation using both the `DBMS_SQL` package and native dynamic SQL.

Table 8–4 DML Returning Operation Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL DML Returning Operation	Native Dynamic SQL DML Returning Operation

DECLARE
  deptname_array DBMS_SQL.VARCHAR2_TABLE;
  v_cur_hdl INT;
  v_stmt_str VARCHAR2(200);
  v_location VARCHAR2(20);
  v_deptnumber NUMBER := 10;
  v_rows_procsd NUMBER;
BEGIN
  v_stmt_str := 'UPDATE dept
  SET loc = :g_newloc
  WHERE deptno = :g_deptno
  RETURNING dname INTO :g_dname';
  v_cur_hdl := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE
  (v_cur_hdl, v_stmt_str, DBMS_SQL.NATIVE);
  -- Supply binds
  DBMS_SQL.BIND_VARIABLE
  (v_cur_hdl, ':g_newloc', v_location);
  DBMS_SQL.BIND_VARIABLE
  (v_cur_hdl, ':g_deptno', v_deptnumber);
  DBMS_SQL.BIND_ARRAY
  (v_cur_hdl, ':g_dname', deptname_array);
  -- Execute cursor
 v_rows_procsd := DBMS_SQL.EXECUTE(v_cur_hdl);
  -- Get RETURNING column into OUT bind array
  DBMS_SQL.VARIABLE_VALUE
  (v_cur_hdl, ':g_dname', deptname_array);
  DBMS_SQL.CLOSE_CURSOR(v_cur_hdl);
END;
/
	DECLARE
	  deptname_array DBMS_SQL.VARCHAR2_TABLE;
	  v_stmt_str VARCHAR2(200);
	  v_location VARCHAR2(20);
	  v_deptnumber NUMBER := 10;
	  v_deptname VARCHAR2(20);
	
	BEGIN
	  v_stmt_str := 'UPDATE dept
	  SET loc = :g_newloc
	  WHERE deptno = :g_deptno
	  RETURNING dname INTO :g_dname';
	  EXECUTE IMMEDIATE v_stmt_str
	  USING v_location, v_deptnumber, OUT
	  v_deptname;
	
	END;
	/

Avoiding SQL Injection in PL/SQL

SQL injection is a technique for maliciously exploiting applications that use client-supplied data in SQL statements. The purpose of this technique is to gain unauthorized access to a database in order to query or manipulate restricted data. This section describes SQL injection vulnerabilities in PL/SQL and explains how you can guard against them.

This section contains the following topics:

- Overview of SQL Injection Techniques
- Guarding Against SQL Injection

Overview of SQL Injection Techniques

Although SQL injection techniques differ, they all exploit a single vulnerability: string input is not correctly validated and is concatenated into a dynamic SQL statement. For the purposes of this discussion, SQL injection attacks can be classified as follows:

- Statement Modification
- Statement Injection

The following sections describe these techniques. To try the examples in your sample database, run the script in Example 8–14.

Example 8–14 Setup for Injection Examples

```
CONNECT hr/hr
SET SERVEROUTPUT ON
SET LINESIZE 150
SET ECHO OFF

DROP TABLE user_pwd;
CREATE TABLE user_pwd( username VARCHAR2(100), password VARCHAR2(100) );
INSERT INTO user_pwd VALUES('whitehat', 'secret');
DROP TABLE delemp;
CREATE TABLE delemp AS SELECT * FROM employees;
COMMIT;
```

Statement Modification

SQL modification involves deliberately altering a dynamic SQL statement so that it executes in a way unintended by the application developer. Typically, the user retrieves unauthorized data by changing the `WHERE` clause of a query or by inserting a `UNION ALL` clause. The classic example of this technique is bypassing password authentication by making a `WHERE` clause always `TRUE`.

Suppose a Web form prompts a user to enter a username and password. When the user clicks **Submit**, the form invokes a PL/SQL stored procedure that concatenates the username and password entered in the form to build a dynamic SQL statement. The procedure executes the query to authenticate the user.

Example 8–15 illustrates an authentication procedure that you can test in SQL*Plus. The `ckpwd` procedure uses concatenation to build a SQL query of the `user_pwd` table. If the user enters a username and password stored in the table, then the execution of the query retrieves a single row and the user is authenticated. The `ckpwd` procedure also displays the concatenated query so that you can see which query is executed.

Example 8–15 ckpwd Procedure

```
CREATE OR REPLACE PROCEDURE ckpwd (p_user IN VARCHAR2, p_pass IN VARCHAR2)
IS
 v_query  VARCHAR2(100);
 v_output NUMBER;
BEGIN
 v_query :=    q'{SELECT COUNT(*) FROM user_pwd }'
         ||    q'{WHERE username = '}'
         ||    p_user
         ||    q'{' AND password = '}'
         ||    p_pass
         ||    q'{'}';
 DBMS_OUTPUT.PUT_LINE(CHR(10)||'Built the following query:'||CHR(10)||v_query);
 EXECUTE IMMEDIATE v_query
  INTO v_output;
 IF v_output = 1 THEN
   DBMS_OUTPUT.PUT_LINE(CHR(10)||p_user||' is authenticated');
 ELSE
   DBMS_OUTPUT.PUT_LINE(CHR(10)||'access denied');
 END IF;
END;
/
```

Suppose that the user `whitehat` enters the password `secret` in a Web form. You can simulate this scenario by invoking the code shown in Example 8–16 in SQL*Plus to authenticate `whitehat` (sample output included).

Example 8–16 Authenticating a User with the ckpwd Procedure

```
BEGIN
  ckpwd
  (
    p_user => q'{whitehat}',
    p_pass => q'{secret}'
  );
END;
/

Built the following query:
SELECT COUNT(*) FROM user_pwd WHERE username = 'whitehat' AND password = 'secret'

whitehat is authenticated
```

A malicious user could exploit the concatenation vulnerability and enter the username `x` in the Web-based form and the text shown in Example 8–17 as a password.

Example 8–17 Password String Entered in Form

```
x' OR 'x' = 'x
```

You can simulate this scenario by executing the code in Example 8–18 in SQL*Plus (sample output included).

Example 8–18 Performing Statement Modification with the ckpwd Procedure

```
BEGIN
  ckpwd
  (
    p_user => q'{x}',
    p_pass => q'{x' OR 'x' = 'x}'
  );
END;
/

Built the following query:
SELECT COUNT(*) FROM user_pwd WHERE username = 'x' AND password = 'x' OR 'x' = 'x'

x is authenticated
```

By using the cleverly constructed password in Example 8–17, you alter the concatenated SQL statement so that the `OR` condition always returns `TRUE`. Thus, the query of the `user_pwd` table always succeeds no matter which username is entered.

Statement Injection

Statement injection occurs when a user appends one or more new SQL statements to a dynamically generated SQL statement. Anonymous PL/SQL blocks are vulnerable to this technique.

Suppose a Web form prompts a user to enter a username and password. When the user clicks **Submit**, the form invokes a PL/SQL stored procedure that concatenates the username and password entered in the form into an anonymous PL/SQL block. The procedure then executes the anonymous block to authenticate the user.

Example 8–19 illustrates an authentication procedure that you can test in SQL*Plus. The `call_ckpwd` procedure uses concatenation to build an anonymous block that invokes the `ckpwd` procedure from Example 8–15. If the user enters a username and password stored in the `user_pwd` table, then the execution of the block retrieves a

single row and the user is authenticated. The `call_ckpwd` procedure also prints the concatenated text so that you can see which block is executed.

Example 8–19 call_ckpwd Procedure

```
CREATE OR REPLACE PROCEDURE call_ckpwd (p_user IN VARCHAR2, p_pass IN VARCHAR2)
IS
  v_block VARCHAR2(100);
BEGIN
  v_block := q'{BEGIN ckpwd( '}'
          ||    p_user
          || q'{' , '}'
          ||    p_pass
          || q'{' ); END; }';

  DBMS_OUTPUT.PUT_LINE(CHR(10)||
                       'Built the following anonymous block:'||CHR(10)||v_block);
  EXECUTE IMMEDIATE v_block;
END;
/
```

Suppose that the user `whitehat` enters the password `secret` in a Web-based form. You can simulate this scenario by invoking the `call_ckpwd` procedure shown in Example 8–20 in SQL*Plus (sample output included).

Example 8–20 Authenticating a User with the call_ckpwd Procedure

```
BEGIN
  call_ckpwd
  (
    p_user => q'{whitehat}',
    p_pass => q'{secret}'
  );
END;
/

Built the following anonymous block:
BEGIN ckpwd( 'whitehat' , 'secret' ); END;

Built the following query:
SELECT COUNT(*) FROM user_pwd WHERE username = 'whitehat' AND password = 'secret'

whitehat is authenticated
```

If `whitehat` turns bad, then he could enter the string shown in Example 8–21 as the password in a Web form.

Example 8–21 Bogus Password Entered in Form

```
secret'); DELETE FROM hr.delemp WHERE UPPER('x') = UPPER('x
```

You can simulate this technique by invoking the `call_ckpwd` procedure shown in Example 8–22 in SQL*Plus (sample output included).

Example 8–22 Performing Statement Injection with the call_ckpwd Procedure

```
BEGIN
  call_ckpwd
  (
    p_user => q'{whitehat}',
```

```
    p_pass => q'{secret'); DELETE FROM hr.delemp WHERE UPPER('x') = UPPER('x}'
  );
END;
/

Built the following anonymous block:
BEGIN ckpwd( 'whitehat' , 'secret' ); DELETE FROM hr.delemp WHERE UPPER('x') = UPPER('x'); END;

Built the following query:
SELECT COUNT(*) FROM user_pwd WHERE username = 'whitehat' AND password = 'secret'

whitehat is authenticated
```

The bogus password in Example 8–21 causes the system to authenticate `whitehat` and silently execute the injected `DELETE` statement. A query of the `delemp` table shows that the injected statement silently removed all rows from the table:

```
SELECT * FROM delemp;

no rows selected
```

Guarding Against SQL Injection

If you use dynamic SQL in your PL/SQL applications, then you must check the input text to ensure that it is exactly and only what is expected. You have the following useful techniques at your disposal:

- Using Bind Variables to Guard Against SQL Injection
- Using Validation Checks to Guard Against SQL Injection

Using Bind Variables to Guard Against SQL Injection

"Improving Performance Through Bind Variables" on page 8-11 shows how you can use bind variables to improve performance in dynamic SQL. Besides improving performance, binding placeholders renders your PL/SQL code immune to SQL injection attacks.

The `ckpwd` procedure shown in Example 8–15 used concatenation instead of bind variables. Example 8–23 shows how you could rewrite the procedure to use bind variables instead of concatenation.

Example 8–23 ckpwd_bind Procedure

```
CREATE OR REPLACE PROCEDURE ckpwd_bind (p_user IN VARCHAR2, p_pass IN VARCHAR2)
IS
 v_query  VARCHAR2(100);
 v_output NUMBER;
BEGIN
 v_query :=
   q'{SELECT COUNT(*) FROM user_pwd WHERE username = :1 AND password = :2}';
 DBMS_OUTPUT.PUT_LINE(CHR(10)||'Built the following query:'||CHR(10)||v_query);
 EXECUTE IMMEDIATE v_query
  INTO v_output
  USING p_user, p_pass;
 IF v_output = 1 THEN
   DBMS_OUTPUT.PUT_LINE(CHR(10)||p_user||' is authenticated');
 ELSE
   DBMS_OUTPUT.PUT_LINE(CHR(10)||'access denied');
 END IF;
END;
```

```
/
```

If the user tries to pass the bogus password shown in Example 8–17 to the `ckpwd_bind` procedure, then the technique fails to authenticate the user. You can execute the block shown in Example 8–24 in SQL*Plus to test the revised version of the code (sample output included).

Example 8–24 Preventing Statement Modification with the ckpwd_bind Procedure

```
BEGIN
  ckpwd_bind
  (
    p_user => q'{x}',
    p_pass => q'{x' OR 'x' = 'x}'
  );
END;
/

Built the following query:
SELECT COUNT(*) FROM user_pwd WHERE username = :1 AND password = :2

access denied
```

The same binding technique fixes the vulnerable `call_ckpwd` procedure shown in Example 8–19. By using bind variables exclusively in your code, you avoid concatenating SQL statements and thereby prevent malicious users from altering or injecting additional statements. Oracle database uses the value of the bind variable exclusively and does not interpret its contents in any way. This technique is the most effective way to prevent SQL injection in PL/SQL programs.

Using Validation Checks to Guard Against SQL Injection

A program should always validate user input to ensure that it is what is intended. For example, if the user is passing in a department number for a `DELETE` statement, then check the validity of this department number by querying the `departments` table. Similarly, if a user enters the name of a table to be deleted, check that this table exists by querying the `ALL_TABLES` view.

9

Coding Triggers

Triggers are procedures that are stored in the database and are implicitly run, or **fired**, when something happens.

Traditionally, triggers supported the execution of a PL/SQL block when an `INSERT`, `UPDATE`, or `DELETE` occurred on a table or view. Triggers support system and other data events on `DATABASE` and `SCHEMA`. Oracle Database also supports the execution of PL/SQL or Java procedures.

This chapter discusses DML triggers, `INSTEAD OF` triggers, and system triggers (triggers on `DATABASE` and `SCHEMA`). Topics include:

Designing Triggers

Use the following guidelines when designing your triggers:

- Use triggers to guarantee that when a specific operation is performed, related actions are performed.
- Do not define triggers that duplicate features already built into Oracle Database. For example, do not define triggers to reject bad data if you can do the same checking through declarative integrity constraints.
- Limit the size of triggers. If the logic for your trigger requires much more than 60 lines of PL/SQL code, it is better to include most of the code in a stored procedure and call the procedure from the trigger.
- Use triggers only for centralized, global operations that should be fired for the triggering statement, regardless of which user or database application issues the statement.

- *Do not create recursive triggers.* For example, creating an AFTER UPDATE statement trigger on the Emp_tab table that itself issues an UPDATE statement on Emp_tab, causes the trigger to fire recursively until it has run out of memory.
- Use triggers on DATABASE judiciously. They are executed for *every* user *every* time the event occurs on which the trigger is created.

Creating Triggers

Triggers are created using the CREATE TRIGGER statement. This statement can be used with any interactive tool, such as SQL*Plus or Enterprise Manager. When using an interactive tool, a single slash (/) on the last line is necessary to activate the CREATE TRIGGER statement.

The following statement creates a trigger for the Emp_tab table.

```
CREATE OR REPLACE TRIGGER Print_salary_changes
  BEFORE DELETE OR INSERT OR UPDATE ON Emp_tab
  FOR EACH ROW
WHEN (new.Empno > 0)
DECLARE
    sal_diff number;
BEGIN
    sal_diff  := :new.sal  - :old.sal;
    dbms_output.put('Old salary: ' || :old.sal);
    dbms_output.put('  New salary: ' || :new.sal);
    dbms_output.put_line('  Difference ' || sal_diff);
END;
/
```

The trigger is fired when DML operations (INSERT, UPDATE, and DELETE statements) are performed on the table. You can choose what combination of operations should fire the trigger.

Because the trigger uses the BEFORE keyword, it can access the new values before they go into the table, and can change the values if there is an easily-corrected error by assigning to :NEW.*column_name*. You might use the AFTER keyword if you want the trigger to query or change the same table, because triggers can only do that after the initial changes are applied and the table is back in a consistent state.

Because the trigger uses the FOR EACH ROW clause, it might be executed multiple times, such as when updating or deleting multiple rows. You might omit this clause if you just want to record the fact that the operation occurred, but not examine the data for each row.

Once the trigger is created, entering the following SQL statement:

```
UPDATE Emp_tab SET sal = sal + 500.00 WHERE deptno = 10;
```

fires the trigger once for each row that is updated, in each case printing the new salary, old salary, and the difference.

The CREATE (or CREATE OR REPLACE) statement fails if any errors exist in the PL/SQL block.

> **Note:** The size of the trigger cannot be more than 32K.

The following sections use this example to illustrate the way that parts of a trigger are specified.

See Also: "Examples of Trigger Applications" on page 9-23 for more realistic examples of `CREATE TRIGGER` statements

Types of Triggers

A trigger is either a stored PL/SQL block or a PL/SQL, C, or Java procedure associated with a table, view, schema, or the database itself. Oracle Database automatically executes a trigger when a specified event takes place, which may be in the form of a system event or a DML statement being issued against the table.

Triggers can be:

- DML triggers on tables.
- `INSTEAD OF` triggers on views.
- System triggers on `DATABASE` or `SCHEMA`: With `DATABASE`, triggers fire for each event for all users; with `SCHEMA`, triggers fire for each event for that specific user.

See Also: *Oracle Database SQL Reference* for information on trigger creation syntax

Overview of System Events

You can create triggers to be fired on any of the following:

- DML statements (`DELETE`, `INSERT`, `UPDATE`)
- DDL statements (`CREATE`, `ALTER`, `DROP`)
- Database operations (`SERVERERROR`, `LOGON`, `LOGOFF`, `STARTUP`, `SHUTDOWN`)

Getting the Attributes of System Events

You can get certain event-specific attributes when the trigger is fired.

Creating a trigger on `DATABASE` implies that the triggering event is outside the scope of a user (for example, database `STARTUP` and `SHUTDOWN`), and it applies to all users (for example, a trigger created on `LOGON` event by the DBA).

Creating a trigger on `SCHEMA` implies that the trigger is created in the current user's schema and is fired only for that user.

For each trigger, publication can be specified on DML and system events.

See Also: "Responding to System Events through Triggers" on page 9-37

Naming Triggers

Trigger names must be unique with respect to other triggers in the same schema. Trigger names do not need to be unique with respect to other schema objects, such as tables, views, and procedures. For example, a table and a trigger can have the same name (however, to avoid confusion, this is not recommended).

When Is the Trigger Fired?

A trigger is fired based on a **triggering statement**, which specifies:

- The SQL statement or the system event, database event, or DDL event that fires the trigger body. The options include `DELETE`, `INSERT`, and `UPDATE`. One, two, or all three of these options can be included in the triggering statement specification.

- The table, view, DATABASE, or SCHEMA associated with the trigger.

> **Note:** Exactly one table or view can be specified in the triggering statement. If the INSTEAD OF option is used, then the triggering statement may only specify a view; conversely, if a view is specified in the triggering statement, then only the INSTEAD OF option may be used.

For example, the PRINT_SALARY_CHANGES trigger fires after any DELETE, INSERT, or UPDATE on the Emp_tab table. Any of the following statements trigger the PRINT_SALARY_CHANGES trigger given in the previous example:

```
DELETE FROM Emp_tab;
INSERT INTO Emp_tab VALUES ( ... );
INSERT INTO Emp_tab SELECT ... FROM ... ;
UPDATE Emp_tab SET ... ;
```

Do Import and SQL*Loader Fire Triggers?

INSERT triggers fire during SQL*Loader conventional loads. (For direct loads, triggers are disabled before the load.)

The IGNORE parameter of the IMP command determines whether triggers fire during import operations:

- If IGNORE=N (default) and the table already exists, then import does not change the table and no existing triggers fire.
- If the table does not exist, then import creates and loads it before any triggers are defined, so again no triggers fire.
- If IGNORE=Y, then import loads rows into existing tables. Any existing triggers fire, and indexes are updated to account for the imported data.

How Column Lists Affect UPDATE Triggers

An UPDATE statement might include a list of columns. If a triggering statement includes a column list, the trigger is fired only when one of the specified columns is updated. If a triggering statement omits a column list, the trigger is fired when any column of the associated table is updated. A column list cannot be specified for INSERT or DELETE triggering statements.

The previous example of the PRINT_SALARY_CHANGES trigger could include a column list in the triggering statement. For example:

```
... BEFORE DELETE OR INSERT OR UPDATE OF ename ON Emp_tab ...
```

Notes:

- You cannot specify a column list for UPDATE with INSTEAD OF triggers.
- If the column specified in the UPDATE OF clause is an object column, then the trigger is also fired if any of the attributes of the object are modified.
- You cannot specify UPDATE OF clauses on collection columns.

Controlling When a Trigger Is Fired (BEFORE and AFTER Options)

The BEFORE or AFTER option in the CREATE TRIGGER statement specifies exactly when to fire the trigger body in relation to the triggering statement that is being run. In

a CREATE TRIGGER statement, the BEFORE or AFTER option is specified just before the triggering statement. For example, the PRINT_SALARY_CHANGES trigger in the previous example is a BEFORE trigger.

In general, you use BEFORE or AFTER triggers to achieve the following results:

- Use BEFORE row triggers to modify the row before the row data is written to disk.
- Use AFTER row triggers to obtain, and perform operations, using the row ID.

> **Note:** BEFORE row triggers are slightly more efficient than AFTER row triggers. With AFTER row triggers, affected data blocks must be read (logical read, not physical read) once for the trigger and then again for the triggering statement. Alternatively, with BEFORE row triggers, the data blocks must be read only once for both the triggering statement and the trigger.

BEFORE Triggers Fired Multiple Times

If an UPDATE or DELETE statement detects a conflict with a concurrent UPDATE, then Oracle Database performs a transparent ROLLBACK to SAVEPOINT and restarts the update. This can occur many times before the statement completes successfully. Each time the statement is restarted, the BEFORE statement trigger is fired again. The rollback to savepoint does not undo changes to any package variables referenced in the trigger. Your package should include a counter variable to detect this situation.

Ordering of Triggers

A relational database does not guarantee the order of rows processed by a SQL statement. Therefore, do not create triggers that depend on the order in which rows are processed. For example, do not assign a value to a global package variable in a row trigger if the current value of the global variable is dependent on the row being processed by the row trigger. Also, if global package variables are updated within a trigger, then it is best to initialize those variables in a BEFORE statement trigger.

When a statement in a trigger body causes another trigger to be fired, the triggers are said to be *cascading*. Oracle Database allows up to 32 triggers to cascade at any one time. However, you can effectively limit the number of trigger cascades using the initialization parameter OPEN_CURSORS, because a cursor must be opened for every execution of a trigger.

Trigger Evaluation Order

Although any trigger can run a sequence of operations either in-line or by calling procedures, using multiple triggers of the same type enhances database administration by permitting the modular installation of applications that have triggers on the same tables.

Oracle Database executes all triggers of the same type before executing triggers of a different type. If you have multiple triggers of the same type on a single table, then Oracle Database chooses an arbitrary order to execute these triggers.

> **See Also:** *Oracle Database Concepts* for more information on the firing order of triggers

Each subsequent trigger sees the changes made by the previously fired triggers. Each trigger can see the old and new values. The old values are the original values, and the

new values are the current values, as set by the most recently fired UPDATE or INSERT trigger.

To ensure that multiple triggered actions occur in a specific order, you must consolidate these actions into a single trigger (for example, by having the trigger call a series of procedures).

Modifying Complex Views (INSTEAD OF Triggers)

An **updatable** view is one that lets you perform DML on the underlying table. Some views are inherently updatable, but others are not because they were created with one or more of the constructs listed in"Views that Require INSTEAD OF Triggers".

Any view that contains one of those constructs can be made updatable by using an INSTEAD OF trigger. INSTEAD OF triggers provide a transparent way of modifying views that cannot be modified directly through UPDATE, INSERT, and DELETE statements. These triggers are called INSTEAD OF triggers because, unlike other types of triggers, Oracle Database fires the trigger *instead* of executing the triggering statement. The trigger must determine what operation was intended and perform UPDATE, INSERT, or DELETE operations directly on the underlying tables.

With an INSTEAD OF trigger, you can write normal UPDATE, INSERT, and DELETE statements against the view, and the INSTEAD OF trigger works invisibly in the background to make the right actions take place.

INSTEAD OF triggers can only be activated for each row.

See Also: "Firing Triggers One or Many Times (FOR EACH ROW Option)" on page 9-9

Note:

- The INSTEAD OF option can *only* be used for triggers created over views.
- The BEFORE and AFTER options *cannot* be used for triggers created over views.
- The CHECK option for views is not enforced when inserts or updates to the view are done using INSTEAD OF triggers. The INSTEAD OF trigger body must enforce the check.

Views that Require INSTEAD OF Triggers

A view cannot be modified by UPDATE, INSERT, or DELETE statements if the view query contains any of the following constructs:

- A set operator
- A DISTINCT operator
- An aggregate or analytic function
- A GROUP BY, ORDER BY, MODEL, CONNECT BY, or START WITH clause
- A collection expression in a SELECT list
- A subquery in a SELECT list
- A subquery designated WITH READ ONLY

- Joins, with some exceptions, as documented in *Oracle Database Administrator's Guide*

If a view contains pseudocolumns or expressions, then you can only update the view with an UPDATE statement that does not refer to any of the pseudocolumns or expressions.

INSTEAD OF Trigger Example

Note: You may need to set up the following data structures for this example to work:

```
CREATE TABLE Project_tab (
   Prj_level NUMBER,
   Projno    NUMBER,
   Resp_dept NUMBER);
CREATE TABLE Emp_tab (
   Empno     NUMBER NOT NULL,
   Ename     VARCHAR2(10),
   Job       VARCHAR2(9),
   Mgr       NUMBER(4),
   Hiredate  DATE,
   Sal       NUMBER(7,2),
   Comm      NUMBER(7,2),
   Deptno    NUMBER(2) NOT NULL);

CREATE TABLE Dept_tab (
   Deptno    NUMBER(2) NOT NULL,
   Dname     VARCHAR2(14),
   Loc       VARCHAR2(13),
   Mgr_no    NUMBER,
   Dept_type NUMBER);
```

The following example shows an INSTEAD OF trigger for inserting rows into the MANAGER_INFO view.

```
CREATE OR REPLACE VIEW manager_info AS
    SELECT e.ename, e.empno, d.dept_type, d.deptno, p.prj_level,
           p.projno
        FROM   Emp_tab e, Dept_tab d, Project_tab p
        WHERE  e.empno =  d.mgr_no
        AND    d.deptno = p.resp_dept;

CREATE OR REPLACE TRIGGER manager_info_insert
INSTEAD OF INSERT ON manager_info
REFERENCING NEW AS n                -- new manager information

FOR EACH ROW
DECLARE
   rowcnt number;
BEGIN
   SELECT COUNT(*) INTO rowcnt FROM Emp_tab WHERE empno = :n.empno;
   IF rowcnt = 0  THEN
       INSERT INTO Emp_tab (empno,ename) VALUES (:n.empno, :n.ename);
   ELSE
      UPDATE Emp_tab SET Emp_tab.ename = :n.ename
        WHERE Emp_tab.empno = :n.empno;
   END IF;
   SELECT COUNT(*) INTO rowcnt FROM Dept_tab WHERE deptno = :n.deptno;
```

```
   IF rowcnt = 0 THEN
      INSERT INTO Dept_tab (deptno, dept_type)
         VALUES(:n.deptno, :n.dept_type);
   ELSE
      UPDATE Dept_tab SET Dept_tab.dept_type = :n.dept_type
         WHERE Dept_tab.deptno = :n.deptno;
   END IF;
   SELECT COUNT(*) INTO rowcnt FROM Project_tab
      WHERE Project_tab.projno = :n.projno;
   IF rowcnt = 0 THEN
      INSERT INTO Project_tab (projno, prj_level)
         VALUES(:n.projno, :n.prj_level);
   ELSE
      UPDATE Project_tab SET Project_tab.prj_level = :n.prj_level
         WHERE Project_tab.projno = :n.projno;
   END IF;
END;
```

The actions shown for rows being inserted into the MANAGER_INFO view first test to see if appropriate rows already exist in the base tables from which MANAGER_INFO is derived. The actions then insert new rows or update existing rows, as appropriate. Similar triggers can specify appropriate actions for UPDATE and DELETE.

Object Views and INSTEAD OF Triggers

INSTEAD OF triggers provide the means to modify object view instances on the client-side through OCI calls.

> **See Also:** *Oracle Call Interface Programmer's Guide*

To modify an object materialized by an object view in the client-side object cache and flush it back to the persistent store, you must specify INSTEAD OF triggers, unless the object view is modifiable. If the object is read only, then it is not necessary to define triggers to pin it.

Triggers on Nested Table View Columns

INSTEAD OF triggers can also be created over nested table view columns. These triggers provide a way of updating elements of the nested table. They fire for each nested table element being modified. The row correlation variables inside the trigger correspond to the nested table element. This type of trigger also provides an additional correlation name for accessing the parent row that contains the nested table being modified.

Note: These triggers:

- Can only be defined over nested table columns in views.
- Fire only when the nested table elements are modified using the THE() or TABLE() clauses. They do not fire when a DML statement is performed on the view.

For example, consider a department view that contains a nested table of employees.

```
CREATE OR REPLACE VIEW Dept_view AS
SELECT d.Deptno, d.Dept_type, d.Dept_name,
   CAST (MULTISET ( SELECT e.Empno, e.Empname, e.Salary)
      FROM Emp_tab e
```

```
      WHERE e.Deptno = d.Deptno) AS Amp_list_ Emplist
FROM Dept_tab d;
```

The CAST (MULTISET..) operator creates a multi-set of employees for each department. If you want to modify the emplist column, which is the nested table of employees, then you can define an INSTEAD OF trigger over the column to handle the operation.

The following example shows how an insert trigger might be written:

```
CREATE OR REPLACE TRIGGER Dept_emplist_tr
   INSTEAD OF INSERT ON NESTED TABLE Emplist OF Dept_view
   REFERENCING NEW AS Employee
      PARENT AS Department
   FOR EACH ROW
BEGIN
-- The insert on the nested table is translated to an insert on the base table:
   INSERT INTO Emp_tab VALUES (
      :Employee.Empno, :Employee.Empname,:Employee.Salary, :Department.Deptno);
END;
```

Any INSERT into the nested table fires the trigger, and the Emp_tab table is filled with the correct values. For example:

```
INSERT INTO TABLE (SELECT d.Emplist FROM Dept_view d WHERE Deptno = 10)
   VALUES (1001, 'John Glenn', 10000);
```

The :department.deptno correlation variable in this example would have a value of 10.

Firing Triggers One or Many Times (FOR EACH ROW Option)

The FOR EACH ROW option determines whether the trigger is a *row* trigger or a *statement* trigger. If you specify FOR EACH ROW, then the trigger fires once for each row of the table that is affected by the triggering statement. The absence of the FOR EACH ROW option indicates that the trigger fires only once for each applicable statement, but not separately for each row affected by the statement.

For example, you define the following trigger:

> **Note:** You may need to set up the following data structures for certain examples to work:
>
> ```
> CREATE TABLE Emp_log (
>    Emp_id     NUMBER,
>    Log_date   DATE,
>    New_salary NUMBER,
>    Action     VARCHAR2(20));
> ```

```
CREATE OR REPLACE TRIGGER Log_salary_increase
AFTER UPDATE ON Emp_tab
FOR EACH ROW
WHEN (new.Sal > 1000)
BEGIN
    INSERT INTO Emp_log (Emp_id, Log_date, New_salary, Action)
       VALUES (:new.Empno, SYSDATE, :new.SAL, 'NEW SAL');
END;
```

Then, you enter the following SQL statement:

```
UPDATE Emp_tab SET Sal = Sal + 1000.0
    WHERE Deptno = 20;
```

If there are five employees in department 20, then the trigger fires five times when this statement is entered, because five rows are affected.

The following trigger fires only once for each `UPDATE` of the `Emp_tab` table:

```
CREATE OR REPLACE TRIGGER Log_emp_update
AFTER UPDATE ON Emp_tab
BEGIN
    INSERT INTO Emp_log (Log_date, Action)
        VALUES (SYSDATE, 'Emp_tab COMMISSIONS CHANGED');
END;
```

See Also: *Oracle Database Concepts* for the order of trigger firing

The statement level triggers are useful for performing validation checks for the entire statement.

Firing Triggers Based on Conditions (WHEN Clause)

Optionally, a trigger restriction can be included in the definition of a row trigger by specifying a Boolean SQL expression in a `WHEN` clause.

Note: A `WHEN` clause cannot be included in the definition of a statement trigger.

If included, then the expression in the `WHEN` clause is evaluated for each row that the trigger affects.

If the expression evaluates to `TRUE` for a row, then the trigger body is fired on behalf of that row. However, if the expression evaluates to `FALSE` or `NOT TRUE` for a row (unknown, as with nulls), then the trigger body is not fired for that row. The evaluation of the `WHEN` clause does not have an effect on the execution of the triggering SQL statement (in other words, the triggering statement is not rolled back if the expression in a `WHEN` clause evaluates to `FALSE`).

For example, in the `PRINT_SALARY_CHANGES` trigger, the trigger body is not run if the new value of `Empno` is zero, `NULL`, or negative. In more realistic examples, you might test if one column value is less than another.

The expression in a `WHEN` clause of a row trigger can include correlation names, which are explained later. The expression in a `WHEN` clause must be a SQL expression, and it cannot include a subquery. You cannot use a PL/SQL expression (including user-defined functions) in the `WHEN` clause.

Note: You cannot specify the `WHEN` clause for `INSTEAD OF` triggers.

Coding the Trigger Body

The trigger body is a `CALL` procedure or a PL/SQL block that can include SQL and PL/SQL statements. The `CALL` procedure can be either a PL/SQL or a Java procedure that is encapsulated in a PL/SQL wrapper. These statements are run if the triggering statement is entered and if the trigger restriction (if included) evaluates to `TRUE`.

The trigger body for row triggers has some special constructs that can be included in the code of the PL/SQL block: correlation names and the `REFERENCEING` option, and the conditional predicates `INSERTING`, `DELETING`, and `UPDATING`.

> **Note:** The `INSERTING`, `DELETING`, and `UPDATING` conditional predicates cannot be used for the `CALL` procedures; they can only be used in a PL/SQL block.

Example: Monitoring Logons with a Trigger

> **Note:** You may need to set up data structures similar to the following for certain examples to work:
>
> ```
> CONNECT system/manager
> GRANT ADMINISTER DATABASE TRIGGER TO scott;
> CONNECT scott/tiger
> CREATE TABLE audit_table (
>    seq number,
>    user_at  VARCHAR2(10),
>    time_now DATE,
>    term     VARCHAR2(10),
>    job      VARCHAR2(10),
>    proc     VARCHAR2(10),
>    enum     NUMBER);
> ```

```
CREATE OR REPLACE PROCEDURE foo (c VARCHAR2) AS
   BEGIN
      INSERT INTO Audit_table (user_at) VALUES(c);
   END;

CREATE OR REPLACE TRIGGER logontrig AFTER LOGON ON DATABASE
-- Just call an existing procedure. The ORA_LOGIN_USER is a function
-- that returns information about the event that fired the trigger.
CALL foo (ora_login_user)
/
```

Example: Calling a Java Procedure from a Trigger

Although triggers are declared using PL/SQL, they can call procedures in other languages, such as Java:

```
CREATE OR REPLACE PROCEDURE Before_delete (Id IN NUMBER, Ename VARCHAR2)
IS language Java
name 'thjvTriggers.beforeDelete (oracle.sql.NUMBER, oracle.sql.CHAR)';

CREATE OR REPLACE TRIGGER Pre_del_trigger BEFORE DELETE ON Tab
FOR EACH ROW
CALL Before_delete (:old.Id, :old.Ename)
/
```

The corresponding Java file is `thjvTriggers.java`:

```
import java.sql.*
import java.io.*
import oracle.sql.*
import oracle.oracore.*
public class thjvTriggers
{
```

```
public state void
beforeDelete (NUMBER old_id, CHAR old_name)
Throws SQLException, CoreException
   {
   Connection conn = JDBCConnection.defaultConnection();
   Statement stmt = conn.CreateStatement();
   String sql = "insert into logtab values
   ("+ old_id.intValue() +", '"+ old_ename.toString() + ", BEFORE DELETE');
   stmt.executeUpdate (sql);
   stmt.close();
   return;
   }
}
```

Accessing Column Values in Row Triggers

Within a trigger body of a row trigger, the PL/SQL code and SQL statements have access to the old and new column values of the current row affected by the triggering statement. Two correlation names exist for every column of the table being modified: one for the old column value, and one for the new column value. Depending on the type of triggering statement, certain correlation names might not have any meaning.

- A trigger fired by an `INSERT` statement has meaningful access to new column values only. Because the row is being created by the `INSERT`, the old values are null.
- A trigger fired by an `UPDATE` statement has access to both old and new column values for both `BEFORE` and `AFTER` row triggers.
- A trigger fired by a `DELETE` statement has meaningful access to `:old` column values only. Because the row no longer exists after the row is deleted, the `:new` values are `NULL`. However, you cannot modify `:new` values because `ORA-4084` is raised if you try to modify `:new` values.

The new column values are referenced using the `new` qualifier before the column name, while the old column values are referenced using the `old` qualifier before the column name. For example, if the triggering statement is associated with the `Emp_tab` table (with the columns `SAL`, `COMM`, and so on), then you can include statements in the trigger body. For example:

```
IF :new.Sal > 10000 ...
IF :new.Sal < :old.Sal ...
```

Old and new values are available in both `BEFORE` and `AFTER` row triggers. A `new` column value can be assigned in a `BEFORE` row trigger, but not in an `AFTER` row trigger (because the triggering statement takes effect before an `AFTER` row trigger is fired). If a `BEFORE` row trigger changes the value of `new.column`, then an `AFTER` row trigger fired by the same statement sees the change assigned by the `BEFORE` row trigger.

Correlation names can also be used in the Boolean expression of a `WHEN` clause. A colon (`:`) must precede the `old` and `new` qualifiers when they are used in a trigger body, but a colon is not allowed when using the qualifiers in the `WHEN` clause or the `REFERENCING` option.

Example: Modifying LOB Columns with a Trigger

You can treat LOB columns the same as other columns, using regular SQL and PL/SQL functions with `CLOB` columns, and calls to the `DBMS_LOB` package with `BLOB` columns:

```
drop table tab1;

create table tab1 (c1 clob);
insert into tab1 values ('<h1>HTML Document Fragment</h1><p>Some text.');

create or replace trigger trg1
  before update on tab1
  for each row
begin
  dbms_output.put_line('Old value of CLOB column: '||:OLD.c1);
  dbms_output.put_line('Proposed new value of CLOB column: '||:NEW.c1);

-- Previously, we couldn't change the new value for a LOB.
-- Now, we can replace it, or construct a new value using SUBSTR, INSTR...
-- operations for a CLOB, or DBMS_LOB calls for a BLOB.
  :NEW.c1 := :NEW.c1 || to_clob('<hr><p>Standard footer paragraph.');

  dbms_output.put_line('Final value of CLOB column: '||:NEW.c1);
end;
/

set serveroutput on;
update tab1 set c1 = '<h1>Different Document Fragment</h1><p>Different text.';

select * from tab1;
```

INSTEAD OF Triggers on Nested Table View Columns

In the case of `INSTEAD OF` triggers on nested table view columns, the `new` and `old` qualifiers correspond to the new and old nested table elements. The parent row corresponding to this nested table element can be accessed using the `parent` qualifier. The parent correlation name is meaningful and valid only inside a nested table trigger.

Avoiding Name Conflicts with Triggers (REFERENCING Option)

The `REFERENCING` option can be specified in a trigger body of a row trigger to avoid name conflicts among the correlation names and tables that might be named `old` or `new`. Because this is rare, this option is infrequently used.

For example, assume you have a table named `new` with columns `field1` (number) and `field2` (character). The following `CREATE TRIGGER` example shows a trigger associated with the `new` table that can use correlation names and avoid naming conflicts between the correlation names and the table name:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE new (
   field1     NUMBER,
   field2     VARCHAR2(20));
```

```
CREATE OR REPLACE TRIGGER Print_salary_changes
BEFORE UPDATE ON new
REFERENCING new AS Newest
FOR EACH ROW
BEGIN
   :Newest.Field2 := TO_CHAR (:newest.field1);
END;
```

Notice that the new qualifier is renamed to newest using the REFERENCING option, and it is then used in the trigger body.

Detecting the DML Operation That Fired a Trigger

If more than one type of DML operation can fire a trigger (for example, ON INSERT OR DELETE OR UPDATE OF Emp_tab), the trigger body can use the conditional predicates INSERTING, DELETING, and UPDATING to check which type of statement fire the trigger.

Within the code of the trigger body, you can execute blocks of code depending on the kind of DML operation fired the trigger:

```
IF INSERTING THEN ... END IF;
IF UPDATING THEN ... END IF;
```

The first condition evaluates to TRUE only if the statement that fired the trigger is an INSERT statement; the second condition evaluates to TRUE only if the statement that fired the trigger is an UPDATE statement.

In an UPDATE trigger, a column name can be specified with an UPDATING conditional predicate to determine if the named column is being updated. For example, assume a trigger is defined as the following:

```
CREATE OR REPLACE TRIGGER ...
... UPDATE OF Sal, Comm ON Emp_tab ...
BEGIN

... IF UPDATING ('SAL') THEN ... END IF;

END;
```

The code in the THEN clause runs only if the triggering UPDATE statement updates the SAL column. This way, the trigger can minimize its overhead when the column of interest is not being changed.

Error Conditions and Exceptions in the Trigger Body

If a predefined or user-defined error condition or exception is raised during the execution of a trigger body, then all effects of the trigger body, as well as the triggering statement, are rolled back (unless the error is trapped by an exception handler). Therefore, a trigger body can prevent the execution of the triggering statement by raising an exception. User-defined exceptions are commonly used in triggers that enforce complex security authorizations or integrity constraints.

The only exception to this is when the event under consideration is database STARTUP, SHUTDOWN, or LOGIN when the user logging in is SYSTEM. In these scenarios, only the trigger action is rolled back.

Triggers on Object Tables

You can use the OBJECT_VALUE pseudocolumn in a trigger on an object table since 10*g* Release 1 (10.1). OBJECT_VALUE means the object as a whole. This is one example of its use. You can also call a PL/SQL function with OBJECT_VALUE as the datatype of an IN formal parameter.

Here is an example of the use of OBJECT_VALUE in a trigger. To keep track of updates to values in an object table tbl, a history table, tbl_history, is also created in the following example. For tbl, the values 1 through 5 are inserted into n, while m is kept at 0. The trigger is a row-level trigger that executes once for each row affected by a

DML statement. The trigger causes the old and new values of the object `t` in `tbl` to be written in `tbl_history` when `tbl` is updated. These old and new values are `:OLD.OBJECT_VALUE` and `:NEW.OBJECT_VALUE`. An update of the table `tbl` is done (each value of `n` is increased by 1). A select from the history table to check that the trigger works is then shown at the end of the example:

```
CREATE OR REPLACE TYPE t AS OBJECT (n NUMBER, m NUMBER)
/
CREATE TABLE tbl OF t
/
BEGIN
  FOR j IN 1..5 LOOP
    INSERT INTO tbl VALUES (t(j, 0));
  END LOOP;
END;
/
CREATE TABLE tbl_history ( d DATE, old_obj t, new_obj t)
/
CREATE OR REPLACE TRIGGER Tbl_Trg
AFTER UPDATE ON tbl
FOR EACH ROW
BEGIN
  INSERT INTO tbl_history (d, old_obj, new_obj)
    VALUES (SYSDATE, :OLD.OBJECT_VALUE, :NEW.OBJECT_VALUE);
END Tbl_Trg;
/
--------------------------------------------------------------------------------

UPDATE tbl SET tbl.n = tbl.n+1
/
BEGIN
  FOR j IN (SELECT d, old_obj, new_obj FROM tbl_history) LOOP
    Dbms_Output.Put_Line (
      j.d||
      ' -- old: '||j.old_obj.n||' '||j.old_obj.m||
      ' -- new: '||j.new_obj.n||' '||j.new_obj.m);
  END LOOP;
END;
/
```

The result of the select shows that the values of the column `n` have been all increased by 1. The value of `m` remains 0. The output of the select is:

```
23-MAY-05 -- old: 1 0 -- new: 2 0
23-MAY-05 -- old: 2 0 -- new: 3 0
23-MAY-05 -- old: 3 0 -- new: 4 0
23-MAY-05 -- old: 4 0 -- new: 5 0
23-MAY-05 -- old: 5 0 -- new: 6 0
```

Triggers and Handling Remote Exceptions

A trigger that accesses a remote site cannot do remote exception handling if the network link is unavailable. For example:

```
CREATE OR REPLACE TRIGGER Example
AFTER INSERT ON Emp_tab
FOR EACH ROW
BEGIN
  INSERT INTO Emp_tab@Remote     -- <- compilation fails here
  VALUES ('x');                  --    when dblink is inaccessible
EXCEPTION
  WHEN OTHERS THEN
```

```
    INSERT INTO Emp_log
    VALUES ('x');
END;
```

A trigger is compiled when it is created. Thus, if a remote site is unavailable when the trigger must compile, then Oracle Database cannot validate the statement accessing the remote database, and the compilation fails. The previous example exception statement cannot run, because the trigger does not complete compilation.

Because stored procedures are stored in a compiled form, the work-around for the previous example is as follows:

```
CREATE OR REPLACE TRIGGER Example
AFTER INSERT ON Emp_tab
FOR EACH ROW
BEGIN
   Insert_row_proc;
END;

CREATE OR REPLACE PROCEDURE Insert_row_proc AS
BEGIN
    INSERT INTO Emp_tab@Remote
    VALUES ('x');
EXCEPTION
   WHEN OTHERS THEN
       INSERT INTO Emp_log
       VALUES ('x');
END;
```

The trigger in this example compiles successfully and calls the stored procedure, which already has a validated statement for accessing the remote database; thus, when the remote `INSERT` statement fails because the link is down, the exception is caught.

Restrictions on Creating Triggers

Coding triggers requires some restrictions that are not required for standard PL/SQL blocks. The following sections discuss these restrictions.

Maximum Trigger Size

The size of a trigger cannot be more than 32K.

SQL Statements Allowed in Trigger Bodies

The body of a trigger can contain DML SQL statements. It can also contain `SELECT` statements, but they must be `SELECT... INTO...` statements or the `SELECT` statement in the definition of a cursor.

DDL statements are not allowed in the body of a trigger. Also, no transaction control statements are allowed in a trigger. `ROLLBACK`, `COMMIT`, and `SAVEPOINT` cannot be used.For system triggers, {`CREATE/ALTER/DROP`} `TABLE` statements and `ALTER...COMPILE` are allowed.

Note: A procedure called by a trigger cannot run the previous transaction control statements, because the procedure runs within the context of the trigger body.

Statements inside a trigger can reference remote schema objects. However, pay special attention when calling remote procedures from within a local trigger. If a timestamp or signature mismatch is found during execution of the trigger, then the remote procedure is not run, and the trigger is invalidated.

Trigger Restrictions on LONG and LONG RAW Datatypes

LONG and LONG RAW datatypes in triggers are subject to the following restrictions:

- A SQL statement within a trigger can insert data into a column of LONG or LONG RAW datatype.
- If data from a LONG or LONG RAW column can be converted to a constrained datatype (such as CHAR and VARCHAR2), then a LONG or LONG RAW column can be referenced in a SQL statement within a trigger. The maximum length for these datatypes is 32000 bytes.
- Variables cannot be declared using the LONG or LONG RAW datatypes.
- :NEW and :PARENT cannot be used with LONG or LONG RAW columns.

Trigger Restrictions on Mutating Tables

A **mutating** table is a table that is being modified by an UPDATE, DELETE, or INSERT statement, or a table that might be updated by the effects of a DELETE CASCADE constraint.

The session that issued the triggering statement cannot query or modify a mutating table. This restriction prevents a trigger from seeing an inconsistent set of data.

This restriction applies to all triggers that use the FOR EACH ROW clause. Views being modified in INSTEAD OF triggers are not considered mutating.

When a trigger encounters a mutating table, a runtime error occurs, the effects of the trigger body and triggering statement are rolled back, and control is returned to the user or application.

Consider the following trigger:

```
CREATE OR REPLACE TRIGGER Emp_count
AFTER DELETE ON Emp_tab
FOR EACH ROW
DECLARE
    n INTEGER;
BEGIN
    SELECT COUNT(*) INTO n FROM Emp_tab;
    DBMS_OUTPUT.PUT_LINE(' There are now ' || n ||
        ' employees.');
END;
```

If the following SQL statement is entered:

```
DELETE FROM Emp_tab WHERE Empno = 7499;
```

An error is returned because the table is mutating when the row is deleted:

```
ORA-04091: table SCOTT.Emp_tab is mutating, trigger/function may not see it
```

If you delete the line "FOR EACH ROW" from the trigger, it becomes a statement trigger which is not subject to this restriction, and the trigger.

If you need to update a mutating table, you could bypass these restrictions by using a temporary table, a PL/SQL table, or a package variable. For example, in place of a single AFTER row trigger that updates the original table, resulting in a mutating table

error, you might use two triggers—an AFTER row trigger that updates a temporary table, and an AFTER statement trigger that updates the original table with the values from the temporary table.

Declarative integrity constraints are checked at various times with respect to row triggers.

> **See Also:** *Oracle Database Concepts* for information about the interaction of triggers and integrity constraints

Because declarative referential integrity constraints are not supported between tables on different nodes of a distributed database, the mutating table restrictions do not apply to triggers that access remote nodes. These restrictions are also not enforced among tables in the same database that are connected by loop-back database links. A loop-back database link makes a local table appear remote by defining an Oracle Net path back to the database that contains the link.

Restrictions on Mutating Tables Relaxed

The mutating error, discussed earlier in this section, still prevents the trigger from reading or modifying the table that the parent statement is modifying. However, starting in Oracle Database Release 8.1, a delete against the parent table causes before/after statement triggers to be fired once. That way, you can create triggers (just not row triggers) to read and modify the parent and child tables.

This allows most foreign key constraint actions to be implemented through their obvious after-row trigger, providing the constraint is not self-referential. Update cascade, update set null, update set default, delete set default, inserting a missing parent, and maintaining a count of children can all be implemented easily. For example, this is an implementation of update cascade:

```
create table p (p1 number constraint ppk primary key);
create table f (f1 number constraint ffk references p);
create trigger pt after update on p for each row begin
  update f set f1 = :new.p1 where f1 = :old.p1;
end;
/
```

This implementation requires care for multirow updates. For example, if a table p has three rows with the values (1), (2), (3), and table f also has three rows with the values (1), (2), (3), then the following statement updates p correctly but causes problems when the trigger updates f:

```
update p set p1 = p1+1;
```

The statement first updates (1) to (2) in p, and the trigger updates (1) to (2) in f, leaving two rows of value (2) in f. Then the statement updates (2) to (3) in p, and the trigger updates both rows of value (2) to (3) in f. Finally, the statement updates (3) to (4) in p, and the trigger updates all three rows in f from (3) to (4). The relationship of the data in p and f is lost.

To avoid this problem, you must forbid multirow updates to p that change the primary key and reuse existing primary key values. It could also be solved by tracking which foreign key values have already been updated, then modifying the trigger so that no row is updated twice.

That is the only problem with this technique for foreign key updates. The trigger cannot miss rows that have been changed but not committed by another transaction, because the foreign key constraint guarantees that no matching foreign key rows are locked before the after-row trigger is called.

System Trigger Restrictions

Depending on the event, different event attribute functions are available. For example, certain DDL operations may not be allowed on DDL events. Check "Event Attribute Functions" on page 9-38 before using an event attribute function, because its effects might be undefined rather than producing an error condition.

Only committed triggers are fired. For example, if you create a trigger that should be fired after all `CREATE` events, then the trigger itself does not fire after the creation, because the correct information about this trigger was not committed at the time when the trigger on `CREATE` events was fired.

For example, if you execute the following SQL statement:

```
CREATE OR REPLACE TRIGGER my_trigger AFTER CREATE ON DATABASE
BEGIN null;
END;
```

Then, trigger `my_trigger` is not fired after the creation of `my_trigger`. Oracle Database does not fire a trigger that is not committed.

Foreign Function Callouts

All restrictions on foreign function callouts also apply.

Who Is the Trigger User?

The following statement, inside a trigger, returns the owner of the trigger, not the name of user who is updating the table:

```
SELECT Username FROM USER_USERS;
```

Privileges Needed to Work with Triggers

To create a trigger in your schema, you must have the `CREATE TRIGGER` system privilege, and either:

- Own the table specified in the triggering statement, or
- Have the `ALTER` privilege for the table in the triggering statement, or
- Have the `ALTER ANY TABLE` system privilege

To create a trigger in another user's schema, or to reference a table in another schema from a trigger in your schema, you must have the `CREATE ANY TRIGGER` system privilege. With this privilege, the trigger can be created in any schema and can be associated with any user's table. In addition, the user creating the trigger must also have `EXECUTE` privilege on the referenced procedures, functions, or packages.

To create a trigger on `DATABASE`, you must have the `ADMINISTER DATABASE TRIGGER` privilege. If this privilege is later revoked, then you can drop the trigger, but not alter it.

The object privileges to the schema objects referenced in the trigger body must be granted to the trigger owner explicitly (not through a role). The statements in the trigger body operate under the privilege domain of the trigger owner, not the privilege domain of the user issuing the triggering statement. This is similar to the privilege model for stored procedures.

Compiling Triggers

Triggers are similar to PL/SQL anonymous blocks with the addition of the :new and :old capabilities, but their compilation is different. A PL/SQL anonymous block is compiled each time it is loaded into memory. Compilation involves three stages:

1. Syntax checking: PL/SQL syntax is checked, and a parse tree is generated.
2. Semantic checking: Type checking and further processing on the parse tree.
3. Code generation: The pcode is generated.

Triggers, in contrast, are fully compiled when the CREATE TRIGGER statement is entered, and the pcode is stored in the data dictionary. Hence, firing the trigger no longer requires the opening of a shared cursor to run the trigger action. Instead, the trigger is executed directly.

If errors occur during the compilation of a trigger, then the trigger is still created. If a DML statement fires this trigger, then the DML statement fails. (Runtime that trigger errors always cause the DML statement to fail.) You can use the SHOW ERRORS statement in SQL*Plus or Enterprise Manager to see any compilation errors when you create a trigger, or you can SELECT the errors from the USER_ERRORS view.

Dependencies for Triggers

Compiled triggers have dependencies. They become invalid if a depended-on object, such as a stored procedure or function called from the trigger body, is modified. Triggers that are invalidated for dependency reasons are recompiled when next invoked.

You can examine the ALL_DEPENDENCIES view to see the dependencies for a trigger. For example, the following statement shows the dependencies for the triggers in the SCOTT schema:

```
SELECT NAME, REFERENCED_OWNER, REFERENCED_NAME, REFERENCED_TYPE
    FROM ALL_DEPENDENCIES
    WHERE OWNER = 'SCOTT' and TYPE = 'TRIGGER';
```

Triggers may depend on other functions or packages. If the function or package specified in the trigger is dropped, then the trigger is marked invalid. An attempt is made to validate the trigger on occurrence of the event. If the trigger cannot be validated successfully, then it is marked VALID WITH ERRORS, and the event fails.

Note:

- There is an exception for STARTUP events: STARTUP events succeed even if the trigger fails. There are also exceptions for SHUTDOWN events and for LOGON events if you login as SYSTEM.
- Because the DBMS_AQ package is used to enqueue a message, dependency between triggers and queues cannot be maintained.

Recompiling Triggers

Use the ALTER TRIGGER statement to recompile a trigger manually. For example, the following statement recompiles the PRINT_SALARY_CHANGES trigger:

```
ALTER TRIGGER Print_salary_changes COMPILE;
```

To recompile a trigger, you must own the trigger or have the ALTER ANY TRIGGER system privilege.

Modifying Triggers

Like a stored procedure, a trigger cannot be explicitly altered: It must be replaced with a new definition. (The ALTER TRIGGER statement is used only to recompile, enable, or disable a trigger.)

When replacing a trigger, you must include the OR REPLACE option in the CREATE TRIGGER statement. The OR REPLACE option is provided to allow a new version of an existing trigger to replace the older version, without affecting any grants made for the original version of the trigger.

Alternatively, the trigger can be dropped using the DROP TRIGGER statement, and you can rerun the CREATE TRIGGER statement.

To drop a trigger, the trigger must be in your schema, or you must have the DROP ANY TRIGGER system privilege.

Debugging Triggers

You can debug a trigger using the same facilities available for stored procedures.

See Also: "Debugging Stored Procedures" on page 7-29

Enabling and Disabling Triggers

A trigger can be in one of two distinct modes:

Enabled. An enabled trigger executes its trigger body if a triggering statement is entered and the trigger restriction (if any) evaluates to TRUE.

Disabled. A disabled trigger does not execute its trigger body, even if a triggering statement is entered and the trigger restriction (if any) evaluates to TRUE.

Enabling Triggers

By default, a trigger is automatically enabled when it is created; however, it can later be disabled. After you have completed the task that required the trigger to be disabled, re-enable the trigger, so that it fires when appropriate.

Enable a disabled trigger using the ALTER TRIGGER statement with the ENABLE option. To enable the disabled trigger named REORDER of the INVENTORY table, enter the following statement:

```
ALTER TRIGGER Reorder ENABLE;
```

All triggers defined for a specific table can be enabled with one statement using the ALTER TABLE statement with the ENABLE clause with the ALL TRIGGERS option. For example, to enable all triggers defined for the INVENTORY table, enter the following statement:

```
ALTER TABLE Inventory
    ENABLE ALL TRIGGERS;
```

Disabling Triggers

You might temporarily disable a trigger if:

- An object it references is not available.
- You need to perform a large data load, and you want it to proceed quickly without firing triggers.
- You are reloading data.

By default, triggers are enabled when first created. Disable a trigger using the ALTER TRIGGER statement with the DISABLE option.

For example, to disable the trigger named REORDER of the INVENTORY table, enter the following statement:

```
ALTER TRIGGER Reorder DISABLE;
```

All triggers associated with a table can be disabled with one statement using the ALTER TABLE statement with the DISABLE clause and the ALL TRIGGERS option. For example, to disable all triggers defined for the INVENTORY table, enter the following statement:

```
ALTER TABLE Inventory
    DISABLE ALL TRIGGERS;
```

Viewing Information About Triggers

The following data dictionary views reveal information about triggers:

- USER_TRIGGERS
- ALL_TRIGGERS
- DBA_TRIGGERS

The new column, BASE_OBJECT_TYPE, specifies whether the trigger is based on DATABASE, SCHEMA, table, or view. The old column, TABLE_NAME, is null if the base object is not table or view.

The column ACTION_TYPE specifies whether the trigger is a call type trigger or a PL/SQL trigger.

The column TRIGGER_TYPE includes two additional values: BEFORE EVENT and AFTER EVENT, applicable only to system events.

The column TRIGGERING_EVENT includes all system and DML events.

> **See Also:** *Oracle Database Reference* for a complete description of these data dictionary views

For example, assume the following statement was used to create the REORDER trigger:

> **Caution:** You may need to set up data structures for certain examples to work:

```
CREATE OR REPLACE TRIGGER Reorder
AFTER UPDATE OF Parts_on_hand ON Inventory
FOR EACH ROW
WHEN(new.Parts_on_hand < new.Reorder_point)
DECLARE
   x NUMBER;
BEGIN
   SELECT COUNT(*) INTO x
```

```
      FROM Pending_orders
      WHERE Part_no = :new.Part_no;
   IF x = 0  THEN
      INSERT INTO Pending_orders
         VALUES (:new.Part_no, :new.Reorder_quantity,
                 sysdate);
   END IF;
END;
```

The following two queries return information about the `REORDER` trigger:

```
SELECT Trigger_type, Triggering_event, Table_name
   FROM USER_TRIGGERS
   WHERE Trigger_name = 'REORDER';

TYPE             TRIGGERING_STATEMENT       TABLE_NAME
---------------- -------------------------- ------------
AFTER EACH ROW   UPDATE                     INVENTORY

SELECT Trigger_body
   FROM USER_TRIGGERS
   WHERE Trigger_name = 'REORDER';

TRIGGER_BODY
-------------------------------------------
DECLARE
   x NUMBER;
BEGIN
   SELECT COUNT(*) INTO x
      FROM Pending_orders
      WHERE Part_no = :new.Part_no;
   IF x = 0
      THEN INSERT INTO Pending_orders
         VALUES (:new.Part_no, :new.Reorder_quantity,
            sysdate);
   END IF;
END;
```

Examples of Trigger Applications

You can use triggers in a number of ways to customize information management in Oracle Database. For example, triggers are commonly used to:

- Provide sophisticated auditing
- Prevent invalid transactions
- Enforce referential integrity (either those actions not supported by declarative integrity constraints or across nodes in a distributed database)
- Enforce complex business rules
- Enforce complex security authorizations
- Provide transparent event logging
- Automatically generate derived column values
- Enable building complex views that are updatable
- Track system events

This section provides an example of each of these trigger applications. These examples are not meant to be used exactly as written: They are provided to assist you in designing your own triggers.

Auditing with Triggers: Example

Triggers are commonly used to supplement the built-in auditing features of Oracle Database. Although triggers can be written to record information similar to that recorded by the `AUDIT` statement, triggers should be used only when more detailed audit information is required. For example, use triggers to provide value-based auditing for each row.

Sometimes, the `AUDIT` statement is considered a *security* audit facility, while triggers can provide *financial* audit facility.

When deciding whether to create a trigger to audit database activity, consider what Oracle Database's auditing features provide, compared to auditing defined by triggers, as shown in Table 9–1.

Table 9–1 Comparison of Built-in Auditing and Trigger-Based Auditing

Audit Feature	Description
DML and DDL Auditing	Standard auditing options permit auditing of DML and DDL statements regarding all types of schema objects and structures. Comparatively, *triggers* permit auditing of DML statements entered against tables, and DDL auditing at `SCHEMA` or `DATABASE` level.
Centralized Audit Trail	All database audit information is recorded centrally and automatically using the auditing features of Oracle Database.
Declarative Method	Auditing features enabled using the standard Oracle Database features are easier to declare and maintain, and less prone to errors, when compared to auditing functions defined by triggers.
Auditing Options can be Audited	Any changes to existing auditing options can also be audited to guard against malicious database activity.
Session and Execution time Auditing	Using the database auditing features, records can be generated once every time an audited statement is entered (`BY ACCESS`) or once for every session that enters an audited statement (`BY SESSION`). Triggers cannot audit by session; an audit record is generated each time a trigger-audited table is referenced.
Auditing of Unsuccessful Data Access	Database auditing can be set to audit when unsuccessful data access occurs. However, unless autonomous transactions are used, any audit information generated by a trigger is rolled back if the triggering statement is rolled back. For more information on autonomous transactions, refer to *Oracle Database Concepts*.
Sessions can be Audited	Connections and disconnections, as well as session activity (physical I/Os, logical I/Os, deadlocks, and so on), can be recorded using standard database auditing.

When using triggers to provide sophisticated auditing, `AFTER` triggers are normally used. By using `AFTER` triggers, auditing information is recorded after the triggering statement is subjected to any applicable integrity constraints, preventing cases where the audit processing is carried out unnecessarily for statements that generate exceptions to integrity constraints.

Choosing between `AFTER` row and `AFTER` statement triggers depends on the information being audited. For example, row triggers provide value-based auditing for each table row. Triggers can also require the user to supply a "reason code" for

issuing the audited SQL statement, which can be useful in both row and statement-level auditing situations.

The following example demonstrates a trigger that audits modifications to the `Emp_tab` table for each row. It requires that a "reason code" be stored in a global package variable before the update. This shows how triggers can be used to provide value-based auditing and how to use public package variables.

Note: You may need to set up the following data structures for the examples to work:

```
CREATE OR REPLACE PACKAGE Auditpackage AS
   Reason VARCHAR2(10);
PROCEDURE Set_reason(Reason VARCHAR2);
END;
CREATE TABLE Emp99 (
   Empno               NOT NULL   NUMBER(4),
   Ename               VARCHAR2(10),
   Job                 VARCHAR2(9),
   Mgr                 NUMBER(4),
   Hiredate            DATE,
   Sal                 NUMBER(7,2),
   Comm                NUMBER(7,2),
   Deptno              NUMBER(2),
   Bonus               NUMBER,
   Ssn                 NUMBER,
   Job_classification  NUMBER);

CREATE TABLE Audit_employee (
   Oldssn              NUMBER,
   Oldname             VARCHAR2(10),
   Oldjob              VARCHAR2(2),
   Oldsal              NUMBER,
   Newssn              NUMBER,
   Newname             VARCHAR2(10),
   Newjob              VARCHAR2(2),
   Newsal              NUMBER,
   Reason              VARCHAR2(10),
   User1               VARCHAR2(10),
   Systemdate          DATE);
```

```
CREATE OR REPLACE TRIGGER Audit_employee
AFTER INSERT OR DELETE OR UPDATE ON Emp99
FOR EACH ROW
BEGIN
/* AUDITPACKAGE is a package with a public package
   variable REASON.  REASON could be set by the
   application by a command such as EXECUTE
   AUDITPACKAGE.SET_REASON(reason_string). Note that a
   package variable has state for the duration of a
   session and that each session has a separate copy of
   all package variables. */

IF Auditpackage.Reason IS NULL THEN
   Raise_application_error(-20201, 'Must specify reason'
      || ' with AUDITPACKAGE.SET_REASON(Reason_string)');
END IF;

/* If the preceding conditional evaluates to TRUE, the
```

```
   user-specified error number and message is raised,
   the trigger stops execution, and the effects of the
   triggering statement are rolled back.  Otherwise, a
   new row is inserted into the predefined auditing
   table named AUDIT_EMPLOYEE containing the existing
   and new values of the Emp_tab table and the reason code
   defined by the REASON variable of AUDITPACKAGE.  Note
   that the "old" values are NULL if triggering
   statement is an INSERT and the "new" values are NULL
   if the triggering statement is a DELETE. */

INSERT INTO Audit_employee VALUES
   (:old.Ssn, :old.Ename, :old.Job_classification, :old.Sal,
   :new.Ssn, :new.Ename, :new.Job_classification, :new.Sal,
   auditpackage.Reason, User, Sysdate );
END;
```

Optionally, you can also set the reason code back to `NULL` if you wanted to force the reason code to be set for every update. The following simple `AFTER` statement trigger sets the reason code back to `NULL` after the triggering statement is run:

```
CREATE OR REPLACE TRIGGER Audit_employee_reset
AFTER INSERT OR DELETE OR UPDATE ON Emp_tab
BEGIN
   auditpackage.set_reason(NULL);
END;
```

Notice that the previous two triggers are both fired by the same type of SQL statement. However, the `AFTER` row trigger is fired once for each row of the table affected by the triggering statement, while the `AFTER` statement trigger is fired only once after the triggering statement execution is completed.

This next trigger also uses triggers to do auditing. It tracks changes made to the `Emp_tab` table and stores this information in `AUDIT_TABLE` and `AUDIT_TABLE_VALUES`.

Note: You may need to set up the following data structures for the example to work:

```
CREATE TABLE Audit_table (
   Seq      NUMBER,
   User_at  VARCHAR2(10),
   Time_now DATE,
   Term     VARCHAR2(10),
   Job      VARCHAR2(10),
   Proc     VARCHAR2(10),
   enum     NUMBER);
CREATE SEQUENCE Audit_seq;
CREATE TABLE Audit_table_values (
   Seq      NUMBER,
   Dept     NUMBER,
   Dept1    NUMBER,
   Dept2    NUMBER);
```

```
CREATE OR REPLACE TRIGGER Audit_emp
   AFTER INSERT OR UPDATE OR DELETE ON Emp_tab
   FOR EACH ROW
   DECLARE
      Time_now DATE;
```

```
      Terminal CHAR(10);
   BEGIN
      -- get current time, and the terminal of the user:
      Time_now := SYSDATE;
      Terminal := USERENV('TERMINAL');
      -- record new employee primary key
      IF INSERTING THEN
         INSERT INTO Audit_table
            VALUES (Audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'INSERT', :new.Empno);
      -- record primary key of the deleted row:
      ELSIF DELETING THEN
         INSERT INTO Audit_table
            VALUES (Audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'DELETE', :old.Empno);
      -- for updates, record the primary key
      -- of the row being updated:
      ELSE
         INSERT INTO Audit_table
            VALUES (audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'UPDATE', :old.Empno);
         -- and for SAL and DEPTNO, record old and new values:
         IF UPDATING ('SAL') THEN
            INSERT INTO Audit_table_values
               VALUES (Audit_seq.CURRVAL, 'SAL',
                  :old.Sal, :new.Sal);

         ELSIF UPDATING ('DEPTNO') THEN
            INSERT INTO Audit_table_values
               VALUES (Audit_seq.CURRVAL, 'DEPTNO',
                  :old.Deptno, :new.DEPTNO);
         END IF;
      END IF;
END;
```

Integrity Constraints and Triggers: Examples

Triggers and declarative integrity constraints can both be used to constrain data input. However, triggers and integrity constraints have significant differences.

Declarative integrity constraints are statements about the database that are always true. A constraint applies to existing data in the table and any statement that manipulates the table.

> **See Also:** Chapter 6, "Maintaining Data Integrity in Application Development"

Triggers constrain what a transaction can do. A trigger does not apply to data loaded before the definition of the trigger; therefore, it is not known if all data in a table conforms to the rules established by an associated trigger.

Although triggers can be written to enforce many of the same rules supported by Oracle Database's declarative integrity constraint features, triggers should only be used to enforce complex business rules that cannot be defined using standard integrity constraints. The declarative integrity constraint features provided with Oracle Database offer the following advantages when compared to constraints defined by triggers:

Centralized integrity checks. All points of data access must adhere to the global set of rules defined by the integrity constraints corresponding to each schema object.

Declarative method. Constraints defined using the standard integrity constraint features are much easier to write and are less prone to errors, when compared with comparable constraints defined by triggers.

While most aspects of data integrity can be defined and enforced using declarative integrity constraints, triggers can be used to enforce complex business constraints not definable using declarative integrity constraints. For example, triggers can be used to enforce:

- UPDATE SET NULL, and UPDATE and DELETE SET DEFAULT referential actions.
- Referential integrity when the parent and child tables are on different nodes of a distributed database.
- Complex check constraints not definable using the expressions allowed in a CHECK constraint.

Referential Integrity Using Triggers

There are many cases where referential integrity can be enforced using triggers. Note, however, you should only use triggers when there is no declarative support for the action you are performing.

When using triggers to maintain referential integrity, declare the PRIMARY (or UNIQUE) KEY constraint in the parent table. If referential integrity is being maintained between a parent and child table in the same database, then you can also declare the foreign key in the child table, but disable it; this prevents the corresponding PRIMARY KEY constraint from being dropped (unless the PRIMARY KEY constraint is explicitly dropped with the CASCADE option).

To maintain referential integrity using triggers:

- A trigger must be defined for the child table that guarantees values inserted or updated in the foreign key correspond to values in the parent key.
- One or more triggers must be defined for the parent table. These triggers guarantee the desired referential action (RESTRICT, CASCADE, or SET NULL) for values in the foreign key when values are updated or deleted in the parent key. No action is required for inserts into the parent table (no dependent foreign keys exist).

The following sections provide examples of the triggers necessary to enforce referential integrity. The Emp_tab and Dept_tab table relationship is used in these examples.

Several of the triggers include statements that lock rows (SELECT... FOR UPDATE). This operation is necessary to maintain concurrency as the rows are being processed.

Foreign Key Trigger for Child Table The following trigger guarantees that before an INSERT or UPDATE statement affects a foreign key value, the corresponding value exists in the parent key. The mutating table exception included in the following example allows this trigger to be used with the UPDATE_SET_DEFAULT and UPDATE_CASCADE triggers. This exception can be removed if this trigger is used alone.

```
CREATE OR REPLACE TRIGGER Emp_dept_check
BEFORE INSERT OR UPDATE OF Deptno ON Emp_tab
FOR EACH ROW WHEN (new.Deptno IS NOT NULL)

-- Before a row is inserted, or DEPTNO is updated in the Emp_tab
-- table, fire this trigger to verify that the new foreign
-- key value (DEPTNO) is present in the Dept_tab table.
```

```
DECLARE
   Dummy              INTEGER;  -- to be used for cursor fetch
   Invalid_department EXCEPTION;
   Valid_department   EXCEPTION;
   Mutating_table     EXCEPTION;
   PRAGMA EXCEPTION_INIT (Mutating_table, -4091);

-- Cursor used to verify parent key value exists.  If
-- present, lock parent key's row so it can't be
-- deleted by another transaction until this
-- transaction is committed or rolled back.
  CURSOR Dummy_cursor (Dn NUMBER) IS
   SELECT Deptno FROM Dept_tab
      WHERE Deptno = Dn
         FOR UPDATE OF Deptno;
BEGIN
   OPEN Dummy_cursor (:new.Deptno);
   FETCH Dummy_cursor INTO Dummy;

   -- Verify parent key.  If not found, raise user-specified
   -- error number and message.  If found, close cursor
   -- before allowing triggering statement to complete:
   IF Dummy_cursor%NOTFOUND THEN
      RAISE Invalid_department;
   ELSE
      RAISE valid_department;
   END IF;
   CLOSE Dummy_cursor;
EXCEPTION
   WHEN Invalid_department THEN
      CLOSE Dummy_cursor;
      Raise_application_error(-20000, 'Invalid Department'
         || ' Number' || TO_CHAR(:new.deptno));
   WHEN Valid_department THEN
      CLOSE Dummy_cursor;
   WHEN Mutating_table THEN
      NULL;
END;
```

UPDATE and DELETE RESTRICT Trigger for Parent Table The following trigger is defined on the DEPT_TAB table to enforce the UPDATE and DELETE RESTRICT referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_restrict
BEFORE DELETE OR UPDATE OF Deptno ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab or the primary key
-- (DEPTNO) of Dept_tab is updated, check for dependent
-- foreign key values in Emp_tab; rollback if any are found.
DECLARE
   Dummy                INTEGER;      -- to be used for cursor fetch
   Employees_present    EXCEPTION;
   employees_not_present EXCEPTION;

   -- Cursor used to check for dependent foreign key values.
   CURSOR Dummy_cursor (Dn NUMBER) IS
      SELECT Deptno FROM Emp_tab WHERE Deptno = Dn;

BEGIN
```

```
   OPEN Dummy_cursor (:old.Deptno);
   FETCH Dummy_cursor INTO Dummy;
   -- If dependent foreign key is found, raise user-specified
   -- error number and message.  If not found, close cursor
   -- before allowing triggering statement to complete.
   IF Dummy_cursor%FOUND THEN
      RAISE Employees_present;     -- dependent rows exist
   ELSE
      RAISE Employees_not_present; -- no dependent rows
   END IF;
   CLOSE Dummy_cursor;

EXCEPTION
   WHEN Employees_present THEN
      CLOSE Dummy_cursor;
      Raise_application_error(-20001, 'Employees Present in'
         || ' Department ' || TO_CHAR(:old.DEPTNO));
   WHEN Employees_not_present THEN
      CLOSE Dummy_cursor;
END;
```

> **Caution:** This trigger does not work with self-referential tables (tables with both the primary/unique key and the foreign key). Also, this trigger does not allow triggers to cycle (such as, A fires B fires A).

UPDATE and DELETE SET NULL Triggers for Parent Table: Example The following trigger is defined on the DEPT_TAB table to enforce the UPDATE and DELETE SET NULL referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_set_null
AFTER DELETE OR UPDATE OF Deptno ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab or the primary key
-- (DEPTNO) of Dept_tab is updated, set all corresponding
-- dependent foreign key values in Emp_tab to NULL:
BEGIN
   IF UPDATING AND :OLD.Deptno != :NEW.Deptno OR DELETING THEN
      UPDATE Emp_tab SET Emp_tab.Deptno = NULL
         WHERE Emp_tab.Deptno = :old.Deptno;
   END IF;
END;
```

DELETE Cascade Trigger for Parent Table: Example The following trigger on the DEPT_TAB table enforces the DELETE CASCADE referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_del_cascade
AFTER DELETE ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab, delete all
-- rows from the Emp_tab table whose DEPTNO is the same as
-- the DEPTNO being deleted from the Dept_tab table:
BEGIN
   DELETE FROM Emp_tab
      WHERE Emp_tab.Deptno = :old.Deptno;
END;
```

> **Note:** Typically, the code for DELETE CASCADE is combined with the code for UPDATE SET NULL or UPDATE SET DEFAULT to account for both updates and deletes.

UPDATE Cascade Trigger for Parent Table: Example The following trigger ensures that if a department number is updated in the Dept_tab table, then this change is propagated to dependent foreign keys in the Emp_tab table:

```
-- Generate a sequence number to be used as a flag for
-- determining if an update has occurred on a column:
CREATE SEQUENCE Update_sequence
    INCREMENT BY 1 MAXVALUE 5000
    CYCLE;

CREATE OR REPLACE PACKAGE Integritypackage AS
   Updateseq NUMBER;
END Integritypackage;

CREATE OR REPLACE PACKAGE BODY Integritypackage AS
END Integritypackage;
-- create flag col:
ALTER TABLE Emp_tab ADD Update_id NUMBER;

CREATE OR REPLACE TRIGGER Dept_cascade1 BEFORE UPDATE OF Deptno ON Dept_tab
DECLARE
   Dummy NUMBER;

-- Before updating the Dept_tab table (this is a statement
-- trigger), generate a new sequence number and assign
-- it to the public variable UPDATESEQ of a user-defined
-- package named INTEGRITYPACKAGE:
BEGIN
   SELECT Update_sequence.NEXTVAL
      INTO Dummy
      FROM dual;
   Integritypackage.Updateseq := Dummy;
END;

CREATE OR REPLACE TRIGGER Dept_cascade2 AFTER DELETE OR UPDATE
   OF Deptno ON Dept_tab FOR EACH ROW

-- For each department number in Dept_tab that is updated,
-- cascade the update to dependent foreign keys in the
-- Emp_tab table.  Only cascade the update if the child row
-- has not already been updated by this trigger:
BEGIN
   IF UPDATING THEN
      UPDATE Emp_tab
         SET Deptno = :new.Deptno,
         Update_id = Integritypackage.Updateseq   --from 1st
         WHERE Emp_tab.Deptno = :old.Deptno
         AND Update_id IS NULL;
         /* only NULL if not updated by the 3rd trigger
            fired by this same triggering statement */
   END IF;
   IF DELETING THEN

   -- Before a row is deleted from Dept_tab, delete all
```

```
   -- rows from the Emp_tab table whose DEPTNO is the same as
   -- the DEPTNO being deleted from the Dept_tab table:
      DELETE FROM Emp_tab
      WHERE Emp_tab.Deptno = :old.Deptno;
   END IF;
END;
CREATE OR REPLACE TRIGGER Dept_cascade3 AFTER UPDATE OF Deptno ON Dept_tab
BEGIN  UPDATE Emp_tab
   SET Update_id = NULL
   WHERE Update_id = Integritypackage.Updateseq;
END;
```

Note: Because this trigger updates the `Emp_tab` table, the `Emp_dept_check` trigger, if enabled, is also fired. The resulting mutating table error is trapped by the `Emp_dept_check` trigger. You should carefully test any triggers that require error trapping to succeed to ensure that they always work properly in your environment.

Trigger for Complex Check Constraints: Example

Triggers can enforce integrity rules other than referential integrity. For example, this trigger performs a complex check before allowing the triggering statement to run.

Note: You may need to set up the following data structures for the example to work:

```
CREATE TABLE Salgrade (
   Grade                NUMBER,
   Losal                NUMBER,
   Hisal                NUMBER,
   Job_classification   NUMBER)
```

```
CREATE OR REPLACE TRIGGER Salary_check
BEFORE INSERT OR UPDATE OF Sal, Job ON Emp99
FOR EACH ROW
DECLARE
   Minsal               NUMBER;
   Maxsal               NUMBER;
   Salary_out_of_range  EXCEPTION;
BEGIN

/* Retrieve the minimum and maximum salary for the
   employee's new job classification from the SALGRADE
   table into MINSAL and MAXSAL: */

SELECT Minsal, Maxsal INTO Minsal, Maxsal FROM Salgrade
   WHERE Job_classification = :new.Job;


/* If the employee's new salary is less than or greater
   than the job classification's limits, the exception is
   raised.  The exception message is returned and the
   pending INSERT or UPDATE statement that fired the
   trigger is rolled back:*/

   IF (:new.Sal < Minsal OR :new.Sal > Maxsal) THEN
```

```
      RAISE Salary_out_of_range;
   END IF;
EXCEPTION
   WHEN Salary_out_of_range THEN
      Raise_application_error (-20300,
         'Salary '||TO_CHAR(:new.Sal)||' out of range for '
         ||'job classification '||:new.Job
         ||' for employee '||:new.Ename);
   WHEN NO_DATA_FOUND THEN
      Raise_application_error(-20322,
         'Invalid Job Classification '
         ||:new.Job_classification);
END;
```

Complex Security Authorizations and Triggers: Example

Triggers are commonly used to enforce complex security authorizations for table data. Only use triggers to enforce complex security authorizations that cannot be defined using the database security features provided with Oracle Database. For example, a trigger can prohibit updates to salary data of the `Emp_tab` table during weekends, holidays, and non-working hours.

When using a trigger to enforce a complex security authorization, it is best to use a `BEFORE` statement trigger. Using a `BEFORE` statement trigger has these benefits:

- The security check is done before the triggering statement is allowed to run, so that no wasted work is done by an unauthorized statement.
- The security check is performed only once for the triggering statement, not for each row affected by the triggering statement.

This example shows a trigger used to enforce security.

> **Note:** You may need to set up the following data structures for the example to work:
>
> ```
> CREATE TABLE Company_holidays (Day DATE);
> ```

```
CREATE OR REPLACE TRIGGER Emp_permit_changes
BEFORE INSERT OR DELETE OR UPDATE ON Emp99
DECLARE
   Dummy             INTEGER;
   Not_on_weekends   EXCEPTION;
   Not_on_holidays   EXCEPTION;
   Non_working_hours EXCEPTION;
BEGIN
   /* check for weekends: */
   IF (TO_CHAR(Sysdate, 'DY') = 'SAT' OR
      TO_CHAR(Sysdate, 'DY') = 'SUN') THEN
      RAISE Not_on_weekends;
   END IF;
   /* check for company holidays:*/
   SELECT COUNT(*) INTO Dummy FROM Company_holidays
      WHERE TRUNC(Day) = TRUNC(Sysdate);
      /* TRUNC gets rid of time parts of dates: */
   IF dummy > 0 THEN
      RAISE Not_on_holidays;
   END IF;
   /* Check for work hours (8am to 6pm): */
   IF (TO_CHAR(Sysdate, 'HH24') < 8 OR
```

```
       TO_CHAR(Sysdate, 'HH24') > 18) THEN
       RAISE Non_working_hours;
   END IF;
EXCEPTION
   WHEN Not_on_weekends THEN
      Raise_application_error(-20324,'May not change '
         ||'employee table during the weekend');
   WHEN Not_on_holidays THEN
      Raise_application_error(-20325,'May not change '
         ||'employee table during a holiday');
   WHEN Non_working_hours THEN
      Raise_application_error(-20326,'May not change '
      ||'Emp_tab table during non-working hours');
END;
```

> **See Also:** *Oracle Database Security Guide* for details on database security features

Transparent Event Logging and Triggers

Triggers are very useful when you want to transparently perform a related change in the database following certain events.

The `REORDER` trigger example shows a trigger that reorders parts as necessary when certain conditions are met. (In other words, a triggering statement is entered, and the `PARTS_ON_HAND` value is less than the `REORDER_POINT` value.)

Derived Column Values and Triggers: Example

Triggers can derive column values automatically, based upon a value provided by an `INSERT` or `UPDATE` statement. This type of trigger is useful to force values in specific columns that depend on the values of other columns in the same row. `BEFORE` row triggers are necessary to complete this type of operation for the following reasons:

- The dependent values must be derived before the `INSERT` or `UPDATE` occurs, so that the triggering statement can use the derived values.
- The trigger must fire for each row affected by the triggering `INSERT` or `UPDATE` statement.

The following example illustrates how a trigger can be used to derive new column values for a table whenever a row is inserted or updated.

> **Note:** You may need to set up the following data structures for the example to work:
>
> ```
> ALTER TABLE Emp99 ADD(
>    Uppername   VARCHAR2(20),
>    Soundexname VARCHAR2(20));
> ```

```
CREATE OR REPLACE TRIGGER Derived
BEFORE INSERT OR UPDATE OF Ename ON Emp99

/* Before updating the ENAME field, derive the values for
   the UPPERNAME and SOUNDEXNAME fields. Users should be
   restricted from updating these fields directly: */
FOR EACH ROW
BEGIN
   :new.Uppername := UPPER(:new.Ename);
```

```
   :new.Soundexname := SOUNDEX(:new.Ename);
END;
```

Building Complex Updatable Views Using Triggers: Example

Views are an excellent mechanism to provide logical windows over table data. However, when the view query gets complex, the system implicitly cannot translate the DML on the view into those on the underlying tables. `INSTEAD OF` triggers help solve this problem. These triggers can be defined over views, and they fire *instead* of the actual DML.

Consider a library system where books are arranged under their respective titles. The library consists of a collection of book type objects. The following example explains the schema.

```
CREATE OR REPLACE TYPE Book_t AS OBJECT
(
   Booknum   NUMBER,
   Title     VARCHAR2(20),
   Author    VARCHAR2(20),
   Available CHAR(1)
);
CREATE OR REPLACE TYPE Book_list_t AS TABLE OF Book_t;
```

Assume that the following tables exist in the relational schema:

```
Table Book_table (Booknum, Section, Title, Author, Available)
```

Booknum	Section	Title	Author	Available
121001	Classic	Iliad	Homer	Y
121002	Novel	Gone With the Wind	Mitchell M	N

Library consists of `library_table`(`section`).

Section
Geography
Classic

You can define a complex view over these tables to create a logical view of the library with sections and a collection of books in each section.

```
CREATE OR REPLACE VIEW Library_view AS
SELECT i.Section, CAST (MULTISET (
   SELECT b.Booknum, b.Title, b.Author, b.Available
   FROM Book_table b
   WHERE b.Section = i.Section) AS Book_list_t) BOOKLIST
FROM Library_table i;
```

Make this view updatable by defining an `INSTEAD OF` trigger over the view.

```
CREATE OR REPLACE TRIGGER Library_trigger INSTEAD OF INSERT ON Library_view FOR
EACH ROW
   Bookvar BOOK_T;
   i       INTEGER;
BEGIN
   INSERT INTO Library_table VALUES (:NEW.Section);
   FOR i IN 1..:NEW.Booklist.COUNT LOOP
```

```
      Bookvar := Booklist(i);
      INSERT INTO book_table
         VALUES ( Bookvar.booknum, :NEW.Section, Bookvar.Title, Bookvar.Author,
bookvar.Available);
   END LOOP;
END;
/
```

The `library_view` is an updatable view, and any `INSERT`s on the view are handled by the trigger that gets fired automatically. For example:

```
INSERT INTO Library_view VALUES ('History', book_list_t(book_t(121330,
'Alexander', 'Mirth', 'Y');
```

Similarly, you can also define triggers on the nested table `booklist` to handle modification of the nested table element.

Tracking System Events Using Triggers

Fine-Grained Access Control Using Triggers: Example System triggers can be used to set application context. Application context is a relatively new feature that enhances your ability to implement fine-grained access control. Application context is a secure session cache, and it can be used to store session-specific attributes.

In the example that follows, procedure `set_ctx` sets the application context based on the user profile. The trigger `setexpensectx` ensures that the context is set for every user.

```
CONNECT secdemo/secdemo

CREATE OR REPLACE CONTEXT Expenses_reporting USING Secdemo.Exprep_ctx;

REM ================================================================
REM Creation of the package which implements the context:
REM ================================================================

CREATE OR REPLACE PACKAGE Exprep_ctx AS
 PROCEDURE Set_ctx;
END;

SHOW ERRORS

CREATE OR REPLACE PACKAGE BODY Exprep_ctx IS
   PROCEDURE Set_ctx IS
      Empnum   NUMBER;
      Countrec NUMBER;
      Cc       NUMBER;
      Role     VARCHAR2(20);
   BEGIN

      -- SET emp_number:
      SELECT Employee_id INTO Empnum FROM Employee
         WHERE Last_name = SYS_CONTEXT('userenv', 'session_user');

      DBMS_SESSION.SET_CONTEXT('expenses_reporting','emp_number', Empnum);

      -- SET ROLE:
      SELECT COUNT (*) INTO Countrec FROM Cost_center WHERE Manager_id=Empnum;
      IF (countrec > 0) THEN
         DBMS_SESSION.SET_CONTEXT('expenses_reporting','exp_role','MANAGER');
```

```
      ELSE
         DBMS_SESSION.SET_CONTEXT('expenses_reporting','exp_role','EMPLOYEE');
      END IF;

      -- SET cc_number:
      SELECT Cost_center_id INTO Cc FROM Employee
         WHERE Last_name = SYS_CONTEXT('userenv','session_user');
      DBMS_SESSION.SET_CONTEXT(expenses_reporting','cc_number',Cc);
   END;
END;
```

CALL Syntax

```
CREATE OR REPLACE TRIGGER Secdemo.Setexpseetx
AFTER LOGON ON DATABASE
CALL Secdemo.Exprep_etx.Set_otx
```

Responding to System Events through Triggers

System event publication lets applications subscribe to database events, just like they subscribe to messages from other applications. The system events publication framework includes the following features:

- Infrastructure for publish/subscribe, by making the database an active publisher of events.
- Integration of data cartridges in the server. The system events publication can be used to notify cartridges of state changes in the server.
- Integration of fine-grained access control in the server.

By creating a trigger, you can specify a procedure that runs when an event occurs. DML events are supported on tables, and system events are supported on `DATABASE` and `SCHEMA`. You can turn notification on and off by enabling and disabling the trigger using the `ALTER TRIGGER` statement.

This feature is integrated with the Advanced Queueing engine. Publish/subscribe applications use the `DBMS_AQ.ENQUEUE`() procedure, and other applications such as cartridges use callouts.

See Also:

- *Oracle Database SQL Reference*
- *Oracle Streams Advanced Queuing User's Guide and Reference* for details on how to subscribe to published events

How Events Are Published Through Triggers

When events are detected by the database, the trigger mechanism executes the action specified in the trigger. As part of this action, you can use the `DBMS_AQ` package to publish the event to a queue so that subscribers receive notifications.

Note: Only system-defined database events can be detected this way. You cannot define your own event conditions.

When an event occurs, the database fires all triggers that are enabled on that event, with some exceptions:

- If the trigger is actually the target of the triggering event, it is not fired. For example, a trigger for all `DROP` events is not fired when it is dropped itself.
- If a trigger has been modified but not committed within the same transaction as the firing event. For example, recursive DDL within a system trigger might modify a trigger, which prevents the modified trigger from being fired by events within the same transaction.

You can create more than one trigger on an object. When an event fires more than one trigger, the firing order is not defined and so you should not rely on the triggers being fired in a particular order.

Publication Context

When an event is published, certain runtime context and attributes, as specified in the parameter list, are passed to the callout procedure. A set of functions called event attribute functions are provided.

> **See Also:** "Event Attribute Functions" on page 9-38 for information on event-specific attributes

For each supported system event, you can identify and predefine event-specific attributes for the event. You can choose the parameter list to be any of these attributes, along with other simple expressions. For callouts, these are passed as `IN` arguments.

Error Handling

Return status from publication callout functions for all events are ignored. For example, with `SHUTDOWN` events, the database cannot do anything with the return status.

> **See Also:** "List of Database Events" on page 9-41 for details on return status

Execution Model

Traditionally, triggers execute as the definer of the trigger. The trigger action of an event is executed as the definer of the action (as the definer of the package or function in callouts, or as owner of the trigger in queues). Because the owner of the trigger must have `EXECUTE` privileges on the underlying queues, packages, or procedure, this behavior is consistent.

Event Attribute Functions

When the database fires a trigger, you can retrieve certain attributes about the event that fired the trigger. You can retrieve each attribute with a function call. Table 9–2 describes the system-defined event attributes.

Note:

- To make these attributes available, you must first run the `CATPROC.SQL` script.
- The trigger dictionary object maintains metadata about events that will be published and their corresponding attributes.
- In earlier releases, these functions were accessed through the `SYS` package. We recommend you use these public synonyms whose names begin with `ora_`.

Table 9–2 System-Defined Event Attributes

Attribute	Type	Description	Example

`ora_client_ip_address`	`VARCHAR2`	Returns IP address of the client in a `LOGON` event when the underlying protocol is TCP/IP	`DECLARE`
			`  v_addr VARCHAR2(11);`
			`  IF (ora_sysevent = 'LOGON') THEN`
			`  v_addr := ora_client_ip_address;`
			`  END IF;`
			`END;`

`ora_database_name`	`VARCHAR2(50)`	Database name.	`DECLARE`
			`  v_db_name VARCHAR2(50);`
			`BEGIN`
			`  v_db_name := ora_database_name;`
			`END;`

`ora_des_encrypted_password`	`VARCHAR2`	The DES-encrypted password of the user being created or altered.	`IF (ora_dict_obj_type = 'USER') THEN`
			`  INSERT INTO event_table`
			`  VALUES (ora_des_encrypted_password);`
			`END IF;`

`ora_dict_obj_name`	`VARCHAR(30)`	Name of the dictionary object on which the DDL operation occurred.	`INSERT INTO event_table`
			`  VALUES ('Changed object is ' ||`
			`  ora_dict_obj_name);`

`ora_dict_obj_name_list (name_list OUT ora_name_list_t)`	`BINARY_INTEGER`	Return the list of object names of objects being modified in the event.	`IF (ora_sysevent='ASSOCIATE STATISTICS')`
			`  THEN number_modified :=`
			`  ora_dict_obj_name_list(name_list);`
			`END IF;`

`ora_dict_obj_owner`	`VARCHAR(30)`	Owner of the dictionary object on which the DDL operation occurred.	`INSERT INTO event_table`
			`  VALUES ('object owner is' ||`
			`  ora_dict_obj_owner);`

`ora_dict_obj_owner_list (owner_list OUT ora_name_list_t)`	`BINARY_INTEGER`	Returns the list of object owners of objects being modified in the event.	`IF (ora_sysevent='ASSOCIATE STATISTICS')`
			`  THEN number_of_modified_objects :=`
			`  ora_dict_obj_owner_list(owner_list);`
			`END IF;`

`ora_dict_obj_type`	`VARCHAR(20)`	Type of the dictionary object on which the DDL operation occurred.	`INSERT INTO event_table`
			`  VALUES ('This object is a ' ||`
			`  ora_dict_obj_type);`

`ora_grantee (user_list OUT ora_name_list_t)`	`BINARY_INTEGER`	Returns the grantees of a grant event in the OUT parameter; returns the number of grantees in the return value.	`IF (ora_sysevent = 'GRANT') THEN`
			`  number_of_users=ora_grantee(user_list);`
			`END IF;`

`ora_instance_num`	`NUMBER`	Instance number.	`IF (ora_instance_num = 1) THEN`
			`  INSERT INTO event_table VALUES ('1');`
			`END IF;`

Table 9–2 (Cont.) System-Defined Event Attributes

Attribute	Type	Description	Example
ora_is_alter_column (column_name IN VARCHAR2)	BOOLEAN	Returns true if the specified column is altered.	IF (ora_sysevent = 'ALTER' AND ora_dict_obj_type = 'TABLE') THEN alter_column := ora_is_alter_column('C'); END IF;
ora_is_creating_nested_table	BOOLEAN	Returns true if the current event is creating a nested table	IF (ora_sysevent = 'CREATE' and ora_dict_obj_type = 'TABLE' and ora_is_creating_nested_table) THEN INSERT INTO event_table VALUES ('A nested table is created'); END IF;
ora_is_drop_column (column_name IN VARCHAR2)	BOOLEAN	Returns true if the specified column is dropped.	IF (ora_sysevent = 'ALTER' AND ora_dict_obj_type = 'TABLE') THEN drop_column := ora_is_drop_column('C'); END IF;
ora_is_servererror	BOOLEAN	Returns TRUE if given error is on error stack, FALSE otherwise.	IF (ora_is_servererror(*error_number*)) THEN INSERT INTO event_table VALUES ('Server error!!'); END IF;
ora_login_user	VARCHAR2(30)	Login user name.	SELECT ora_login_user FROM dual;
ora_partition_pos	BINARY_INTEGER	In an INSTEAD OF trigger for CREATE TABLE, the position within the SQL text where you could insert a PARTITION clause.	-- Retrieve ora_sql_txt into -- sql_text variable first. v_n := ora_partition_pos; v_new_stmt := SUBSTR(sql_text,1,v_n - 1) || ' ' || my_partition_clause || ' ' || SUBSTR(sql_text, v_n));
ora_privilege_list (privilege_list OUT ora_name_list_t)	BINARY_INTEGER	Returns the list of privileges being granted by the grantee or the list of privileges revoked from the revokees in the OUT parameter; returns the number of privileges in the return value.	IF (ora_sysevent = 'GRANT' OR ora_sysevent = 'REVOKE') THEN number_of_privileges := ora_privilege_list(priv_list); END IF;
ora_revokee (user_list OUT ora_name_list_t)	BINARY_INTEGER	Returns the revokees of a revoke event in the OUT parameter; returns the number of revokees in the return value.	IF (ora_sysevent = 'REVOKE') THEN number_of_users := ora_revokee(user_list);
ora_server_error	NUMBER	Given a position (1 for top of stack), it returns the error number at that position on error stack	INSERT INTO event_table VALUES ('top stack error ' || ora_server_error(1));
ora_server_error_depth	BINARY_INTEGER	Returns the total number of error messages on the error stack.	n := ora_server_error_depth; -- This value is used with other functions -- such as ora_server_error
ora_server_error_msg (position in binary_integer)	VARCHAR2	Given a position (1 for top of stack), it returns the error message at that position on error stack	INSERT INTO event_table VALUES ('top stack error message' || ora_server_error_msg(1));

Table 9–2 (Cont.) System-Defined Event Attributes

Attribute	Type	Description	Example
ora_server_error_num_params (position in binary_integer)	BINARY_INTEGER	Given a position (1 for top of stack), it returns the number of strings that have been substituted into the error message using a format like %s.	n := ora_server_error_num_params(1);
ora_server_error_param (position in binary_integer, param in binary_integer)	VARCHAR2	Given a position (1 for top of stack) and a parameter number, returns the matching substitution value (%s, %d, and so on) in the error message.	-- For example, the second %s in a -- message: "Expected %s, found %s" param := ora_server_error_param(1,2);

ora_sql_txt (sql_text out ora_name_list_t)	BINARY_INTEGER	Returns the SQL text of the triggering statement in the OUT parameter. If the statement is long, it is broken into multiple PL/SQL table elements. The function return value shows the number of elements are in the PL/SQL table.	sql_text ora_name_list_t;
			v_stmt VARCHAR2(2000);
			...
			n := ora_sql_txt(sql_text);
			FOR i IN 1..n LOOP
			  v_stmt := v_stmt || sql_text(i);
			END LOOP;
			INSERT INTO event_table
			  VALUES ('text of triggering statement: '
			  || v_stmt);

ora_sysevent	VARCHAR2(20)	System event firing the trigger: Event name is same as that in the syntax.	INSERT INTO event_table VALUES (ora_sysevent);

ora_with_grant_option	BOOLEAN	Returns true if the privileges are granted with grant option.	IF (ora_sysevent = 'GRANT' and
			  ora_with_grant_option = TRUE) THEN
			  INSERT INTO event_table
			  VALUES ('with grant option');
			END IF;

space_error_info (error_number OUT NUMBER, error_type OUT VARCHAR2, object_owner OUT VARCHAR2, table_space_name OUT VARCHAR2, object_name OUT VARCHAR2, sub_object_name OUT VARCHAR2)	BOOLEAN	Returns true if the error is related to an out-of-space condition, and fills in the OUT parameters with information about the object that caused the error.	IF (space_error_info(eno,typ,owner,ts,obj,
			  subobj) = TRUE) THEN
			  DBMS_OUTPUT.PUT_LINE('The object '|| obj
			  || ' owned by ' || owner ||
			  ' has run out of space.');
			END IF;

List of Database Events

This section describes important system events and client events.

System Events

System events are related to entire instances or schemas, not individual tables or rows. Triggers created on startup and shutdown events must be associated with the database instance. Triggers created on error and suspend events can be associated with either the database instance or a particular schema.

Table 9–3 contains a list of system manager events.

Table 9–3 System Manager Events

Event	When Fired?	Conditions	Restrictions	Transaction	Attribute Functions
STARTUP	When the database is opened.	None allowed	No database operations allowed in the trigger. Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	ora_sysevent ora_login_user ora_instance_num ora_database_name
SHUTDOWN	Just before the server starts the shutdown of an instance. This lets the cartridge shutdown completely. For abnormal instance shutdown, this event may not be fired.	None allowed	No database operations allowed in the trigger. Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	ora_sysevent ora_login_user ora_instance_num ora_database_name
DB_ROLE_CHANGE	When the database is opened for the first time after a role change.	None allowed	Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	ora_sysevent ora_login_user ora_instance_num ora_database_name
SERVERERROR	When the error eno occurs. If no condition is given, then this event fires whenever an error occurs. The trigger does not fire on ORA-1034, ORA-1403, ORA-1422, ORA-1423, and ORA-4030 because they are not true errors or are too serious to continue processing. It also fails to fire on ORA-18 and ORA-20 because a process is not available to connect to the database to record the error.	ERRNO = eno	Depends on the error. Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_server_error ora_is_servererror space_error_info

Client Events

Client events are the events related to user logon/logoff, DML, and DDL operations. For example:

```
CREATE OR REPLACE TRIGGER On_Logon
  AFTER LOGON
  ON The_user.Schema
BEGIN
  Do_Something;
END;
```

The LOGON and LOGOFF events allow simple conditions on UID and USER. All other events allow simple conditions on the type and name of the object, as well as functions like UID and USER.

The LOGON event starts a separate transaction and commits it after firing the triggers. All other events fire the triggers in the existing user transaction.

The LOGON and LOGOFF events can operate on any objects. For all other events, the corresponding trigger cannot perform any DDL operations, such as DROP and ALTER, on the object that caused the event to be generated.

The DDL allowed inside these triggers is altering, creating, or dropping a table, creating a trigger, and compile operations.

If an event trigger becomes the target of a DDL operation (such as CREATE TRIGGER), it cannot be fired later during the same transaction

Table 9–4 contains a list of client events.

Table 9–4 Client Events

Event	When Fired?	Attribute Functions
BEFORE ALTER AFTER ALTER	When a catalog object is altered.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_type ora_dict_obj_name ora_dict_obj_owner ora_des_encrypted_password (for ALTER USER events) ora_is_alter_column (for ALTER TABLE events) ora_is_drop_column (for ALTER TABLE events)
BEFORE DROP AFTER DROP	When a catalog object is dropped.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_type ora_dict_obj_name ora_dict_obj_owner
BEFORE ANALYZE AFTER ANALYZE	When an analyze statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner
BEFORE ASSOCIATE STATISTICS AFTER ASSOCIATE STATISTICS	When an associate statistics statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner ora_dict_obj_name_list ora_dict_obj_owner_list
BEFORE AUDIT AFTER AUDIT BEFORE NOAUDIT AFTER NOAUDIT	When an audit or noaudit statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name
BEFORE COMMENT AFTER COMMENT	When an object is commented	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner
BEFORE CREATE AFTER CREATE	When a catalog object is created.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_type ora_dict_obj_name ora_dict_obj_owner ora_is_creating_nested_table (for CREATE TABLE events)

Table 9–4 (Cont.) Client Events

Event	When Fired?	Attribute Functions
BEFORE DDL AFTER DDL	When most SQL DDL statements are issued. Not fired for ALTER DATABASE, CREATE CONTROLFILE, CREATE DATABASE, and DDL issued through the PL/SQL procedure interface, such as creating an advanced queue.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner
BEFORE DISASSOCIATE STATISTICS AFTER DISASSOCIATE STATISTICS	When a disassociate statistics statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner ora_dict_obj_name_list ora_dict_obj_owner_list
BEFORE GRANT AFTER GRANT	When a grant statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner ora_grantee ora_with_grant_option ora_privileges
BEFORE LOGOFF	At the start of a user logoff	ora_sysevent ora_login_user ora_instance_num ora_database_name
AFTER LOGON	After a successful logon of a user.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_client_ip_address
BEFORE RENAME AFTER RENAME	When a rename statement is issued.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_owner ora_dict_obj_type

Table 9–4 (Cont.) Client Events

Event	When Fired?	Attribute Functions
BEFORE REVOKE AFTER REVOKE	When a revoke statement is issued	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner ora_revokee ora_privileges
AFTER SUSPEND	After a SQL statement is suspended because of an out-of-space condition. The trigger should correct the condition so the statement can be resumed.	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_server_error ora_is_servererror space_error_info
BEFORE TRUNCATE AFTER TRUNCATE	When an object is truncated	ora_sysevent ora_login_user ora_instance_num ora_database_name ora_dict_obj_name ora_dict_obj_type ora_dict_obj_owner

10

Developing Flashback Applications

This chapter discusses the following flashback topics:

See Also:

- *Oracle Database Backup and Recovery Advanced User's Guide* and *Oracle Database Administrator's Guide* for information on flashback features designed for database administration tasks such as Oracle Flashback Database and Oracle Flashback Table
- *Oracle Database SQL Reference* for the syntax of SQL extensions for flashback features

Overview of Flashback Features

Oracle Database has a group of features, known collectively as **flashback**, that provide ways to view past states of database objects or to return database objects to a previous state without using point-in-time media recovery.

You can use flashback features of the database to do the following:

- Perform queries that return past data.
- Perform queries that return metadata that shows a detailed history of changes to the database.
- Recover tables or rows to a previous point in time.

Flashback features use the Automatic Undo Management system to obtain metadata and historical data for transactions. They rely on **undo data**, which are records of the effects of individual transactions. For example, if a user executes an `UPDATE` statement to change a salary from 1000 to 1100, then Oracle would store the value 1000 in the undo data.

Undo data is persistent and survives a database shutdown. By using flashback features, you can employ undo data to query past data or recover from logical corruptions. Besides using it in flashback operations, Oracle Database uses undo data to perform the following actions:

- Roll back active transactions
- Recover terminated transactions by using database or process recovery
- Provide read consistency for SQL queries

> **See Also:** *Oracle Database Concepts* for more information about flashback features and automatic undo management

Application Development Features

In application development, you can use flashback features to report on historical data or undo erroneous changes. Flashback features include the following:

- Oracle Flashback Query

  You can use this feature to retrieve data for a time in the past that you specify using the `AS OF` clause of the `SELECT` statement.

- Oracle Flashback Version Query

  You can use this feature to retrieve metadata and historical data for a specific time interval. For example, you can view all the rows of a table that ever existed during a given time interval. Metadata about the different versions of rows includes start and end time, type of change operation, and identity of the transaction that created the row version. You use the `VERSIONS BETWEEN` clause of the `SELECT` statement to create a Flashback Version Query.

- Oracle Flashback Transaction Query

  You can use this feature to retrieve metadata and historical data for a given transaction or for all transactions within a given time interval. You can also obtain the SQL code to undo the changes to particular rows affected by a transaction. Typically, you use Flashback Transaction Query in conjunction with a Flashback Version Query that provides the transaction IDs for the rows of interest. To perform a Flashback Transaction Query, select from the `FLASHBACK_TRANSACTION_QUERY` view.

- `DBMS_FLASHBACK` package

  You can use this feature to set the internal Oracle clock to a time in the past so that you can examine data current at that time.

Database Administration Features

You can use the following features for application development or interactively as a database user or administrator:

- `DBMS_FLASHBACK` package
- Flashback Query
- Flashback Version Query
- Flashback Transaction Query

Typically, you use the following flashback features only in database administration:

- Oracle Flashback Table

You can use this feature to recover a table to its state at a previous point in time. You can restore table data while the database is on line, undoing changes to only the specified table.

- Oracle Flashback Drop

  You can use this feature to recover a dropped table. This reverses the effects of a `DROP TABLE` statement.

- Oracle Flashback Database

  You can use this feature to quickly return the database to an earlier point in time, by undoing all of the changes that have taken place since then. This is fast, because you do not have to restore database backups.

Flashback Database, Flashback Table, and Flashback Drop are primarily data recovery mechanisms and are therefore documented elsewhere. The other flashback features, while valuable in data recovery scenarios, are useful for application development. They are the focus of this chapter.

See Also:

- *Oracle Database Backup and Recovery Advanced User's Guide*
- *Oracle Database Administrator's Guide* to learn about the Flashback Drop feature
- *Oracle Database Administrator's Guide* to learn about the Flashback Table feature
- *Oracle Database Administrator's Guide* to learn about Automatic Undo Management

Database Administration Tasks Before Using Flashback Features

Before you can use flashback features in your application, you must perform the following administrative tasks to configure your database. Consult with your database administrator to perform these tasks:

- Create an undo tablespace with enough space to keep the required data for flashback operations. The more often users update the data, the more space is required. Calculating the space requirements is usually performed by a database administrator. You can find the calculation formula in the *Oracle Database Administrator's Guide*.
- Enable Automatic Undo Management, as explained in *Oracle Database Administrator's Guide*. In particular, you must set the following database initialization parameters:
  - `UNDO_MANAGEMENT`
  - `UNDO_TABLESPACE`

  Note that for an undo tablespace with a fixed size, Oracle Database automatically performs the following actions:

  - Tunes the system to give the best possible undo retention for the undo tablespace.

  For an automatically extensible undo tablespace, Oracle Database retains undo data longer than the longest query duration as well as the low threshold of undo retention specified by the `UNDO_RETENTION` parameter.

> **Note:** You can query V$UNDOSTAT.TUNED_UNDORETENTION to determine the amount of time for which undo is retained for the current undo tablespace.

- Specify the RETENTION GUARANTEE clause for the undo tablespace to ensure that unexpired undo is not discarded. Setting UNDO_RETENTION is not, by itself, a strict guarantee. If the system is under space pressure, then Oracle can overwrite unexpired undo with freshly generated undo. Specifying RETENTION GUARANTEE prevents this behavior.
- Grant flashback privileges to users, roles, or applications that need to use flashback features as follows:
  - For the DBMS_FLASHBACK package, grant the EXECUTE privilege on DBMS_FLASHBACK to provide access to the features in this package.
  - For Flashback Query and Flashback Version Query, grant FLASHBACK and SELECT privileges on specific objects to be accessed during queries or grant the FLASHBACK ANY TABLE privilege to allow queries on *all* tables.
  - For Flashback Transaction Query, grant the SELECT ANY TRANSACTION privilege.
  - For Execution of undo SQL code, grant SELECT, UPDATE, DELETE, and INSERT privileges for specific tables, as appropriate, to permit execution of undo SQL code retrieved by a Flashback Transaction Query.
- To use the Flashback Transaction Query feature in Oracle Database 10g, the database must be running with version 10.0 compatibility, and must have supplemental logging turned on with the following SQL statement:

  ```
  ALTER DATABASE ADD SUPPLEMENTAL LOG DATA;
  ```

- To enable flashback operations on specific LOB columns of a table, use the ALTER TABLE command with the RETENTION option. Because undo data for LOB columns can be voluminous, you must define which LOB columns to use with flashback operations.

  See Also:

  - *Oracle Database Backup and Recovery Advanced User's Guide* and *Oracle Database Administrator's Guide* to learn about DBA tasks such as setting up automatic undo management and granting privileges
  - *Oracle Database Application Developer's Guide - Large Objects* to learn about LOB storage and the RETENTION parameter

Using Flashback Query (SELECT ... AS OF)

You perform a Flashback Query by using a SELECT statement with an AS OF clause. You use a Flashback Query to retrieve data as it existed at some time in the past. The query explicitly references a past time by means of a timestamp or SCN. It returns committed data that was current at that point in time.

Potential uses of Flashback Query include:

- Recovering lost data or undoing incorrect, committed changes. For example, if you mistakenly delete or update rows, and then commit them, you can immediately undo the mistake.

- Comparing current data with the corresponding data at some time in the past. For example, you might run a daily report that shows the change in data from yesterday. You can compare individual rows of table data or find intersections or unions of sets of rows.
- Checking the state of transactional data at a particular time. For example, you could verify the account balance of a certain day.
- Simplifying application design, by removing the need to store some kinds of temporal data. By using a Flashback Query, you can retrieve past data directly from the database.
- Applying packaged applications such as report generation tools to past data.
- Providing self-service error correction for an application, thereby enabling users to undo and correct their errors.

> **See Also:** *Oracle Database SQL Reference* for details on the syntax of the `SELECT... AS OF` statement

Examining Past Data: Example

This example uses a Flashback Query to examine the state of a table at a previous time. Suppose that a DBA discovers at 12:30 PM that the row for employee Chung had been deleted from the `employees` table. The DBA also knows that at 9:30AM the data for Chung was correctly stored in the database. The DBA can use a Flashback Query to examine the contents of the table at 9:30 to find out what data had been lost. If appropriate, the DBA can then re-insert the lost data.

Example 10–1 retrieves the state of the record for `Chung` at 9:30AM, April 4, 2004:

Example 10–1 Retrieving a Row with Flashback Query

```
SELECT * FROM employees AS OF TIMESTAMP
   TO_TIMESTAMP('2004-04-04 09:30:00', 'YYYY-MM-DD HH:MI:SS')
   WHERE last_name = 'Chung';
```

The update in Example 10–2 restores Chung's information to the `employees` table:

Example 10–2 Reinserting a Row After a Flashback Query

```
INSERT INTO employees
    (SELECT * FROM employees AS OF TIMESTAMP
     TO_TIMESTAMP('2004-04-04 09:30:00', 'YYYY-MM-DD HH:MI:SS')
     WHERE last_name = 'Chung');
```

Tips for Using Flashback Query

Keep the following in mind when using a Flashback Query (`SELECT ... AS OF`):

- You can specify or omit the `AS OF` clause for each table and specify different times for different tables. Use an `AS OF` clause in a query to perform DDL operations (such as creating and truncating tables) or DML operations (such as inserting and deleting) in the same session as the query.
- To use the results of a Flashback Query in a DDL or DML statement that affects the current state of the database, use an `AS OF` clause inside an `INSERT` or `CREATE TABLE AS SELECT` statement.
- When choosing whether to use a timestamp or an SCN in Flashback Query, remember that Oracle Database uses SCNs internally and maps these to

timestamps at a granularity of 3 seconds. If a possible 3-second error (maximum) is important to a Flashback Query in your application, then use an SCN instead of a timestamp. Refer to "Flashback Tips – General".

- You can create a view that refers to past data by using the `AS OF` clause in the `SELECT` statement that defines the view. If you specify a relative time by subtracting from the current time on the database host, then the past time is recalculated for each query. For example:

```
CREATE VIEW hour_ago AS
  SELECT * FROM employees AS OF
    TIMESTAMP (SYSTIMESTAMP - INTERVAL '60' MINUTE);
-- SYSTIMESTAMP refers to the time zone of the database host environment
```

- You can use the `AS OF` clause in self-joins, or in set operations such as `INTERSECT` and `MINUS`, to extract or compare data from two different times. You can store the results by preceding a Flashback Query with a `CREATE TABLE AS SELECT` or `INSERT INTO TABLE SELECT` statement. For example, the following query reinserts into table `employees` the rows that existed an hour ago:

```
INSERT INTO employees
  (SELECT * FROM employees AS OF
     TIMESTAMP (SYSTIMESTAMP - INTERVAL '60' MINUTE))
-- SYSTIMESTAMP refers to the time zone of the database host environment
  MINUS SELECT * FROM employees);
```

Using the DBMS_FLASHBACK Package

In general, the `DBMS_FLASHBACK` package provides the same functionality as Flashback Query, but Flashback Query is sometimes more convenient.

The `DBMS_FLASHBACK` package acts as a time machine: you can turn back the clock, carry out normal queries as if you were at that time in the past, and then return to the present. Because you can use the `DBMS_FLASHBACK` package to perform queries on past data without special clauses such as `AS OF` or `VERSIONS BETWEEN`, you can reuse existing PL/SQL code to query the database at times in the past.

You must have the `EXECUTE` privilege on the `DBMS_FLASHBACK` package.

To use the `DBMS_FLASHBACK` package in your PL/SQL code:

1. Call `DBMS_FLASHBACK.ENABLE_AT_TIME` or `DBMS_FLASHBACK.ENABLE_AT_SYSTEM_CHANGE_NUMBER` to turn back the clock to a specified time in the past. Afterwards all queries retrieve data that was current at the specified time.
2. Perform normal queries, that is, without any special flashback-feature syntax such as `AS OF`. The database is automatically queried at the specified past time. Perform *only queries*; do not try to perform DDL or DML operations.
3. Call `DBMS_FLASHBACK.DISABLE` to return to the present. You must call `DISABLE` before calling `ENABLE` again for a different time. You cannot nest `ENABLE /DISABLE` pairs.

You can use a cursor to store the results of queries. To do this, open the cursor before calling `DBMS_FLASHBACK.DISABLE`. After storing the results and then calling `DISABLE`, you can do the following:

- Perform `INSERT` or `UPDATE` operations to modify the current database state by using the stored results from the past.

- Compare current data with the past data. After calling DISABLE, open a second cursor. Fetch from the first cursor to retrieve past data; fetch from the second cursor to retrieve current data. You can store the past data in a temporary table, and then use set operators such as MINUS or UNION to contrast or combine the past and current data.

You can call DBMS_FLASHBACK.GET_SYSTEM_CHANGE_NUMBER at any time to obtain the current System Change Number (SCN). Note that the *current* SCN is always returned; this takes no account of previous calls to DBMS_FLASHBACK.ENABLE*.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference* for details about the DBMS_FLASHBACK package
- *Oracle Database Reference* and *Oracle Database Backup and Recovery Reference* for information about SCNs

Using ORA_ROWSCN

ORA_ROWSCN is a pseudocolumn of any table that is not fixed or external. It represents the SCN of the most recent change to a given row, that is, the latest COMMIT operation for the row. For example:

```
SELECT ora_rowscn, last_name, salary
FROM employees
WHERE employee_id = 7788;

ORA_ROWSCN    NAME    SALARY
----------    ----    ------
    202553    Fudd      3000
```

The latest COMMIT operation for the row took place at approximately SCN 202553. You can use function SCN_TO_TIMESTAMP to convert an SCN, like ORA_ROWSCN, to the corresponding TIMESTAMP value.

ORA_SCN is in fact a conservative upper bound of the latest commit time: the actual commit SCN can be somewhat earlier. ORA_SCN is more precise (closer to the actual commit SCN) for a row-dependent table (created using CREATE TABLE with the ROWDEPENDENCIES clause).

Noteworthy uses of ORA_ROWSCN in application development include concurrency control and client cache invalidation. To see how you might use it in concurrency control, consider the following scenario.

Your application examines a row of data, and records the corresponding ORA_ROWSCN as 202553. Later, the application needs to update the row, but only if its record of the data is still accurate. That is, this particular update operation depends, logically, on the row not having been changed. The operation is therefore made conditional on the ORA_ROWSCN being still 202553. Here is an equivalent interactive command:

```
UPDATE employees
  SET salary = salary + 100
  WHERE employee_id = 7788
  AND ora_rowscn = 202553;

0 rows updated.
```

The conditional update fails in this case, because the ORA_ROWSCN is no longer 202553. This means that some user or another application changed the row and performed a COMMIT more recently than the recorded ORA_ROWSCN.

Your application queries again to obtain the new row data and ORA_ROWSCN. Suppose that the ORA_ROWSCN is now 415639. The application tries the conditional update again, using the new ORA_ROWSCN. This time, the update succeeds, and it is committed. Here is an interactive equivalent:

```
SQL> UPDATE employees SET salary = salary + 100
     WHERE empno = 7788 AND ora_rowscn = 415639;

1 row updated.

SQL> COMMIT;

Commit complete.

SQL> SELECT ora_rowscn, name, salary FROM employees WHERE empno = 7788;

ORA_ROWSCN    NAME    SALARY
----------    ----    ------
    465461    Fudd      3100
```

The SCN corresponding to the new COMMIT is 465461.

Besides using ORA_ROWSCN in an UPDATE statement WHERE clause, you can use it in a DELETE statement WHERE clause or the AS OF clause of a Flashback Query.

See Also:

- *Oracle Database SQL Reference*

Using Flashback Version Query

You use a Flashback Version Query to retrieve the different versions of specific rows that existed during a given time interval. A new row version is created whenever a COMMIT statement is executed.

You specify a Flashback Version Query using the VERSIONS BETWEEN clause of the SELECT statement. Here is the syntax:

```
VERSIONS {BETWEEN {SCN | TIMESTAMP} start AND end}
```

where *start* and *end* are expressions representing the start and end of the time interval to be queried, respectively. The interval is *closed* at both ends: the upper and lower limits specified (*start* and *end*) are both included in the time interval.

The Flashback Version Query returns a table with a *row for each version* of the row that existed at any time during the time interval you specify. Each row in the table includes pseudocolumns of metadata about the row version, described in Table 10–1. This information can reveal when and how a particular change (perhaps erroneous) occurred to your database.

Table 10–1 Flashback Version Query Row Data Pseudocolumns

Pseudocolumn Name	Description
VERSIONS_STARTSCN VERSIONS_STARTTIME	Starting System Change Number (SCN) or TIMESTAMP when the row version was created. This identifies the time when the data first took on the values reflected in the row version. You can use this to identify the past target time for a Flashback Table or Flashback Query operation. If this is NULL, then the row version was created before the lower time bound of the query BETWEEN clause.
VERSIONS_ENDSCN VERSIONS_ENDTIME	SCN or TIMESTAMP when the row version expired. This identifies the row expiration time. If this is NULL, then either the row version was still current at the time of the query or the row corresponds to a DELETE operation.
VERSIONS_XID	Identifier of the transaction that created the row version.
VERSIONS_OPERATION	Operation performed by the transaction: I for insertion, D for deletion, or U for update. The version is that of the row that was inserted, deleted, or updated; that is, the row *after* an INSERT operation, the row *before* a DELETE operation, or the row affected by an UPDATE operation. *Note:* For user updates of an index key, a Flashback Version Query may treat an UPDATE operation as two operations, DELETE plus INSERT, represented as two version rows with a D followed by an I VERSIONS_OPERATION.

A given row version is valid starting at its time VERSIONS_START* up to, but not including, its time VERSIONS_END*. That is, it is valid for any time *t* such that VERSIONS_START* <= *t* < VERSIONS_END*. For example, the following output indicates that the salary was 10243 from September 9, 2002, included, to November 25, 2003, not included.

```
VERSIONS_START_TIME     VERSIONS_END_TIME     SALARY
-------------------     -----------------     ------
09-SEP-2003             25-NOV-2003           10243
```

Here is a typical Flashback Version Query:

```
SELECT versions_startscn, versions_starttime,
       versions_endscn, versions_endtime,
       versions_xid, versions_operation,
       name, salary
  FROM employees
  VERSIONS BETWEEN TIMESTAMP
      TO_TIMESTAMP('2003-07-18 14:00:00', 'YYYY-MM-DD HH24:MI:SS')
  AND TO_TIMESTAMP('2003-07-18 17:00:00', 'YYYY-MM-DD HH24:MI:SS')
  WHERE name = 'JOE';
```

Pseudocolumn VERSIONS_XID provides a unique identifier for the transaction that put the data in that state. You can use this value in connection with a Flashback Transaction Query to locate metadata about this transaction in the FLASHBACK_TRANSACTION_QUERY view, including the SQL required to undo the row change and the user responsible for the change – see "Using Flashback Transaction Query" on page 10-10.

> **See Also:** *Oracle Database SQL Reference* for information on the Flashback Version Query pseudocolumns and the syntax of the VERSIONS clause

Using Flashback Transaction Query

A Flashback Transaction Query is a query on the view `FLASHBACK_TRANSACTION_QUERY`. You use a Flashback Transaction Query to obtain transaction information, including SQL code that you can use to undo each of the changes made by the transaction.

> **See Also:** *Oracle Database Backup and Recovery Advanced User's Guide.* and *Oracle Database Administrator's Guide* for information on how a DBA can use the Flashback Table feature to restore an entire table, rather than individual rows

As an example, the following statement queries the `FLASHBACK_TRANSACTION_QUERY` view for transaction information, including the transaction ID, the operation, the operation start and end SCNs, the user responsible for the operation, and the SQL code to undo the operation:

```
SELECT xid, operation, start_scn,commit_scn, logon_user, undo_sql
     FROM flashback_transaction_query
     WHERE xid = HEXTORAW('000200030000002D');
```

As another example, the following query uses a Flashback Version Query as a subquery to associate each row version with the `LOGON_USER` responsible for the row data change.

```
SELECT xid, logon_user FROM flashback_transaction_query
     WHERE xid IN (SELECT versions_xid FROM employees VERSIONS BETWEEN TIMESTAMP
      TO_TIMESTAMP('2003-07-18 14:00:00', 'YYYY-MM-DD HH24:MI:SS') AND
      TO_TIMESTAMP('2003-07-18 17:00:00', 'YYYY-MM-DD HH24:MI:SS'));
```

Flashback Transaction Query and Flashback Version Query: Example

This example demonstrates the use of a Flashback Transaction Query in conjunction with a Flashback Version Query. The example assumes simple variations of the `employees` and `departments` tables in the sample `hr` schema.

In this example, a DBA carries out the following series of actions in SQL*Plus:

```
connect hr/hr
CREATE TABLE emp
   (empno   NUMBER PRIMARY KEY,
    empname VARCHAR2(16),
    salary  NUMBER);
INSERT INTO emp VALUES (111, 'Mike', 555);
COMMIT;

CREATE TABLE dept
   (deptno   NUMBER,
    deptname VARCHAR2(32));
INSERT INTO dept VALUES (10, 'Accounting');
COMMIT;
```

At this point, `emp` and `dept` have one row each. In terms of row versions, each table has one version of one row. Next, suppose that an erroneous transaction deletes employee id `111` from table `emp`:

```
UPDATE emp SET salary = salary + 100 WHERE empno = 111;
INSERT INTO dept VALUES (20, 'Finance');
DELETE FROM emp WHERE empno = 111;
COMMIT;
```

Subsequently, a new transaction reinserts employee id 111 with a new employee name into the emp table.

```
INSERT INTO emp VALUES (111, 'Tom', 777);
UPDATE emp SET salary = salary + 100 WHERE empno = 111;
UPDATE emp SET salary = salary + 50 WHERE empno = 111;
COMMIT;
```

At this point, the DBA detects the application error and needs to diagnose the problem. The DBA issues the following query to retrieve versions of the rows in the emp table that correspond to empno 111. The query uses Flashback Version Query pseudocolumns.

```
connect dba_name/password
SELECT versions_xid XID, versions_startscn START_SCN,
  versions_endscn END_SCN, versions_operation OPERATION,
  empname, salary FROM hr.emp
  VERSIONS BETWEEN SCN MINVALUE AND MAXVALUE
  where empno = 111;

XID              START_SCN  END_SCN   OPERATION  EMPNAME    SALARY
---------------- ---------- --------- ---------- ---------- ----------
0004000700000058 113855               I          Tom        927
000200030000002D 113564               D          Mike       555
000200030000002E 112670     113564    I          Mike       555
3 rows selected
```

The results table reads chronologically, from bottom to top. The third row corresponds to the version of the row in emp that was originally inserted in the table when the table was created. The second row corresponds to the row in emp that was deleted by the erroneous transaction. The first row corresponds to the version of the row in emp that was reinserted with a new employee name.

The DBA identifies transaction 000200030000002D as the erroneous transaction and issues the following Flashback Transaction Query to audit all changes made by this transaction:

```
SELECT  xid, start_scn START, commit_scn COMMIT,
        operation OP, logon_user USER,
        undo_sql FROM flashback_transaction_query
        WHERE xid = HEXTORAW('000200030000002D');

XID               START   COMMIT  OP       USER   UNDO_SQL
----------------  -----   ------  --       ----   --------------------------
000200030000002D  195243  195244  DELETE   HR     insert into "HR"."EMP"
("EMPNO","EMPNAME","SALARY") values ('111','Mike','655');

000200030000002D  195243  195244  INSERT   HR     delete from "HR"."DEPT"
where ROWID = 'AAAKD4AABAAAJ3BAAB';

000200030000002D  195243  195244  UPDATE   HR     update "HR"."EMP"
set "SALARY" = '555' where ROWID = 'AAAKD2AABAAAJ29AAA';

000200030000002D  195243  113565  BEGIN  HR

4 rows selected
```

The rightmost column (undo_sql) contains the SQL code that will undo the corresponding change operation. The DBA can execute this code to undo the changes

made by that transaction. The USER column (logon_user) shows the user responsible for the transaction.

A DBA might also be interested in knowing all changes made in a certain time window. In our scenario, the DBA performs the following query to view the details of all transactions that executed since the erroneous transaction identified earlier (including the erroneous transaction itself):

```
SELECT xid, start_scn, commit_scn, operation, table_name, table_owner
  FROM flashback_transaction_query
  WHERE table_owner = 'HR' AND
        start_timestamp >=
          TO_TIMESTAMP ('2002-04-16 11:00:00','YYYY-MM-DD HH:MI:SS');

XID               START_SCN  COMMIT_SCN  OPERATION  TABLE_NAME  TABLE_OWNER
----------------  ---------  ----------  ---------  ----------  -----------
0004000700000058  195245     195246      UPDATE     EMP         HR
0004000700000058  195245     195246      UPDATE     EMP         HR
0004000700000058  195245     195246      INSERT     EMP         HR
000200030000002D  195243     195244      DELETE     EMP         HR
000200030000002D  195243     195244      INSERT     DEPT        HR
000200030000002D  195243     195244      UPDATE     EMP         HR

6 rows selected
```

Flashback Tips

The following tips and restrictions apply to using flashback features.

Flashback Tips – Performance

- For better performance, generate statistics on all tables involved in a Flashback Query by using the DBMS_STATS package, and keep the statistics current. Flashback Query always uses the cost-based optimizer, which relies on these statistics.
- The performance of a query into the past depends on how much undo data must be accessed. For better performance, use queries to select small sets of past data using indexes, not to scan entire tables. If you must do a full table scan, consider adding a parallel hint to the query.
- The performance cost in I/O is the cost of paging in data and undo blocks that are not already in the buffer cache. The performance cost in CPU use is the cost of applying undo information to affected data blocks. When operating on changes in the recent past, flashback features essentially CPU bound.
- Use index structures for Flashback Version Query: the database keeps undo data for index changes as well as data changes. Performance of index lookup-based Flashback Version Query is an order of magnitude faster than the full table scans that are otherwise needed.
- In a Flashback Transaction Query, the type of the xid column is RAW(8). To take advantage of the index built on the xid column, use the HEXTORAW conversion function: HEXTORAW(xid).
- Flashback Query against a materialized view does not take advantage of query rewrite optimizations.

See Also: *Oracle Database Performance Tuning Guide*

Flashback Tips – General

- Use the DBMS_FLASHBACK package or other flashback features? Use ENABLE/DISABLE calls to the DBMS_FLASHBACK package around SQL code that you do not control, or when you want to use the same past time for several consecutive queries. Use Flashback Query, Flashback Version Query, or Flashback Transaction Query for SQL that you write, for convenience. A Flashback Query, for example, is flexible enough to do comparisons and store results in a single query.
- To obtain an SCN to use later with a flashback feature, use DBMS_FLASHBACK.GET_SYSTEM_CHANGE_NUMBER.
- You can compute or retrieve a past time to use in a query by using a function return value as a timestamp or SCN argument. For example, you can perform date and time calculations by adding or subtracting an INTERVAL value to the value of the SYSTIMESTAMP function.
- You can query locally or *remotely* (Flashback Query, Flashback Version Query, or Flashback Transaction Query). for example here is a remote Flashback Query:

```
(SELECT * FROM employees@some_remote_host AS OF
       TIMESTAMP (SYSTIMESTAMP - INTERVAL '60' MINUTE);
```

- To ensure database consistency, always perform a COMMIT or ROLLBACK operation before querying past data.
- Remember that all flashback processing is done using the current session settings, such as national language and character set, not the settings that were in effect at the time being queried.
- Some DDLs that alter the structure of a table, such as drop/modify column, move table, drop partition, and truncate table/partition, invalidate any existing undo data for the table. It is not possible to retrieve data from a point earlier than the time such DDLs were executed. Trying such a query results in error ORA-1466. This restriction does not apply to DDL operations that alter the storage attributes of a table, such as PCTFREE, INITRANS, and MAXTRANS.
- Use an SCN to query past data at a precise time. If you use a timestamp, the actual time queried might be up to 3 seconds earlier than the time you specify. Internally, Oracle Database uses SCNs; these are mapped to timestamps at a granularity of every 3 seconds.

  For example, assume that the SCN values 1000 and 1005 are mapped to the times 8:41 and 8:46 AM respectively. A query for a time between 8:41:00 and 8:45:59 AM is mapped to SCN 1000; a Flashback Query for 8:46 AM is mapped to SCN 1005.

  Due to this time-to-SCN mapping, if you specify a time that is slightly after a DDL operation (such as a table creation) the database might actually use an SCN that is just before the DDL operation. This can result in error ORA-1466.
- You cannot retrieve past data from a V$ view in the data dictionary. Performing a query on such a view always returns the current data. You can, however, perform queries on past data in other views of the data dictionary, such as USER_TABLES.

11

Developing Applications with the PL/SQL Web Toolkit

Java is not the only language that can do network operations and produce dynamic Web content. PL/SQL has a number of features that you can use to make your database available on the Web and make back-office data accessible on the intranet.

This chapter discusses the following topics:

- Developing PL/SQL Web Applications: Overview
- Using the mod_plsql Gateway
- Generating HTML Output with PL/SQL
- Passing Parameters to a PL/SQL Web Application
- Performing Network Operations within PL/SQL Stored Procedures

Developing PL/SQL Web Applications: Overview

This section contains the following topics:

- Invoking a PL/SQL Web Application
- Implementing a PL/SQL Web Application

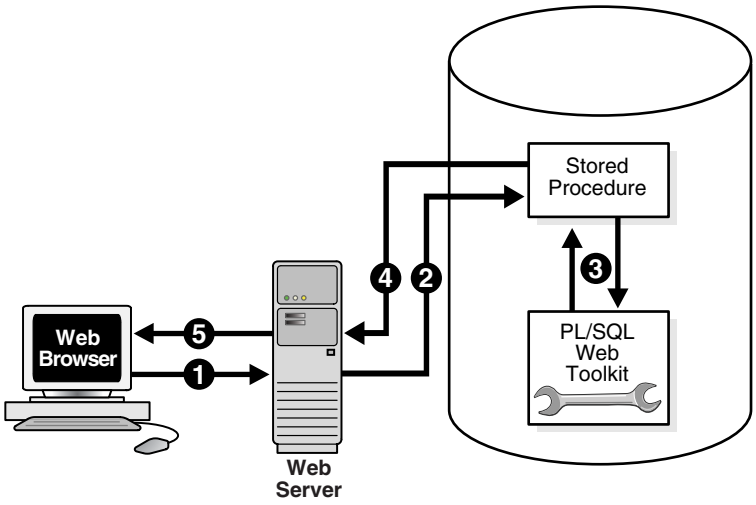
Invoking a PL/SQL Web Application

Typically, a Web application written in PL/SQL is a set of stored procedures that interact with Web browsers through HTTP. A set of interlinked, dynamically generated HTML pages forms the user interface of a web application.

The program flow of a PL/SQL Web application is similar to that in a CGI Perl script. Developers often use CGI scripts to produce Web pages dynamically, but such scripts are often not optimal for accessing Oracle Database. Delivering Web content with PL/SQL stored procedures provides the power and flexibility of database processing. For example, you can use DML, dynamic SQL, and cursors. You also eliminate the process overhead of forking a new CGI process to handle each HTTP request.

Figure 11–1 illustrates the generic process for a PL/SQL Web application.

Figure 11–1 PL/SQL Web Application



The process includes the following steps:

1. A user visits a Web page, follows a hypertext link, or submits data in a form, which causes the browser to send a HTTP request for a URL to an HTTP server.
2. The HTTP server invokes a stored procedure on an Oracle database according to the data encoded in the URL. The data in the URL takes the form of parameters to be passed to the stored procedure.
3. The stored procedure calls subprograms in the PL/SQL Web Toolkit. Typically, subprograms such as `HTP.Print` generate Web pages dynamically. A generated Web page varies depending on the database contents and the input parameters.
4. The subprograms pass the dynamically generated page to the Web server.
5. The Web server delivers the page to the client.

Implementing a PL/SQL Web Application

You can implement a Web browser-based application entirely in PL/SQL with the Oracle Database components described in this section.

PL/SQL Web Toolkit

This set of PL/SQL packages is a generic interface that enables you to use stored procedures called by mod_plsql at runtime.

In response to a browser request, a PL/SQL procedure updates or retrieves data from Oracle Database according to the user input. It then generates an HTTP response to the browser, typically in the form of a file download or HTML to be displayed. The Web Toolkit API enables stored procedures to perform actions such as the following:

- Obtain information about an HTTP request
- Generate HTTP headers such as content-type and mime-type
- Set browser cookies
- Generate HTML pages

Table 11–1 describes commonly used PL/SQL Web Toolkit packages.

Table 11–1 Commonly Used Packages in the PL/SQL Web Toolkit

Package	Description of Contents
HTF	Function versions of the procedures in the htp package. The function versions do not directly generate output in a Web page. Instead, they pass their output as return values to the statements that invoke them. Use these functions when you need to nest function calls.
HTP	Procedures that generate HTML tags. For instance, the procedure htp.anchor generates the HTML anchor tag, <A>.
OWA_CACHE	Functions and procedures that enable the PL/SQL gateway cache feature to improve performance of your PL/SQL Web application. You can use this package to enable expires-based and validation-based caching with the PL/SQL gateway file system.
OWA_COOKIE	Subprograms that send and retrieve HTTP cookies to and from a client Web browser. Cookies are strings a browser uses to maintain state between HTTP calls. State can be maintained throughout a client session or longer if a cookie expiration date is included.
OWA_CUSTOM	The authorize function used by cookies.
OWA_IMAGE	Subprograms that obtain the coordinates where a user clicked an image. Use this package when you have an image map whose destination links invoke a PL/SQL gateway.
OWA_OPT_LOCK	Subprograms that impose database optimistic locking strategies to prevent lost updates. Lost updates can otherwise occur if a user selects, and then attempts to update, a row whose values have been changed in the meantime by another user.
OWA_PATTERN	Subprograms that perform string matching and string manipulation with regular expressions.
OWA_SEC	Subprograms used by the PL/SQL gateway for authenticating requests.
OWA_TEXT	Subprograms used by package OWA_PATTERN for manipulating strings. You can also use them directly.
OWA_UTIL	The following types of utility subprograms: ■ Dynamic SQL utilities to produce pages with dynamically generated SQL code. ■ HTML utilities to retrieve the values of CGI environment variables and perform URL redirects. ■ Date utilities for correct date-handling. Date values are simple strings in HTML, but must be properly treated as an Oracle Database datatype.
WPG_DOCLOAD	Subprograms that download documents from a document repository that you define using the DAD configuration.

See Also: *Oracle Database PL/SQL Packages and Types Reference* for syntax, descriptions, and examples for the PL/SQL Web Toolkit packages

Using the mod_plsql Gateway

As explained in detail in the *Oracle Application Server mod_plsql User's Guide*, mod_plsql maps Web client requests to PL/SQL stored procedures over HTTP. Refer to this documentation for instructions.

See Also:

- *Oracle Application Server mod_plsql User's Guide* to learn how to configure and use mod_plsql
- *Oracle HTTP Server Administrator's Guide* to obtain mod_plsql reference material

Generating HTML Output with PL/SQL

Traditionally, PL/SQL Web applications use function calls to generate each HTML tag for output. These functions are part of the PL/SQL Web Toolkit packages that come with Oracle Database. Example 11–1 illustrates how to generate a simple HTML page by calling the `HTP` functions that correspond to each HTML tag.

Example 11–1 Displaying HTML Tags with HTP Functions

```
CREATE OR REPLACE PROCEDURE html_page
IS
BEGIN
  HTP.HTMLOPEN;                              -- generates <HTML>
  HTP.HEADOPEN;                              -- generates <HEAD>
  HTP.TITLE('Title');                        -- generates <TITLE>Hello</TITLE>
  HTP.HEADCLOSE;                             -- generates </HTML>

  -- generates <BODY TEXT="#000000" BGCOLOR="#FFFFFF">
  HTP.BODYOPEN( cattributes => 'TEXT="#000000" BGCOLOR="#FFFFFF"');

  -- generates <H1>Heading in the HTML File</H1>
  HTP.HEADER(1, 'Heading in the HTML File');

  HTP.PARA;                                   -- generates <P>
  HTP.PRINT('Some text in the HTML file.');
  HTP.BODYCLOSE;                             -- generates </BODY>
  HTP.HTMLCLOSE;                             -- generates </HTML>
END;
```

An alternative to making function calls that correspond to each tag is to use the `HTP.PRINT` function to print the text and tags together. Example 11–2 illustrates this technique.

Example 11–2 Displaying HTML Tags with HTP.PRINT

```
CREATE OR REPLACE PROCEDURE html_page2
IS
BEGIN
  HTP.PRINT('<html>');
  HTP.PRINT('<head>');
  HTP.PRINT('<meta http-equiv="Content-Type" content="text/html">');
  HTP.PRINT('<title>Title of the HTML File</title>');
  HTP.PRINT('</head>');

  HTP.PRINT('<body TEXT="#000000" BGCOLOR="#FFFFFF">');
  HTP.PRINT('<h1>Heading in the HTML File</h1>');
  HTP.PRINT('<p>Some text in the HTML file.');
  HTP.PRINT('</body>');

  HTP.PRINT('</html>');
END;
```

Chapter 12, "Developing PL/SQL Server Pages" describes an additional method for delivering using PL/SQL to generate HTML content. PL/SQL server pages enables you to build on your knowledge of HTML tags and avoid learning a new set of function calls. In an application written as a set of PL/SQL server pages, you can still use functions from the PL/SQL Web toolkit to do the following:

- Simplify the processing involved in displaying tables
- Store persistent data (cookies)
- Work with CGI protocol internals

Passing Parameters to a PL/SQL Web Application

To be useful in a wide variety of situations, a Web application must be interactive enough to allow user choices. To keep the attention of impatient Web surfers, you should streamline the interaction so that users can specify these choices very simply, without excessive decision-making or data entry.

The main methods of passing parameters to PL/SQL Web applications are:

- Using HTML form tags. The user fills in a form on one Web page, and all the data and choices are transmitted to a stored procedure when the user clicks the `Submit` button on the page.
- Hard-coded in the URL. The user clicks on a link, and a set of predefined parameters are transmitted to a stored procedure. Typically, you would include separate links on your Web page for all the choices that the user might want.

This section contains the following topics:

Passing List and Dropdown List Parameters from an HTML Form

List boxes and drop-down lists are implemented with the HTML tag `<SELECT>`.

Use a list box for a large number of choices or to allow multiple selections. List boxes are good for showing items in alphabetical order so that users can find an item quickly without reading all the choices.

Use a drop-down list in the following situations:

- There are a small number of choices
- Screen space is limited.
- Choices are in an unusual order.

The drop-down captures the attention of first-time users and makes them read the items. If you keep the choices and order consistent, then users can memorize the

motion of selecting an item from the drop-down list, allowing them to make selections quickly as they gain experience. Example 11–3 shows a simple drop-down list.

Example 11–3 HTML Drop-Down List

```
<form>
<select name="seasons">
<option value="winter">Winter
<option value="spring">Spring
<option value="summer">Summer
<option value="fall">Fall
</select>
```

Passing Radio Button and Checkbox Parameters from an HTML Form

Radio buttons pass either a null value (if none of the radio buttons in a group is checked), or the value specified on the radio button that is checked.

To specify a default value for a set of radio buttons, you can include the `CHECKED` attribute in one of the `INPUT` tags, or include a `DEFAULT` clause on the parameter within the stored procedure. When setting up a group of radio buttons, be sure to include a choice that indicates "no preference", because once the user selects a radio button, they can still select a different one, but they cannot clear the selection completely. For example, include a "Don't Care" or "Don't Know" selection along with "Yes" and "No" choices, in case someone makes a selection and then realizes it was wrong.

Checkboxes need special handling, because your stored procedure might receive a null value, a single value, or multiple values:

All the checkboxes with the same `NAME` attribute make up a checkbox group. If none of the checkboxes in a group is checked, the stored procedure receives a null value for the corresponding parameter.

If one checkbox in a group is checked, the stored procedure receives a single `VARCHAR2` parameter.

If more than one checkbox in a group is checked, the stored procedure receives a parameter with the PL/SQL type `TABLE OF VARCHAR2`. You must declare a type like this, or use a predefined one like `OWA_UTIL.IDENT_ARR`. To retrieve the values, use a loop:

```
CREATE OR REPLACE PROCEDURE handle_checkboxes ( checkboxes owa_util.ident_arr )
AS
BEGIN
  ...
  FOR i IN 1..checkboxes.count
  LOOP
    htp.print('<p>Checkbox value: ' || checkboxes(i));
  END LOOP;
  ...
END;
/
SHOW ERRORS;
```

Passing Entry Field Parameters from an HTML Form

Entry fields require the most validation, because a user might enter data in the wrong format, out of range, and so on. If possible, validate the data on the client side using

dynamic HTML or Java, and format it correctly for the user or prompt them to enter it again.

For example:

- You might prevent the user from entering alphabetic characters in a numeric entry field, or from entering characters once a length limit is reached.
- You might silently remove spaces and dashes from a credit card number if the stored procedure expects the value in that format.
- You might inform the user immediately when they type a number that is too large, so that they can retype it.

Because you cannot always rely on such validation to succeed, code the stored procedures to deal with these cases anyway. Rather than forcing the user to use the `Back` button when they enter wrong data, display a single page with an error message and the original form with all the other values filled in.

For sensitive information such as passwords, a special form of the entry field, `<INPUT TYPE=PASSWORD>`, hides the text as it is typed in.

For example, the following procedure accepts two strings as input. The first time it is called, the user sees a simple form prompting for the input values. When the user submits the information, the same procedure is called again to check if the input is correct. If the input is OK, the procedure processes it. If not, the procedure prompts for new input, filling in the original values for the user.

```
-- Store a name and associated zip code in the database.
CREATE OR REPLACE PROCEDURE associate_name_with_zipcode
(
  name VARCHAR2 DEFAULT NULL,
  zip VARCHAR2 DEFAULT NULL
)
AS
  booktitle VARCHAR2(256);
BEGIN
-- Both entry fields must contain a value. The zip code must be 6 characters.
-- (In a real program you would perform more extensive checking.)
  IF name IS NOT NULL AND zip IS NOT NULL AND length(zip) = 6 THEN
    store_name_and_zipcode(name, zip);
    htp.print('<p>The person ' || name || ' has the zip code ' || zip || '.');
-- If the input was OK, we stop here and the user does not see the form again.
    RETURN;
  END IF;

-- If some data was entered, but it is not correct, show the error message.
  IF (name IS NULL AND zip IS NOT NULL)
    OR (name IS NOT NULL AND zip IS NULL)
    OR (zip IS NOT NULL AND length(zip) != 6)
  THEN
    htp.print('<p><b>Please re-enter the data. Fill in all fields, and use a
              6-digit zip code.</b>');
  END IF;

-- If the user has not entered any data, or entered bad data, prompt for
-- input values.

-- Make the form call the same procedure to check the input values.
  htp.formOpen( 'scott.associate_name_with_zipcode', 'GET');
  htp.print('<p>Enter your name:</td>');
  htp.print('<td valign=center><input type=text name=name value="' || name ||
```

```
 '">');
  htp.print('<p>Enter your zip code:</td>');
  htp.print('<td valign=center><input type=text name=zip value="' || zip || '">');
  htp.formSubmit(NULL, 'Submit');
  htp.formClose;
END;
/
SHOW ERRORS;
```

Passing Hidden Parameters from an HTML Form

One technique for passing information through a sequence of stored procedures, without requiring the user to specify the same choices each time, is to include hidden parameters in the form that calls a stored procedure. The first stored procedure places information, such as a user name, into the HTML form that it generates. The value of the hidden parameter is passed to the next stored procedure, as if the user had entered it through a radio button or entry field.

Other techniques for passing information from one stored procedure to another include:

- Sending a "cookie" containing the persistent information to the browser. The browser then sends this same information back to the server when accessing other Web pages from the same site. Cookies are set and retrieved through the HTTP headers that are transferred between the browser and the Web server before the HTML text of each Web page.
- Storing the information in the database itself, where later stored procedures can retrieve it. This technique involves some extra overhead on the database server, and you must still find a way to keep track of each user as multiple users access the server at the same time.

Uploading a File from an HTML Form

You can use an HTML form to choose a file on a client system, and transfer it to the server. A stored procedure can insert the file into the database as a `CLOB`, `BLOB`, or other type that can hold large amounts of data.

The PL/SQL Web toolkit and the PL/SQL gateway have the notion of a "document table" that holds uploaded files.

See Also: *mod_plsql User's Guide*

Submitting a Completed HTML Form

By default, an HTML form must have a `Submit` button, which transmits the data from the form to a stored procedure or CGI program. You can label this button with text of your choice, such as "Search", "Register", and so on.

You can have multiple forms on the same page, each with its own form elements and `Submit` button. You can even have forms consisting entirely of hidden parameters, where the user makes no choice other than clicking the button.

Using JavaScript or other scripting languages, you can do away with the Submit button and have the form submitted in response to some other action, such as selecting from a drop-down list. This technique is best when the user only makes a single selection, and the confirmation step of the `Submit` button is not essential.

Handling Missing Input from an HTML Form

When an HTML form is submitted, your stored procedure receives null parameters for any form elements that are not filled in. For example, null parameters can result from an empty entry field, a set of checkboxes, radio buttons, or list items with none checked, or a `VALUE` parameter of "" (empty quotation marks).

Regardless of any validation you do on the client side, always code stored procedures to handle the possibility that some parameters are null:

- Use a `DEFAULT` clause in all parameter declarations, to prevent an exception when the stored procedure is called with a missing form parameter. You can set the default to zero for numeric values (when that makes sense), and use `DEFAULT NULL` when you want to check whether or not the user actually specifies a value.
- Before using an input parameter value that has a `DEFAULT NULL` declaration, check if it is null.
- Make the procedure generate sensible results even when not all input parameters are specified. You might leave some sections out of a report, or display a text string or image in a report to indicate where parameters were not specified.
- Provide a way to fill in the missing values and run the stored procedure again, directly from the results page. For example, you could include a link that calls the same stored procedure with an additional parameter, or display the original form with its values filled in as part of the output.

Maintaining State Information Between Web Pages

Web applications are particularly concerned with the idea of **state**, the set of data that is current at a particular moment in time. It is easy to lose state information when switching from one Web page to another, which might result in asking the user to make the same choices over and over.

You can pass state information between dynamic Web pages using HTML forms. The information is passed as a set of name-value pairs, which are turned into stored procedure parameters for you.

If the user has to make multiple selections, or one selection from many choices, or it is important to avoid an accidental selection, use an HTML form. After the user makes and reviews all the choices, they confirm the choices with the `Submit` button. Subsequent pages can use forms with hidden parameters (`<INPUT TYPE=HIDDEN>` tags) to pass these choices from one page to the next.

If the user is only considering one or two choices, or the decision points are scattered throughout the Web page, you can save the user from hunting around for the `Submit` button by representing actions as hyperlinks and including any necessary name-value pairs in the query string (the part following the `?` within a URL).

An alternative way to main state information is to use Oracle Application Server and its `mod_ose` module. This approach lets you store state information in package variables that remain available as a user moves around a Web site.

> **See Also:** The Oracle Application Server documentation set at `http://www.oracle.com/technology/documentation`

Performing Network Operations within PL/SQL Stored Procedures

While built-in PL/SQL features are focused on traditional database operations and programming logic, Oracle Database provides packages that open up Internet computing to PL/SQL programmers.

This section contains the following topics:

Sending E-Mail from PL/SQL

You can send e-mail from a PL/SQL program or stored procedure with the `UTL_SMTP` package. You can read about this package in the *Oracle Database PL/SQL Packages and Types Reference*.

The following code example illustrates how the SMTP package might be used by an application to send e-mail. The application connects to an SMTP server at port 25 and sends a simple text message.

```
PROCEDURE send_test_message
IS
    mailhost    VARCHAR2(64) := 'mailhost.fictional-domain.com';
    sender      VARCHAR2(64) := 'me@fictional-domain.com';
    recipient   VARCHAR2(64) := 'you@fictional-domain.com';
    mail_conn  utl_smtp.connection;
BEGIN
    mail_conn := utl_smtp.open_connection(mailhost, 25);
    utl_smtp.helo(mail_conn, mailhost);
    utl_smtp.mail(mail_conn, sender);
    utl_smtp.rcpt(mail_conn, recipient);
-- If we had the message in a single string, we could collapse
-- open_data(), write_data(), and close_data() into a single call to data().
    utl_smtp.open_data(mail_conn);
    utl_smtp.write_data(mail_conn, 'This is a test message.' || chr(13));
    utl_smtp.write_data(mail_conn, 'This is line 2.' || chr(13));
    utl_smtp.close_data(mail_conn);
    utl_smtp.quit(mail_conn);
    EXCEPTION
        WHEN OTHERS THEN
           -- Insert error-handling code here
           NULL;
END;
```

Getting a Host Name or Address from PL/SQL

You can determine the host name of the local machine, or the IP address of a given host name from a PL/SQL program or stored procedure using the `UTL_INADDR` package. You can find details about this package in the *Oracle Database PL/SQL Packages and Types Reference*. You use the results in calls to the `UTL_TCP` package.

Working with TCP/IP Connections from PL/SQL

You can open TCP/IP connections to machines on the network, and read or write to the corresponding sockets, using the UTL_TCP package. You can find details about this package in the *Oracle Database PL/SQL Packages and Types Reference*.

Retrieving the Contents of an HTTP URL from PL/SQL

You can retrieve the contents of an HTTP URL using the UTL_HTTP package. The contents are typically in the form of HTML-tagged text, but may be plain text, a JPEG image, or any sort of file that is downloadable from a Web server. You can find details about this package in the *Oracle Database PL/SQL Packages and Types Reference*.

The UTL_HTTP package lets you:

- Control the details of the HTTP session, including header lines, cookies, redirects, proxy servers, IDs and passwords for protected sites, and CGI parameters through the GET or POST methods.
- Speed up multiple accesses to the same Web site using HTTP 1.1 persistent connections.
- Construct and interpret URLs for use with UTL_HTTP through the ESCAPE and UNESCAPE functions in the UTL_URL package.

Typically, developers have used Java or Perl to perform these operations; this package lets you do them with PL/SQL.

```
CREATE OR REPLACE PROCEDURE show_url
(
    url      IN VARCHAR2,
    username IN VARCHAR2 DEFAULT NULL,
    password IN VARCHAR2 DEFAULT NULL
) AS
    req       utl_http.req;
    resp      utl_http.resp;
    name      VARCHAR2(256);
    value     VARCHAR2(1024);
    data      VARCHAR2(255);
    my_scheme VARCHAR2(256);
    my_realm  VARCHAR2(256);
    my_proxy  BOOLEAN;
BEGIN
-- When going through a firewall, pass requests through this host.
-- Specify sites inside the firewall that don't need the proxy host.
  utl_http.set_proxy('proxy.my-company.com', 'corp.my-company.com');

-- Ask UTL_HTTP not to raise an exception for 4xx and 5xx status codes,
-- rather than just returning the text of the error page.
  utl_http.set_response_error_check(FALSE);

-- Begin retrieving this Web page.
  req := utl_http.begin_request(url);

-- Identify ourselves. Some sites serve special pages for particular browsers.
  utl_http.set_header(req, 'User-Agent', 'Mozilla/4.0');

-- Specify a user ID and password for pages that require them.
  IF (username IS NOT NULL) THEN
    utl_http.set_authentication(req, username, password);
  END IF;
```

```
  BEGIN
-- Start receiving the HTML text.
    resp := utl_http.get_response(req);

-- Show the status codes and reason phrase of the response.
    dbms_output.put_line('HTTP response status code: ' || resp.status_code);
    dbms_output.put_line('HTTP response reason phrase: ' || resp.reason_phrase);

-- Look for client-side error and report it.
    IF (resp.status_code >= 400) AND (resp.status_code <= 499) THEN

-- Detect whether the page is password protected, and we didn't supply
-- the right authorization.
      IF (resp.status_code = utl_http.HTTP_UNAUTHORIZED) THEN
        utl_http.get_authentication(resp, my_scheme, my_realm, my_proxy);
        IF (my_proxy) THEN
          dbms_output.put_line('Web proxy server is protected.');
          dbms_output.put('Please supply the required ' || my_scheme ||
            ' authentication username/password for realm ' || my_realm ||
            ' for the proxy server.');
        ELSE
          dbms_output.put_line('Web page ' || url || ' is protected.');
          dbms_output.put('Please supplied the required ' || my_scheme ||
            ' authentication username/password for realm ' || my_realm ||
            ' for the Web page.');
        END IF;
      ELSE
        dbms_output.put_line('Check the URL.');
      END IF;

      utl_http.end_response(resp);
      RETURN;

-- Look for server-side error and report it.
    ELSIF (resp.status_code >= 500) AND (resp.status_code <= 599) THEN

      dbms_output.put_line('Check if the Web site is up.');
      utl_http.end_response(resp);
      RETURN;

    END IF;

-- The HTTP header lines contain information about cookies, character sets,
-- and other data that client and server can use to customize each session.
    FOR i IN 1..utl_http.get_header_count(resp) LOOP
      utl_http.get_header(resp, i, name, value);
      dbms_output.put_line(name || ': ' || value);
    END LOOP;

-- Keep reading lines until no more are left and an exception is raised.
    LOOP
      utl_http.read_line(resp, value);
      dbms_output.put_line(value);
    END LOOP;
  EXCEPTION
    WHEN utl_http.end_of_body THEN
    utl_http.end_response(resp);
  END;

END;
```

```
/
SET serveroutput ON
-- The following URLs illustrate the use of this procedure,
-- but these pages do not actually exist. To test, substitute
-- URLs from your own Web server.
exec show_url('http://www.oracle.com/no-such-page.html')
exec show_url('http://www.oracle.com/protected-page.html')
exec show_url('http://www.oracle.com/protected-page.html', 'scott', 'tiger')
```

Working with Tables, Image Maps, Cookies, and CGI Variables from PL/SQL

Packages for all of these functions are supplied with Oracle8*i* and higher. You use these packages in combination with the mod_plsql plug-in of Oracle HTTP Server (OHS). You can format the results of a query in an HTML table, produce an image map, set and get HTTP cookies, check the values of CGI variables, and combine other typical Web operations with a PL/SQL program.

Documentation for these packages is not part of the database documentation library. The location of the documentation depends on the particular application server you are running. To get started with these packages, look at their procedure names and parameters using the SQL*Plus `DESCRIBE` command:

```
DESCRIBE HTP;
DESCRIBE HTF;
DESCRIBE OWA_UTIL;
```

12

Developing PL/SQL Server Pages

This section contains the following topics:

PL/SQL Server Pages: Overview

This section contains the following topics:

What Are PL/SQL Server Pages and Why Use Them?

PL/SQL Server Pages (PSP) are server-side scripts that include dynamic content, including the results of SQL queries, inside Web pages. You can author the Web pages in an HTML authoring tool and insert blocks of PL/SQL code.

Example 12–1 shows a simple PL/SQL server page called `simple.psp`.

Example 12–1 simple.psp

```
<%@ page language="PL/SQL" %>
<%@ page contentType="text/html" %>
<%@ plsql procedure="show_employees" %>
<%-- This example displays the last name and first name of every
     employee in the hr.employees table. --%>
<%!
  CURSOR emp_cursor IS
  SELECT last_name, first_name
  FROM hr.employees
  ORDER BY last_name;
%>
```

```
<html>
<head>
<meta http-equiv="Content-Type" content="text/html">
<title>List of Employees</title>
</head>
<body TEXT="#000000" BGCOLOR="#FFFFFF">
<h1>List of Employees</h1>
<table width="40%" border="1">
<tr>
<th align="left">Last Name</th>
<th align="left">First Name</th>
</tr>
<%  FOR emp_record IN emp_cursor LOOP %>
  <tr>
  <td> <%= emp_record.last_name %> </td>
  <td> <%= emp_record.first_name %> </td>
  </tr>
<%  END LOOP; %>
</table>
</body>
</html>
```

You can compile and load this script into an Oracle database with the `loadpsp` command-line utility. The following example loads this server page into the `hr` schema, replacing the `show_employees` procedure if it already exists:

```
loadpsp -replace -user hr/hr simple.psp
```

Browser users can execute the `show_employees` procedure through a URL. An HTML page that displays the last and first names of employees in the `hr.employees` table is returned to the browser through the PL/SQL gateway.

Deploying content through PL/SQL Server Pages has the following advantages:

- For developers familiar with PL/SQL, the server pages are the easiest way to create professional Web pages that included database-generated content. You can develop Web pages as normal and then embed PL/SQL code in the HTML.
- PSP can be more convenient than using the `HTP` and `HTF` packages to write out HTML content line by line.
- Because processing is performed on the database server, the client browser receives a plain HTML page with no special script tags. You can support all browsers and browser levels equally.
- Network traffic is efficient because use of PSP minimizes the number of database round-trips.
- You can write content quickly and follow a rapid, iterative development process. You maintain central control of the software, with only a Web browser required on the client machine.

Prerequisites for Developing and Deploying PL/SQL Server Pages

To develop and deploy PL/SQL server pages, you must meet the following prerequisites:

- To write a PL/SQL server page you need access to a text editor or HTML authoring tool for writing the script. No other development tool is required.
- To load a PL/SQL server page you need:

  - An account on an Oracle database in which to load the server pages.
  - Execution rights to the `loadpsp` command-line utility, which is located in `$ORACLE_HOME/bin`.
- To deploy the server pages you must use mod_plsql. As explained in "PL/SQL Web Toolkit" on page 11-2, the gateway makes use of the PL/SQL Web Toolkit.

  See Also:

  - "Using the mod_plsql Gateway" on page 11-3

PSP and the HTP Package

You can enable browser users to execute PL/SQL program units through HTTP in the following ways:

- By writing an HTML page with embedded PL/SQL code and compiling it as a PL/SQL server page. You may call procedures from the PL/SQL Web Toolkit, but not to generate every line of HTML output.
- By writing a complete stored procedure that produces HTML by calling the `HTP` and `OWA_*` packages in the PL/SQL Web Toolkit. This technique is described in "Generating HTML Output with PL/SQL" on page 11-4.

Thus, you must choose which technique to use when writing your Web application. The key factors in choosing between these techniques are:

- What source are you using as a starting point?
  - If you have a large body of HTML, and if you want to include dynamic content or make it the front end of a database application, then use PSP.
  - If you have a large body of PL/SQL code that produces formatted output, then you may find it more convenient to produce HTML tags by changing your print statements to call the `HTP` package of the PL/SQL Web Toolkit.
- What is the fastest and most convenient authoring environment for your group?
  - If most work is done using HTML authoring tools, then use PSP.
  - If you use authoring tools that produce PL/SQL code, then it might be less convenient to use PSP.

PSP and Other Scripting Solutions

Scripting solutions can be client-side or server-side. JavaScript is one of the most popular client-side scripting language. PSP fully supports JavaScript. Because any kind of tags can be passed unchanged to the browser through a PL/SQL server page, you can include JavaScript or other client-side script code in a PL/SQL server page.

Java Server Pages (JSP) and Active Server Pages (ASP) are two of the most popular server-side scripting solutions. Note the following points of comparison with PSP:

- Java server pages are loosely analogous to PSP pages; Java servlets are analogous to PL/SQL packages. PSP uses the same script tag syntax as JSP to make it easy to switch back and forth.
- PSP uses syntax that is similar to ASP, although not identical. Typically, you must translate from VBScript or JScript to PL/SQL. The best candidates for migration are pages that use the Active Data Object (ADO) interface to perform database operations.

Note: You cannot mix PL/SQL server pages with other server-side script features, such as server-side includes. In many cases, you can get the same results by using the corresponding PSP features.

Writing a PL/SQL Server Page

To write a PL/SQL server page, you can start with an existing Web page or with an existing stored procedure. Either way, with a few additions and changes you can create dynamic Web pages that perform database operations and display the results.

The file for a PL/SQL server page must have the extension `.psp`. It can contain whatever content you choose, with text and tags interspersed with PSP directives, declarations, and scriptlets. A server page can take the following forms:

- In the simplest case, it is an HTML file. Compiling it as a PL/SQL server page produces a stored procedure that outputs exactly the same HTML file.
- In the most complex case, it is a PL/SQL procedure that generates all the content of the Web page, including the tags for title, body, and headings.
- In the typical case, it is a mixture of HTML (providing the static parts of the page) and PL/SQL (providing the dynamic content).

The order and placement of the PSP directives and declarations is usually not significant. It becomes significant only when another file is included. For ease of maintenance, it is recommended that you place the directives and declarations together near the beginning of the file.

Table 12–1 lists the PSP elements and directs you to the section that discusses how to use them. The section "Quoting and Escaping Strings in a PSP Script" on page 12-11 describes how to quote strings that are used in various PSP elements.

Table 12–1 PSP Elements

PSP Element	Name	Specifies . . .	Section
`<%@ page ... %>`	Page Directive	Characteristics of the PL/SQL server page.	"Specifying Basic Server Page Characteristics" on page 12-5
`<%@ parameter ... %>`	Parameter Directive	The name, and optionally the type and default, for each parameter expected by the PSP stored procedure.	"Accepting User Input" on page 12-7
`<%@ plsql ... %>`	Procedure Directive	The name of the stored procedure produced by the PSP file.	"Naming the PL/SQL Stored Procedure" on page 12-8
`<%@ include ... %>`	Include Directive	The name of a file to be included at a specific point in the PSP file.	"Including the Contents of Other Files" on page 12-8
`<%! ... %>`	Declaration Block	The declaration for a set of PL/SQL variables that are visible throughout the page, not just within the next `BEGIN/END` block.	"Declaring Global Variables in a PSP Script" on page 12-9
`<% ... %>`	Code Block	A set of PL/SQL statements to be executed when the procedure is run.	"Specifying Executable Statements in a PSP Script" on page 12-9
`<%= ... %>`	Expression Block	A single PL/SQL expression, such as a string, arithmetic expression, function call, or combination of these.	"Substituting an Expression Result in a PSP Script" on page 12-10
`<%-- ... --%>`	Comment	A comment in a PSP script.	"Including Comments in a PSP Script" on page 12-11

Note: If you are familiar with dynamic HTML and want to start coding right away, you can jump forward to"Examples of PL/SQL Server Pages" on page 12-15.

Specifying Basic Server Page Characteristics

Use the `<%@ page ... %>` directive to specify characteristics of the PL/SQL server page such as the following:

- What scripting language it uses.
- What type of information (MIME type) it produces.
- What code to run to handle all uncaught exceptions. This might be an HTML file with a friendly message, renamed to a `.psp` file. You must specify this same file name in the `loadpsp` command that compiles the main PSP file. You must specify exactly the same name in both the `errorPage` directive and in the `loadpsp` command, including any relative path name such as `../include/`.

The following code shows the syntax of the `page` directive (note that the attribute names `contentType` and `errorPage` are case-sensitive):

```
<%@ page [language="PL/SQL"] [contentType="content type string"] charset="encoding" [errorPage="file.psp"] %>
```

Specifying the Scripting Language

To identify a file as a PL/SQL server page, include the following directive somewhere in the file:

```
<%@ page language="PL/SQL" %>
```

This directive is for compatibility with other scripting environments. Example 12–1 shows an example of a simple PL/SQL server page that includes the language directive.

Returning Data to the Client

You have the following basic options when specifying the type of data to return to the client browser:

- Returning HTML
- Returning XML, Text, or Other Document Types
- Returning Pages Containing Different Character Sets

Returning HTML The PL/SQL parts of a PL/SQL server page are enclosed within special delimiters. All other content is passed along verbatim—including any whitespace—to the browser. To display text or HTML tags, write it as you would a typical Web page. You do not need to call any output functions. As illustration, the server page in Example 12–1 returns the HTML page shown in Example 12–2, except that it includes the table rows for the queried employees.

Example 12–2 Sample Returned HTML Page

```
<html>
<head>
<meta http-equiv="Content-Type" content="text/html">
<title>List of Employees</title>
</head>
<body TEXT="#000000" BGCOLOR="#FFFFFF">
```

```
<h1>List of Employees</h1>
<table width="40%" border="1">
<tr>
<th align="left">Last Name</th>
<th align="left">First Name</th>
</tr>

  <!-- result set of query of hr.employees inserted here -->

</table>
</body>
</html>
```

Sometimes you might want to display one line of output or another, or change the value of an attribute, based on a condition. You can include control structures and variable substitution inside the PSP delimiters, as shown in the following code fragment from Example 12–1:

```
<%  FOR emp_record IN emp_cursor LOOP %>
  <tr>
  <td> <%= emp_record.last_name %> </td>
  <td> <%= emp_record.first_name %> </td>
  </tr>
<%  END LOOP; %>
```

Returning XML, Text, or Other Document Types By default, the PL/SQL gateway transmits files as HTML documents so that the browser interprets the HTML tags. If you want the browser to interpret the document as XML, plain text (with no formatting), or some other document type, then include the following directive:

```
<%@ page contentType="MIMEtype" %>
```

The attribute name is case-sensitive, so be sure to capitalize it as `contentType`. Insert `text/html`, `text/xml`, `text/plain`, `image/jpeg`, or some other MIME type that the browser or other client program recognizes. Users may have to configure their browsers to recognize some MIME types. The following shows an example of a directive for an Excel spreadsheet:

```
<%@ page contentType="application/vnd.ms-excel" %>
```

Typically, a PL/SQL server page is intended to be displayed in a Web browser. It can also be retrieved and interpreted by a program that can make HTTP requests, such as a a Java or Perl client.

Returning Pages Containing Different Character Sets By default, the PL/SQL gateway transmits files with the character set defined by the PL/SQL gateway. To convert the data to a different character set for browser display, include the following directive:

```
<%@ page charset="encoding" %>
```

Specify `Shift_JIS`, `Big5`, `UTF-8`, or another encoding that the client program recognizes.

You must also configure the character set setting in the database accessor descriptor (DAD) of the PL/SQL gateway. Users may have to select the same encoding in their browsers to see the data displayed properly. For example, a database in Japan might have a database character set that uses the `EUC` encoding, but the Web browsers are configured to display `Shift_JIS` encoding.

Handling Script Errors

When writing PL/SQL server pages, be mindful of the following types of errors:

- HTML syntax errors. Any errors in HTML markup are handled by the browser. The `loadpsp` utility does not check for them.
- PL/SQL syntax errors. If you make a syntax error in the PL/SQL code, the `loadpsp` utility stops and displays the line number, column number, and a brief message. You must fix the error before continuing. Note that any previous version of the stored procedure can be erased when you attempt to replace it with a script that contains a syntax error. You might want to use one database for prototyping and debugging, then load the final stored procedure into a different database for production. You can switch databases using a command-line flag without changing any source code.
- Runtime errors. To handle database errors that occur when the script runs, you can include PL/SQL exception-handling code within a PSP file and have any unhandled exceptions bring up a special PL/SQL server page. Use the `errorPage` attribute (note that the name is case-sensitive) of the `<%@ page ... %>` directive to specify the page name.

  The page for unhandled exceptions is a PL/SQL server page with extension `.psp`. The error procedure does not receive any parameters, so to determine the cause of the error, it can call the `SQLCODE` and `SQLERRM` functions. You can also display a standard HTML page without any scripting when an error occurs, but you must still give it the extension `.psp` and load it into the database as a stored procedure.

The following example shows a directive that specifies `errors.psp` as the page to run when errors are encountered:

```
<%@ page language="PL/SQL" contentType="text/html" errorPage="errors.psp" %>
```

Accepting User Input

To set up parameter passing for a PL/SQL server page, include a directive with the following syntax:

```
<%@ plsql parameter="parameter name" [type="PL/SQL type"] [default="value"] %>
```

Example 12–9 shows an example of a script that includes the parameter directive.

By default, parameters are of type `VARCHAR2`. To use a different type, include a `type="PL/SQL type"` attribute within the directive, as in the following example:

```
<%@ plsql parameter="p_employee_id" type="NUMBER" %>
```

To set a default value, so that the parameter becomes optional, include a `default="expression"` attribute in the directive. The values for this attribute are substituted directly into a PL/SQL statement, so any strings must be single-quoted, and you can use special values such as `null`, as in the following example:

```
<%@ plsql parameter="p_last_name" default="null" %>
```

User input comes encoded in the URL that retrieves the HTML page. You can generate the URL by hard-coding it in an HTML link, or by calling your page as the action of an HTML form. Your page receives the input as parameters to a PL/SQL stored procedure. For example, assume that you change the first few lines of Example 12–1 to include a parameter directive as follows, and then load it into the database:

```
<%@ page language="PL/SQL" %>
<%@ page contentType="text/html" %>
```

```
<%@ plsql parameter="p_employee_id" default="null" type="NUMBER" %>
<%@ plsql procedure="show_employees" %>
<%!
  CURSOR emp_cursor IS
  SELECT last_name, first_name
  FROM hr.employees
  WHERE employee_id = p_employee_id
  ORDER BY last_name;
%>
```

If the PL/SQL gateway were configured so that you could execute procedures by calling `http://www.host.com/pls/proc_name`, where `proc_name` is the name of a procedure, then you could pass `200` for parameter `p_employee_id` as follows:

```
http://www.host.com/pls/show_employees?p_employee_id=200
```

Naming the PL/SQL Stored Procedure

Each top-level PL/SQL server page corresponds to a stored procedure within the server. When you load the page with `loadpsp`, the utility creates a PL/SQL stored procedure. By default, the procedure is given the same name as the PSP script, except with the `.psp` extension removed. Thus, if your script is named `hello_world.psp`, then by default the utility creates a procedure named `hello_world`.

To give the procedure a name that is different from the script name, include the following directive, where *`procname`* is the name of a procedure:

```
<%@ plsql procedure="procname" %>
```

Example 12–1 includes the following directive, which gives the stored procedure the name `show_employees`:

```
<%@ plsql procedure="show_employees" %>
```

Thus, you could name the file `empnames.psp` or anything else that ends with `*.psp`, but the procedure is created as `show_employees`. Note that it is the name of the *procedure*, not the name of the PSP script, that you include in the URL.

Including the Contents of Other Files

You can set up an include mechanism to pull in the contents of other files, typically containing either static HTML content or more PL/SQL scripting code. Insert the following directive at the point where the content of the other file should appear, replacing *`filename`* with the name of the file to be included:

```
<%@ include file="filename" %>
```

The included file must have an extension other than `.psp`. You must specify exactly the same name in both the `include` directive and in the `loadpsp` command, including any relative path name such as `../include/`.

Because the files are processed when you load the stored procedure into the database, the substitution is performed only once, not whenever the page is served. Therefore, changes to the included files that occur after the page is loaded into the database are not displayed when the procedure is executed.

You can use the include feature to pull in libraries of code, such as a navigation banners, footers, tables of contents, and so forth into multiple files. Alternatively, you can use this feature as a macro capability to include the same section of script code in more than one place in a page. The following example includes an HTML footer:

```
<%@ include file="footer.htm" %>
```

Note the following characteristics of included files:

- You can use any names and extensions for the included files. For example, you could include a file called `products.txt`.
- If the included files contain PL/SQL scripting code, then they do not need their own set of directives to identify the procedure name, character set, and so on.
- When specifying the names of files to the `loadpsp` utility, you must include the names of all included files also. Specify the names of included files before the names of any `.psp` files.

Declaring Global Variables in a PSP Script

You can use the `<%! ... %>` directive to define a set of PL/SQL variables that are visible throughout the page, not just within the next `BEGIN/END` block. This element typically spans multiple lines, with individual PL/SQL variable declarations ended by semicolons. The syntax for this directive is as follows:

```
<%! PL/SQL declaration;
    [ PL/SQL declaration; ] ... %>
```

The usual PL/SQL syntax is allowed within the block. The delimiters server as shorthand, enabling you to omit the `DECLARE` keyword. All declarations are available to the code later in the file. Example 12–1 includes the following cursor declaration:

```
<%!
  CURSOR emp_cursor IS
  SELECT last_name, first_name
  FROM hr.employees
  ORDER BY last_name;
%>
```

You can specify multiple declaration blocks; internally, they are all merged into a single block when the PSP file is created as a stored procedure.

You can also use explicit `DECLARE` blocks within the `<% ... %>` delimiters that are explained in "Specifying Executable Statements in a PSP Script" on page 12-9. These declarations are only visible to the following `BEGIN/END` block.

> **Note:** To make things easier to maintain, keep all your directives and declarations together near the beginning of a PL/SQL server page.

Specifying Executable Statements in a PSP Script

You can use the `<% ... %>` code block directive to execute a set of PL/SQL statements when the stored procedure is run. The following code shows the syntax for executable statements:

```
<% PL/SQL statement;
   [ PL/SQL statement; ] ... %>
```

This element typically spans multiple lines, with individual PL/SQL statements ended by semicolons. The statements can include complete blocks, as in the following example, which calls the `OWA_UTIL.TABLEPRINT` procedure:

```
<% OWA_UTIL.TABLEPRINT(CTABLE => 'hr.employees', CATTRIBUTES => 'border=2',
   CCOLUMNS => 'last_name,first_name', CCLAUSES => 'WHERE employee_id > 100'); %>
```

The statements can also be the bracketing parts of IF/THEN/ELSE or BEGIN/END blocks. When a code block is split into multiple directives, you can put HTML or other directives in the middle, and the middle pieces are conditionally executed when the stored procedure is run. The following code from Example 12–10 provides an illustration of this technique:

```
<% FOR ITEM IN (SELECT product_name, list_price, catalog_url
                FROM product_information
                WHERE list_price IS NOT NULL
                ORDER BY list_price DESC) LOOP
   IF item.list_price > p_minprice THEN
      v_color := '#CCCCFF';
   ELSE
      v_color := '#CCCCCC';
   END IF;
%>
<TR BGCOLOR="<%= v_color %>">
  <TD><A HREF="<%= item.catalog_url %>"><%= item.product_name %></A></TD>
  <TD><BIG><%= item.list_price %></BIG></TD>
</TR>
<% END LOOP; %>
```

All the usual PL/SQL syntax is allowed within the block. The delimiters server as shorthand, letting you omit the DECLARE keyword. All the declarations are available to the code later on in the file.

> **Note:** To share procedures, constants, and types across different PL/SQL server pages, compile them into a package in the database by using a plain PL/SQL source file. Although you can reference packaged procedures, constants, and types from PSP scripts, the PSP scripts can only produce standalone procedures, not packages.

Substituting an Expression Result in a PSP Script

An expression directive outputs a single PL/SQL expression, such as a string, arithmetic expression, function call, or combination of these things. The result is substituted as a string at that spot in the HTML page that is produced by the stored procedure. The expression result must be a string value or be able to be cast to a string. For any types that cannot be implicitly cast, such as DATE, pass the value to the PL/SQL TO_CHAR function.

The syntax of an expression directive is as follows, where the *expression* placeholder is replaced by the desired expression:

```
<%= expression %>
```

Note that you do not need to end the PL/SQL expression with a semicolon.

Example 12–1 includes a directive to print the value of a variable in a row of a cursor:

```
<%= emp_record.last_name %>
```

Compare the preceding example to the equivalent htp.print call in the following example (note especially the semicolon that ends the statement):

```
<% HTP.PRN (emp_record.last_name); %>
```

The content within the <%= ... %> delimiters is processed by the HTP.PRN function, which trims leading or trailing whitespace and requires that you quote literal strings.

Note that you can use concatenation by using the twin pipe symbol (||) as you would in PL/SQL. The following directive shows an example of concatenation:

```
<%= 'The employee last name is ' || emp_record.last_name %>
```

Quoting and Escaping Strings in a PSP Script

PSP attributes use double quotes to delimit data. When values specified in PSP attributes are used for PL/SQL operations, they are passed exactly as you specify them in the PSP file. Thus, if PL/SQL requires a single-quoted string, then you must specify the string with the single quotes around it—and surround the whole thing with double quotes.

For example, your PL/SQL procedure may use the string Babe Ruth as the default value for a variable. Because the string will be used in PL/SQL, you must enclose it in single quotes as 'Babe Ruth'. If you specify this single-quoted string in the default attribute of a PSP directive, then you must surround it in double quotes as in the following example:

```
<%@ plsql parameter="in_players" default="'Babe Ruth'" %>
```

You can also nest single-quoted strings inside single quotes. In this case, you must *escape* the nested single quotes by specifying the sequence \'. For example:

```
<%@ plsql parameter="in_players" default="'Walter \'Big Train\' Johnson'" %>
```

You can include most characters and character sequences in a PSP file without having them changed by the PSP loader. To include the sequence %>, specify the escape sequence %\>. To include the sequence <%, specify the escape sequence <\%. For example:

```
<%= 'The %\> sequence is used in scripting language: ' || lang_name %>
<%= 'The <\% sequence is used in scripting language: ' || lang_name %>
```

Including Comments in a PSP Script

To put a comment in the HTML portion of a PL/SQL server page for the benefit of those reading the PSP source code, use the following syntax:

```
<%-- PSP comment text --%>
```

Comments in the preceding form do not appear in the HTML output from the PSP and also do not appear when you query the PL/SQL source code in USER_OBJECTS.

To create a comment that is visible in the HTML output and in the USER_OBJECTS source, place the comment in the HTML and use the normal HTML comment syntax:

```
<!-- HTML comment text -->
```

To include a comment inside a PL/SQL block within a PSP, and to make the comment invisible in the HTML output but visible in USER_OBJECTS, use the normal PL/SQL comment syntax, as in the following example:

```
-- Comment in PL/SQL code
```

Example 12–3 shows a fragment of a PSP file with the three types of comments.

Example 12–3 Sample Comments in a PSP File

```
<p>Today we introduce our new model XP-10.
<%--
  This is the project with code name "Secret Project".
  Users viewing the HTML page will not see this PSP script comment.
  The comment is not visible in the USER_OBJECTS source code.
--%>
<!--
  Some pictures of the XP-10.
  Users viewing the HTML page source will see this comment.
  The comment is also visible in the USER_OBJECTS source code.
-->
<%
FOR image_file IN (SELECT pathname, width, height, description
                   FROM image_library WHERE model_num = 'XP-10')
-- Comments interspersed with PL/SQL statements.
-- Users viewing the HTML page source will not see these PL/SQL comments.
-- These comments are visible in the USER_OBJECTS source code.
LOOP
%>
<img src="<%= image_file.pathname %>" width=<% image_file.width %>
height=<% image_file.height %> alt="<% image_file.description %>">
<br>
<% END LOOP; %>
```

Loading a PL/SQL Server Page into the Database

Use the `loadpsp` utility, which is located in `$ORACLE_HOME/bin`, to load one or more PSP files into the database as stored procedures. Each `.psp` file corresponds to one stored procedure. The pages are compiled and loaded in one step, to speed up the development cycle. The syntax of the `loadpsp` utility as follows:

```
loadpsp [ -replace ] -user username/password[@connect_string]
    [ include_file_name ... ] [ error_file_name ] psp_file_name ...
```

To create procedures with `CREATE OR REPLACE` syntax, use the `-replace` flag.

When you load a PSP file, the loader performs the following actions:

1. Logs on to the database with the specified user name, password, and net service name
2. Creates the stored procedures in the user schema

Include the names of all the include files before the names of the PL/SQL server pages. Also include the name of the file specified in the `errorPage` attribute of the `page` directive. These filenames on the loadpsp command line must match exactly the names specified within the PSP `include` and `page` directives, including any relative path name such as `../include/`. Example 12–4 shows a sample PSP load command.

Example 12–4 Loading a PSP

```
loadpsp -replace -user hr/hr@orcl banner.inc error.psp display_order.psp
```

Note the following characteristics of Example 12–4:

- The stored procedure is created in the database `orcl`. The database is accessed as user `hr` with password `hr`, both to create the stored procedure and when the stored procedure is executed.

- `banner.inc` is a file containing boilerplate text and script code that is included by the `.psp` file. The inclusion occurs when the PSP is loaded into the database, not when the stored procedure is executed.
- `error.psp` is a file containing code, text, or both that is processed when an unhandled exception occurs, to present a friendly page rather than an internal error message.
- `display_order.psp` contains the main code and text for the Web page. By default, the corresponding stored procedure is named `display_order`.

Querying PSP Source Code

After you have loaded a PSP file, you can view the source code in the `USER_SOURCE` or `DBA_SOURCE` tables in the data dictionary. For example, suppose that you load the script in Example 12–1 with the following command:

```
loadpsp -replace -user hr/hr simple.psp
```

If you log on to the database as user `hr`, then you can execute the following query in SQL*Plus to view the source code of the PSP:

```
SET HEADING OFF

SELECT TEXT
FROM   USER_SOURCE
WHERE  NAME = 'SHOW_EMPLOYEES'
ORDER BY LINE;
```

Sample output is shown in Example 12–5. Note that the code generated by `loadpsp` is different from the code in the source file. The `loadpsp` utility has added extra code, mainly calls to the `HTP` package, to the PSP code. The `HTP` package generates the HTML tags for the web page.

Example 12–5 Output from Query of USER_SOURCE

```
PROCEDURE show_employees  AS

  CURSOR emp_cursor IS
  SELECT last_name, first_name
  FROM hr.employees
  ORDER BY last_name;

 BEGIN NULL;
owa_util.mime_header('text/html'); htp.prn('
');
htp.prn('
');
htp.prn('

');
htp.prn('
<html>
<head>
<meta http-equiv="Content-Type" content="text/html">
<title>List of Employees</title>
</head>
<body TEXT="#000000" BGCOLOR="#FFFFFF">
<h1>List of Employees</h1>
<table width="40%" border="1">
```

```
<tr>
<th align="left">Last Name</th>
<th align="left">First Name</th>

</tr>
');
  FOR emp_record IN emp_cursor LOOP
htp.prn('
  <tr>
  <td> ');
htp.prn( emp_record.last_name );
htp.prn(' </td>
  <td> ');
htp.prn( emp_record.first_name );
htp.prn(' </td>
  </tr>
');
  END LOOP;
htp.prn('
</table>
</body>
</html>
');
 END;
```

Executing a PL/SQL Server Page Through a URL

After the PL/SQL server page has been turned into a stored procedure, you can run the procedure by retrieving an HTTP URL through a Web browser or other Internet-aware client program. The virtual path in the URL depends on the way the PL/SQL gateway is configured.

The parameters to the stored procedure are passed through either the `POST` method or the `GET` method of the HTTP protocol. With the `POST` method, the parameters are passed directly from an HTML form and are not visible in the URL. With the `GET` method, the parameters are passed as name-value pairs in the query string of the URL, separated by `&` characters, with most non-alphanumeric characters in encoded format (such as `%20` for a space). You can use the `GET` method to call a PSP page from an HTML form, or you can use a hard-coded HTML link to call the stored procedure with a given set of parameters.

Using `METHOD=GET`, the syntax of the URL looks something like the following:

`http://`*`sitename`*`/`*`schemaname`*`/`*`procname`*`?`*`parmname1=value1&parmname2=value2`*

For example, the following URL includes a `p_lname` and `p_fname` parameter:

```
http://www.host.com/pls/show_employees?p_lname=Ashdown&p_fname=Lance
```

Using `METHOD=POST`, the syntax of the URL does not show the parameters:

`http://`*`sitename`*`/`*`schemaname`*`/`*`procname`*

For example, the following URL specifies a procedure name but does not pass parameters:

```
http://www.host.com/pls/show_employees
```

The `METHOD=GET` format is more convenient for debugging and allows visitors to pass exactly the same parameters when they return to the page through a bookmark.

The METHOD=POST format allows a larger volume of parameter data, and is suitable for passing sensitive information that should not be displayed in the URL. (URLs linger on in the browser's history list and in the HTTP headers that are passed to the next-visited page.) It is not practical to bookmark pages that are called this way.

Examples of PL/SQL Server Pages

This section shows how you might start with a very simple PL/SQL server page, and produce progressively more complicated versions as you gain more confidence.

As you go through each step, you can follow the instructions in "Loading a PL/SQL Server Page into the Database" on page 12-12 and "Executing a PL/SQL Server Page Through a URL" on page 12-14 to test the examples.

This section contains the following topics:

Setup for PL/SQL Server Pages Examples

These examples use the product_information table in the oe schema, which is described as follows:

```
Table PRODUCT_INFORMATION
 Name                                      Null?    Type
 ----------------------------------------- -------- ----------------------------
 PRODUCT_ID                                NOT NULL NUMBER(6)
 PRODUCT_NAME                                       VARCHAR2(50)
 PRODUCT_DESCRIPTION                                VARCHAR2(2000)
 CATEGORY_ID                                        NUMBER(2)
 WEIGHT_CLASS                                       NUMBER(1)
 WARRANTY_PERIOD                                    INTERVAL YEAR(2) TO MONTH
 SUPPLIER_ID                                        NUMBER(6)
 PRODUCT_STATUS                                     VARCHAR2(20)
 LIST_PRICE                                         NUMBER(8,2)
 MIN_PRICE                                          NUMBER(8,2)
 CATALOG_URL                                        VARCHAR2(50)
```

The examples assume the following:

- Youn have set up mod_plsql as described in "Using the mod_plsql Gateway" on page 11-3.
- You have created a DAD for static authentication of the oe user.
- You can access PL/SQL stored procedures created in the oe schema through the following URL, where proc_name is the name of a stored procedure:
  http://www.host.com/pls/proc_name

For debugging purposes, you can display the complete contents of an SQL table. You can do this with a single call to OWA_UTIL.TABLEPRINT as illustrated in Example 12–6. In subsequent iterations, we use other techniques to gain more control over the presentation.

Example 12–6 show_prod_simple.psp

```
<%@ plsql procedure="show_prod_simple" %>
<HTML>
<HEAD><TITLE>Show Contents of product_information (Complete Dump)</TITLE></HEAD>
<BODY>
<%
DECLARE
  dummy BOOLEAN;
BEGIN
  dummy := OWA_UTIL.TABLEPRINT('oe.product_information','border');
END;
%>
</BODY>
</HTML>
```

Load the PSP in Example 12–6 at the command line as follows:

```
loadpsp -replace -user oe/oe show_prod_simple.psp
```

Access the PSP through the following URL:

```
http://www.host.com/pls/show_prod_simple
```

Printing the Sample Table with a Loop

Example 12–6 loops through the items in the `product_information` table and adjusts the `SELECT` statement to retrieve only a subset of the rows or columns. In this example, we pick a very simple presentation, a set of list items, to avoid any problems from mismatched or unclosed table tags.

Example 12–7 show_catalog_raw.psp

```
<%@ plsql procedure="show_prod_raw" %>
<HTML>
<HEAD><TITLE>Show Products (Raw Form)</TITLE></HEAD>
<BODY>
<UL>
<% FOR item IN (SELECT product_name, list_price, catalog_url
                FROM product_information
                WHERE list_price IS NOT NULL
                ORDER BY list_price DESC) LOOP %>
<LI>
Item = <%= item.product_name %><BR>
Price = <%= item.list_price %><BR>
URL = <%= item.catalog_url %><BR>
<% END LOOP; %>
</UL>
</BODY>
</HTML>
```

Example 12–8 shows a more sophisticated variation of Example 12–7 in which formatting is added to the HTML to improve the presentation.

Example 12–8 show_catalog_pretty.psp

```
<%@ plsql procedure="show_prod_pretty" %>
<HTML>
<HEAD><TITLE>Show Products (Better Form)</TITLE></HEAD>
<BODY>
<UL>
```

```
<% FOR item IN (SELECT product_name, list_price, catalog_url
                FROM product_information
                WHERE list_price IS NOT NULL
                ORDER BY list_price DESC) LOOP %>
<LI>
Item = <A HREF=<%= item.catalog_url %>><%= item.product_name %></A><BR>
Price = <BIG><%= item.list_price %></BIG><BR>
<% END LOOP; %>
</UL>
</BODY>
</HTML>
```

Allowing a User Selection

In the previous examples, the HTML page remains the same unless the `product_information` table is updated. Example 12–9 livens up the page by:

- Making it accept a minimum price, and present only the items that are more expensive. (Your customers' buying criteria may vary.)
- Setting the default minimum price to 100 units of the appropriate currency. Later, we see how to allow the user to pick a minimum price.

Example 12–9 show_product_partial.psp

```
<%@ plsql procedure="show_product_partial" %>
<%@ plsql parameter="p_minprice" default="100" %>
<HTML>
<HEAD><TITLE>Show Items Greater Than Specified Price</TITLE></HEAD>
<BODY>
<P>This report shows the items whose price is greater than <%= p_minprice %>.
<UL>
<% FOR ITEM IN (SELECT product_name, list_price, catalog_url
                FROM product_information
                WHERE list_price > p_minprice
                ORDER BY list_price DESC)
   LOOP %>
<LI>
Item = <A HREF="<%= item.catalog_url %>"><%= item.product_name %></A><BR>
Price = <BIG><%= item.list_price %></BIG><BR>
<% END LOOP; %>
</UL>
</BODY>
</HTML>
```

After loading Example 12–9 into the database, you can pass a parameter to the `show_product_partial` procedure through a URL. The following example specifies a minimum price of 250:

```
http://www.host.com/pls/show_product_partial?p_minprice=250
```

This technique of filtering results is fine for some applications, such as search results, in which users might worry about being overwhelmed by choices. But in a retail situation, you might want to use the alternative technique illustrated in Example 12–10 so that customers can still choose to purchase other items. Note the following features of this example:

- Instead of filtering the results through a `WHERE` clause, we can retrieve the entire result set and then take different actions for different returned rows.

- We can change the HTML to highlight the output that meets their criteria. In this case, we use the background color for an HTML table row. We could also insert a special icon, increase the font size, or use some other technique to call attention to the most important rows.
- We can present the results in an HTML table.

Example 12–10 show_product_highlighed.psp

```
<%@ plsql procedure="show_product_highlighted" %>
<%@ plsql parameter="p_minprice" default="100" %>
<%! v_color VARCHAR2(7); %>

<HTML>
<HEAD><TITLE>Show Items Greater Than Specified Price</TITLE></HEAD>
<BODY>
<P>This report shows all items, highlighting those whose price is
 greater than <%= p_minprice %>.
<P>
<TABLE BORDER>
  <TR>
    <TH>Product</TH>
    <TH>Price</TH>
  </TR>
  <% FOR ITEM IN (SELECT product_name, list_price, catalog_url
                  FROM product_information
                  WHERE list_price IS NOT NULL
                  ORDER BY list_price DESC) LOOP
     IF item.list_price > p_minprice THEN
        v_color := '#CCCCFF';
     ELSE
        v_color := '#CCCCCC';
     END IF;
  %>
  <TR BGCOLOR="<%= v_color %>">
    <TD><A HREF="<%= item.catalog_url %>"><%= item.product_name %></A></TD>
    <TD><BIG><%= item.list_price %></BIG></TD>
  </TR>
  <% END LOOP; %>
</TABLE>
</BODY>
</HTML>
```

Using an HTML Form to Call a PL/SQL Server Page

Example 12–11 shows a bare-bones HTML form that allows the user to enter a price. The form calls the `show_product_partial` stored procedure illustrated in Example 12–9 and passes it the entered value as the `p_minprice` parameter.

To avoid coding the entire URL of the stored procedure in the `ACTION=` attribute of the form, we can make the form a PSP file so that it resides in the same directory as the PSP file that it calls. Even though this HTML file contains no PL/SQL code, we can give it a `.psp` extension and load it as a stored procedure into the database. When the `product_form` stored procedure is executed through a URL, it displays the HTML exactly as it appears in the file.

Example 12–11 product_form.psp

```
<HTML>
<BODY>
```

```
<FORM method="POST" action="show_product_partial">
  <P>Enter the minimum price you want to pay:
  <INPUT type="text" name="p_minprice">
  <INPUT type="submit" value="Submit">
</FORM>
</BODY>
</HTML>
```

Including JavaScript in a PSP File

To produce an elaborate HTML file, perhaps including dynamic content such as JavaScript, you can simplify the source code by implementing it as a PSP. This technique avoids having to deal with nested quotation marks, escape characters, concatenated literals and variables, and indentation of the embedded content.

Example 12–12 shows a version of Example 12–9 that uses JavaScript to display the order status in the browser status bar when the user moves his or her mouse over the product URL.

Example 12–12 show_product_javascript.psp

```
<%@ plsql procedure="show_product_javascript" %>
<%@ plsql parameter="p_minprice" default="100" %>
<HTML>
<HEAD>
  <TITLE>Show Items Greater Than Specified Price</TITLE>

<SCRIPT language="JavaScript">
<!--hide

var text=" ";

function overlink (text)
{
  window.status=text;
}
function offlink (text)
{
  window.status=text;
}

//-->
</SCRIPT>

</HEAD>
<BODY>
<P>This report shows the items whose price is greater than <%= p_minprice %>.
<P>
<UL>
<% FOR ITEM IN (SELECT product_name, list_price, catalog_url, product_status
                FROM product_information
                WHERE list_price > p_minprice
                ORDER BY list_price DESC)
   LOOP %>
<LI>
Item =
  <A HREF="<%= item.catalog_url %>"
  onMouseover="overlink('PRODUCT STATUS: <%= item.product_status %>');return true"
  onMouseout="offlink(' ');return true">
    <%= item.product_name %>
```

```
  </A>
<BR>
Price = <BIG><%= item.list_price %></BIG><BR>
<% END LOOP; %>
</UL>
</BODY>
</HTML>
```

Debugging PL/SQL Server Page Problems

As you begin experimenting with PSP, and as you adapt your first simple pages into more elaborate ones, keep these guidelines in mind when you encounter problems:

- The first step is to get all the PL/SQL syntax and PSP directive syntax right. If you make a mistake here, the file does not compile.
  - Make sure you use semicolons to terminate lines where required.
  - If a value must be quoted, quote it. You might need to enclose a single-quoted value (needed by PL/SQL) inside double quotes (needed by PSP).
  - Mistakes in the PSP directives are usually reported through PL/SQL syntax messages. Check that your directives use the right syntax, that directives are closed properly, and that you are using the right element (declaration, expression, or code block) depending on what goes inside it.
  - PSP attribute names are case-sensitive. Most are specified in all lowercase; `contentType` and `errorPage` must be specified as mixed-case.
- When using a URL to request a PSP, you may get an error that the file is not found. In this case, note the following:
  - Make sure you are requesting the right virtual path, depending on the way the Web gateway is configured. Typically, the path includes the host name, optionally a port number, the schema name, and the name of the stored procedure (with no `.psp` extension).
  - If you use the `-replace` option when compiling the file, the old version of the stored procedure is erased. So, after a failed compilation, you must fix the error or the page is not available. You might want to test new scripts in a separate schema, then load them into the production schema.
  - If you copied the file from another file, remember to change any procedure name directives in the source to match the new file name.
  - When you get one file-not-found error, make sure to request the latest version of the page the next time. The error page might be cached by the browser. You may need to force a page reload in the browser to bypass the cache.
- When the PSP script is run, and the results come back to the browser, use standard debugging techniques to check for and correct wrong output. The difficult part is to configure the interface between different HTML forms, scripts, and CGI programs so that the right values are passed into your page. The page might return an error because of a parameter mismatch. Note the following tips:
  - To determine exactly what is being passed to your page, use `METHOD=GET` in the calling form so that the parameters are visible in the URL.
  - Make sure that the form or CGI program that calls your page passes the correct number of parameters, and that the names specified by the `NAME=` attributes on the form match the parameter names in the PSP file. If the form

includes any hidden input fields, or uses the NAME= attribute on the Submit or Reset buttons, then the PSP file must declare equivalent parameters.

- Make sure that the parameters can be cast from string into the correct PL/SQL types. For example, do not include alphabetic characters if the parameter in the PSP file is declared as a NUMBER.
- Make sure that the query string of the URL consists of name-value pairs, separated by equals signs, especially if you are passing parameters by constructing a hard-coded link to the page.
- If you are passing a lot of parameter data, such as large strings, you might exceed the volume that can be passed with METHOD=GET. You can switch to METHOD=POST in the calling form without changing your PSP file.
- Although the loadpsp command reports line numbers correctly when there is a syntax error in your source file, line numbers reported for runtime errors refer to a transformed version of the source and do not match the line numbers in the original source. When you encounter errors that produce an error trace instead of the expected Web page, you will need to locate the error through exception handlers and by printing debug output.

Putting PL/SQL Server Pages into Production

Before putting your PSP application into production, consider issues such as usability and download speed:

- Pages can be rendered faster in the browser if the HEIGHT= and WIDTH= attributes are specified for all images. You might standardize on picture sizes, or store the height and width of images in the database along with the data or URL.
- For viewers who turn off graphics, or who use alternative browsers that read the text out loud, include a description of significant images using the ALT= attribute. You might store the description in the database along with the image.
- Although an HTML table provides a good way to display data, a large table can make your application seem slow. Often, the reader sees a blank page until the entire table is downloaded. If the amount of data in an HTML table is large, consider splitting the output into multiple tables.
- If you set text, font, or background colors, test your application with different combinations of browser color settings:
  - Test what happens if you override just the foreground color in the browser, or just the background color, or both.
  - Generally, if you set one color (such as the foreground text color), you should set all the colors through the <BODY> tag, to avoid hard-to-read combinations like white text on a white background.
  - If you use a background image, specify a similar background color to provide proper contrast for viewers who do not load graphics.
  - If the information conveyed by different colors is crucial, consider using an alternative technique. For example, you might put an icon next to special items in a table. Some users may see your page on a monochrome screen or on browsers that cannot represent different colors.
- Providing context information prevents users from getting lost. Include a descriptive <TITLE> tag for your page. If the user is partway through a procedure, indicate which step is represented by your page. Provide links to

logical points to continue with the procedure, return to a previous step, or cancel the procedure completely. Many pages might use a standard set of links that you embed using the include directive.

- In any entry fields, users might enter incorrect values. Where possible, use select lists to present a set of choices. Validate any text entered in a field before passing it to SQL. The earlier you can validate, the better; a JavaScript routine can detect incorrect data and prompt the user to correct it before they press the `Submit` button and make a call to the database.
- Browsers tend to be lenient when displaying incorrect HTML. What looks OK in one browser might look bad or might not display at all in another browser. Note the following guidelines:
  - Pay attention to HTML rules for quotation marks, closing tags, and especially for anything to do with tables.
  - Minimize the dependence on tags that are only supported by a single browser. Sometimes you can provide an extra bonus using such tags, but your application should still be usable with other browsers.
  - You can check the validity, and even in some cases the usability, of your HTML for free at many sites on the World Wide Web.

13

Developing Applications with Database Change Notification

This section contains the following topics:

What Is Database Change Notification?

Database Change Notification is a feature that enables client applications to register queries with the database and receive notifications in response to DML or DDL changes on the objects associated with the queries. The notifications are published by the database when the DML or DDL transaction commits.

During registration, the application specifies a notification handler and associates a set of interesting queries with the notification handler. A notification handler can be either a server side PL/SQL procedure or a client side C callback. Registrations are created on all objects referenced during the execution of the queries. The notification handler is invoked when a transaction subsequently changes any of the registered objects and commits.

Let us assume that the application is interested in being notified about result set changes to a query on the `HR.EMPLOYEES` table. The application can register the query on the `hr.employees` table with the database using the Change Notification Feature. If a user adds an employee, then the application can receive a database change notification when a new row is added to the table. A new query of `hr.employees` returns the changed result set.

When the database issues change notification, it can contain some or all of the following information:

- Names of the modified objects. For example, the notification can specify that the `hr.employees` table was changed.

- The type of change. For example, the message specifies whether the change was caused by an `INSERT`, `UPDATE`, `DELETE`, `ALTER TABLE`, or `DROP TABLE`.
- The `ROWID`s of the changed rows and the type of DML that changed them.
- Global events such as `STARTUP` and `SHUTDOWN` (consistent only). In a Real Applications Cluster, the database delivers a notification when the first instance on the database starts or the last instance shuts down.

The notification contains only metadata about the changed rows or objects rather than the changed data itself. For example, the database does not notify the client that a monthly salary increased from 5000 to 6000. To obtain more recent values for the changed objects or rows, the client must query the database based on the information contained in the notification.

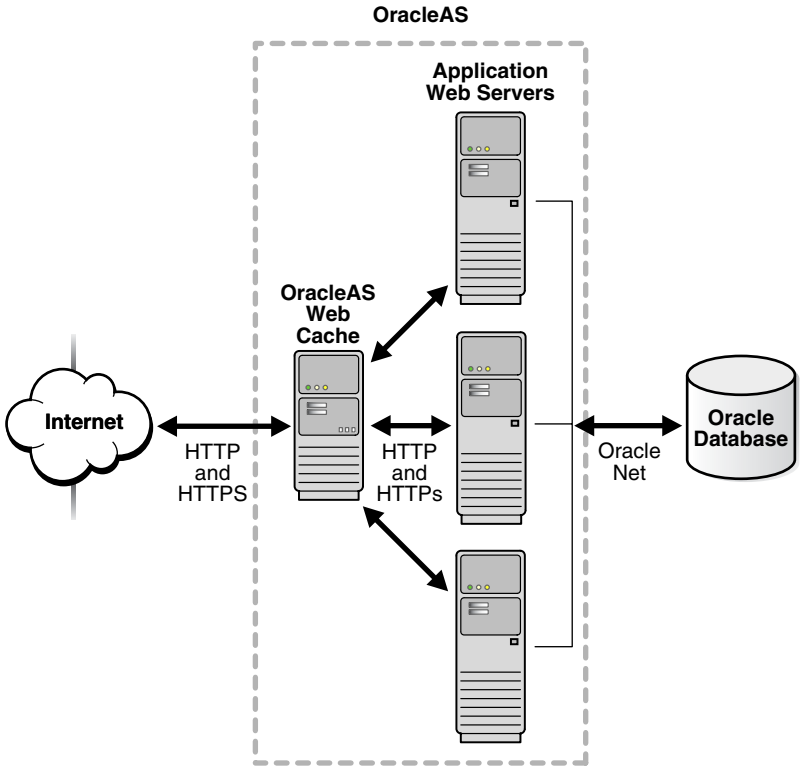
Database Change Notification is useful for an application that caches query result sets on mostly read-only objects in the mid-tier to avoid network round trips to the database. Such an application can create a registration on the queries it is interested in caching using the change notification service. On changes to objects referenced inside those queries, the database publishes a change notification when the underlying transaction commits. In response to the notification, the application can refresh its cache by re-executing the queries.

For example, the users of a Web forum application may not need to view new content as soon as it is inserted into the back-end database. Such an application is intrinsically tolerant of slightly out-of-date data, and hence can benefit from caching in the mid-tier. Database change notification is of help in this scenario in keeping the cache updated with the back-end database.

Using Database Change Notification in the Middle Tier

Database Change Notification is relevant in many development contexts, but is particularly useful to mid-tier applications that rely on cached data. Figure 13–1 illustrates a typical scenario in which a back-end Oracle Database serves data that is cached in the middle-tier and then accessed over the Internet.

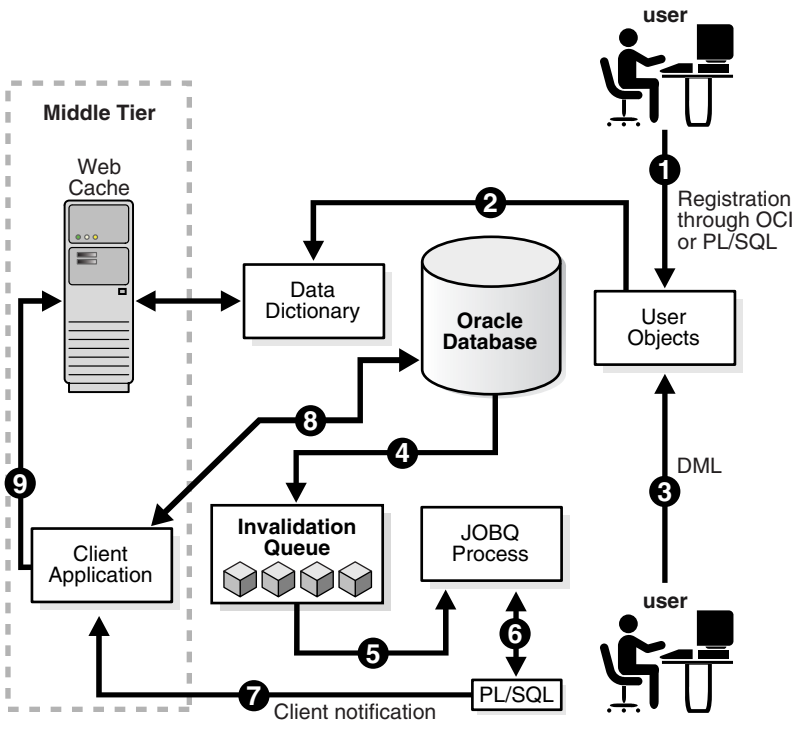
Figure 13–1 Example of Mid-Tier Caching



Applications in the middle tier require rapid access to cached copies of database objects while keeping the cache as current as possible in relation to the database. Cached data becomes out of date or "stale" when a transaction modifies the data and commits, thereby putting the application at risk of accessing incorrect results. If the application uses Database Change Notification, then Oracle Database can publish a notification when a change occurs to registered objects with details on what changed. In response to the notification, the application can refresh cached data by fetching it from the back-end database.

Figure 13–2 illustrates the process by which middle-tier Web clients can receive change and process notifications.

Figure 13–2 Basic Process of Database Change Notification



The explanation of the steps in Figure 13–2 is as follows:

1. In this example, let's assume that the application has cached the result set of a query on `HR.EMPLOYEES`. The developer creates a registration for the query on `HR.EMPLOYEES` using the Change Notification PL/SQL Interface. In addition, he creates a stored PL/SQL procedure to process notifications and supplies the server-side PL/SQL procedure as the notification handler.
2. The database populates the registration information in the data dictionary.
3. A user modifies one of the registered objects with DML statements and commits the transaction. For example, a user updates a row in the `hr.employees` table on the back-end database. The data for `hr.employees` cached in the middle tier is now stale.
4. Oracle Database adds a message that describes the change to an internal queue.
5. A `JOBQ` background process is notified of a new change notification message.
6. The `JOBQ` process executes the stored procedure specified by the client application. In this example, `JOBQ` passes the data to a server-side PL/SQL procedure. The implementation of the PL/SQL callback procedure determines how the notification is handled.
7. Inside the server-side PL/SQL procedure, the developer can implement logic to notify the mid-tier client application of the changes to the registered objects. For example, it notifies the application of the `ROWID` of the changed row in `hr.employees`.
8. The client application in the middle tier queries the back-end database to retrieve the data in the changed row.
9. The client application updates the cache with the new data.

Note: The above steps are applicable to registrations created through PL/SQL. In the case of registrations created via the OCI interface, the application uses the `OCISubscriptionRegister` interface to create a registration and specifies a client side C callback as the notification handler. After registration, an event thread is spawned on the client side program in the process. When a transaction changes any of the registered objects and commits, the `EMON` process of the RDBMS sends the notification to the event thread. The C callback specified by the application is then executed in the context of the event thread.

Registering Queries for Database Change Notification

This section contains the following topics:

Privileges

In order to create a registration for change notification, the user is required to have the `CHANGE NOTIFICATION` system privilege. In addition the user is required to have `SELECT` privileges on all objects to be registered. Note that if the `SELECT` privilege on an object was granted at the time of registration creation but lost subsequently (due to a revoke), then the registration will be purged and a notification to that effect will be published.

What Is a Database Change Registration?

A database change registration can be conceptually thought off as a (recipient R, list-of-queries QL) tuple. The recipient is notified when a change occurs to any of the objects referenced in the queries in the Query List. The recipient can be either a server side PL/SQL stored procedure or a client side C callback. Once created a registration is a persistent entity stored in an Oracle database. It is visible to all instances of an Oracle Real Applications Cluster. Transactions that modify registered objects in any instance of the cluster generate notifications. Once created, the registration survives until explicitly unregistered by the client application or timed-out or implicitly removed by the database for some other reason (such as loss of privileges).

If you have been granted the `CHANGE NOTIFICATION` privilege in a database session, then you can register a query to receive notifications by performing these steps:

1. Create the **notification recipient** for the queries that you want to register. The recipient can be one of the following:

- PL/SQL stored procedure, as described in "Creating a PL/SQL Stored Procedure as the Change Notification Recipient" on page 13-8
- OCI callback function, as described in *Oracle Call Interface Programmer's Guide*

2. Create an **query registration** for a specified notification recipient, as described in "Registering Queries for Change Notification Through PL/SQL" on page 13-9. You can perform this registration by executing SQL queries. After the SQL execution the registration is complete.

> **Note:** You must be connected as a non-SYS user and should NOT be in the middle of an uncommitted transaction in order to be able to create a registration.
>
> The `dml_locks` `init.ora` parameter must have a nonzero value in order to be able to successfully create registrations and receive notifications.
>
> The default value of `dml_locks` is nonzero, therefore this requirement is automatically fulfilled if the application does not configure the `dml_locks` parameter explicitly.

Change Notification Registrations are persistent by default and survive until the application explicitly unregisters them.

After the registration has been successfully created, the Oracle Database notifies client applications in response to any changes to objects referred to in the registered queries, when the underlying transaction commits. Notifications are generated as a result of DML operations like `INSERT`, `UPDATE`, and `DELETE` (on transaction commit) and DDL operations like `ALTER` and `DROP`.

The notification includes information on the names of the objects changed, the Transaction-Id of the transaction that made the change and the `TYPE` of operation (`INSERT`, `UPDATE` or `DELETE`).

> **Note:** If multiple registered objects were modified in a single transaction, then the application will receive one notification for every modified object when the transaction commits.

Supported Query Types

Change Notification allows the application to register most query types including queries executed as part of stored procedures and `REF` cursors. When performing a registration, the application is required to be only executing queries, that is, DML or DDL operations are not permitted. In addition, the following types of queries are not supported for registration.

- Queries on fixed tables or fixed views.
- Queries with dblinks inside them
- Queries over materialized views

Registration Properties

Oracle Database supports the following options for an object registration:

1. Purge On Notify option: Unregistering after the first change notification.

2. Timeout option: Specification of a registration expiration after a time interval.
3. ROWIDs option: ROWIDs of changed rows are part of the notification ROWID option.
4. Reliable Notification option: By default, notifications are generated in shared memory. If this option is chosen, notifications are generated in a persistent database queue. The notifications are enqueued atomically with the transaction that changes a registered object. Since the notifications are persistent in the database, if an instance crashes after generating a notification, they can be delivered when it restarts subsequently OR by a surviving instance of the cluster if running RAC. (Note: there is a trade-off involved here between performance of notifications and reliability. Since there are CPU and I/O costs when generating reliable notifications, it is recommended to choose the default in memory option if better notification performance is desired).
5. Operations filter: Ability to be notified of PARTICULAR operations (for example notifications only for INSERT AND UPDATE).
6. Transaction Lag: Specification of a count between successive notifications.

If the ROWID option is chosen, then ROWIDs of changed rows are published as part of the notification. The ROWIDs are published in the external string format. From the ROWID information in the notification, the application should be subsequently able to retrieve the contents of the changed rows by performing a query of the form "SELECT * from table_name_from_notification where ROWID = rowid_from_notification". The length of the ROWID is 18 character bytes in the case of regular heap tables. In the case of Index Organized Tables (IOTs), the length of the ROWID depends on the size of the primary key and therefore could be larger than 18 bytes.

The ROWID notifications are hierarchically summarized. If enough memory is not available on the server side to hold ROWIDs, then the notification might be rolled up into a FULL-TABLE-NOTIFICATION (a special flag in the notification descriptor is reserved for this purpose). When such a notification is received, the application must conservatively assume that the entire table (that is, all rows) may have been modified. ROWIDs are not part of such a notification. ROWIDs may be rolled-up if the total shared memory consumption due to ROWIDs is too large (exceeds 1% of the dynamic shared pool size), OR if too many rows were modified in a single registered object within a transaction (more than 80 approximately) OR if the total length of the logical ROWIDs of modified rows for an IOT is too large (exceeds. 1800 bytes approximately.).

Drop Table

When a table is dropped, a DROP NOTIFICATION is published. Any registrations on the dropped table will implicitly remove interest from that object (since it does not exist anymore). If those registrations have interest in other objects as well, then the registrations will continue to exist and DML transactions on those other objects will continue to result in notifications on commit. Even if the dropped table is the only object of interest for a particular registration, we still preserve the registration. The user that created that registration can use the registration to add more objects/queries subsequently.

A registration is based on the version and definition of an object at the time the query was registered. If an object was dropped, registrations on the object will lose interest on the object forever. Subsequently, even if a different object was created with a matching name and in the same schema, then the newly created object is a new object for the purposes of existing Database Change Notification Registrations, that is, any changes to this newly created object (with the matching schema/name) will not result in notifications for those registrations that existed on the prior version of the object.

Interfaces for Database Change Registration

Registration interfaces are available in both PL/SQL and OCI.

The PL/SQL API enables you to define a registration block. The registration properties including the PL/SQL notification handler are specified during the begin phase of the registration block. Any queries executed inside the registration block are considered interesting queries and the objects referenced in those queries are added to the registration. The registration is completed upon ending the registration block. In PL/SQL, you use the `DBMS_CHANGE_NOTIFICATION` package to register to receive change notifications.

The OCI Registration APIs involve the invocation of the function `OCISubscriptionRegister` in a namespace called the `DBCHANGE` namespace. The registration properties including the client side C notification callback are specified as attributes on the subscription handle. On return from `OCISubscriptionRegister`, an end-point registration is successfully created in the database. The application can then associate multiple queries with that registration. This can be done by populating the subscription handle as one of the attributes on the statement handle. Registration of objects occurs during statement execution, that is, as part of the `OCIStmtExecute` call if the statement handle has a subscription handle in the `DBCHANGE` namespace associated with it.

> **See Also:** For OCI examples, refer to *Oracle Call Interface Programmer's Guide*, section "Database Change Notification"

Creating a PL/SQL Stored Procedure as the Change Notification Recipient

You can create a PL/SQL stored procedure that the database server invokes in response to a change to a registered object. The procedure that receives the notification must have the following signature, where *`schema_name`* is the name of the database schema and *`proc_name`* is the name of the stored procedure:

```
PROCEDURE schema_name.proc_name( ntfnds IN SYS.CHNF$_DESC )
```

The `JOBQ` process passes the `CHNF$_DESC` object (notification descriptor), whose attributes describe the details of the change, to the callback procedure. For example, the object contains the transaction ID, the type of change that occurred, the tables that were modified, and so forth. The callback procedure can then send this data to a mid-tier client application for further processing.

Note: The `JOB_QUEUE_PROCESSES` initialization parameter specifies the maximum number of processes that can be created for the execution of jobs. You must set it to a nonzero value to receive PL/SQL notifications because the specified callback procedure is executed inside a job queue process.

See Also:

- "Interpreting a Database Change Notification" on page 13-13 for an explanation of the `SYS.CHNF$_DESC` type
- "Creating a PL/SQL Callback Procedure" on page 13-15 for an example of PL/SQL callback procedure

Registering Queries for Change Notification Through PL/SQL

You must register the database queries for which you want to receive change notifications. The registration occurs in two steps:

1. Create a CHNF$_REG_INFO object that specifies the name of the callback procedure and other metadata concerning the notification.
2. Create or update a query registration by executing a program unit in the DBMS_CHANGE_NOTIFICATION package and then execute the queries that you want to register.

Creating a CHNF$_REG_INFO Object

An object of type CHNF$_REG_INFO specifies the callback procedure that the database should execute when one of your registered objects changes. You can view the type attributes in SQL*Plus by running the following command:

```
DESC SYS.CHNF$_REG_INFO
```

Table 13–1 provides brief descriptions of the attributes of SYS.CHNF$_REG_INFO.

Table 13–1 Attributes of SYS.CHNF$_REG_INFO

Attribute	Description
CALLBACK	Specifies the name of the PL/SQL callback procedure to be executed when a notification is generated. You must specify the name in the form schema_name.procedure_name, for example, hr.dcn_callback.
QOSFLAGS	Specifies one of the following constants in the DBMS_CHANGE_NOTIFICATION package: ▪ QOS_RELIABLE, which specifies that notifications persist in the database and survive instance failure. If an instance fails in a Real Applications Cluster, then surviving instances can deliver any queued notification messages. By default, the database buffers change notification messages in shared memory (that is, the messages are not recorded to persistent storage) for better performance. ▪ QOS_DEREG_NFY, which specifies that the database should unregister the registration on the first notification. ▪ QOS_ROWIDS, which specifies that the notification should include information about the modified ROWIDs. It is possible to specify a combination of the above options using bitwise OR for example, (dbms_change_notification.QOS_RELIABLE + dbms_change_notification.QOS_ROWIDS)
TIMEOUT	Specifies the timeout period for registrations. If set to a nonzero value, it specifies the time in seconds after which the database purges the registration. If 0 or NULL, then the registration persists until the client explicitly unregisters it. **Note:** You can combine the TIMEOUT option with the QOS_DEREG_NFY option in the QOSFLAGS attribute.

Table 13–1 (Cont.) Attributes of SYS.CHNF$_REG_INFO

Attribute	Description
OPERATIONS_FILTER	Filters messages based on types of SQL statement. You can specify the following constants in the DBMS_CHANGE_NOTIFICATION package: ■ ALL_OPERATIONS notifies on all changes ■ INSERTOP notifies on inserts ■ UPDATEOP notifies on updates ■ DELETEOP notifies on deletes You can specify a combination of operations with a bitwise OR. For example, you can perform addition as follows: DBMS_CHANGE_NOTIFICATION.INSERTOP + DBMS_CHANGE_NOTIFICATION.DELETEOP.
TRANSACTION_LAG	Specifies the number of transactions or database changes by which the client can lag behind the database. If 0, then the client receives an invalidation message as soon as it is generated. If 5, then every fifth transaction that changes a registered object results in a notification. Oracle Database tracks intervening changes at an object granularity and bundles the changes along with the notification. Thus, the client does not lose intervening changes. **Note1**: Most applications that need to be notified of changes to an object on transaction commit without further deferral would be expected to chose 0 transaction lag. A non-zero transaction lag is useful only if an application wishes to implement some flow control on notifications. When using nonzero transaction lag, it is recommended that the application workload has the property that notifications are generated at a reasonable periodicity in time. Otherwise, notifications maybe deferred indefinitely till the lag is satisfied. **Note2:** If you specify TRANSACTION_LAG, then the ROWID level granularity is not available in the notification messages even if you specified QOS_ROWIDS during registration.

Suppose that you want to invoke the procedure hr.dcn_callback whenever a registered object changes. In Example 13–1, you create a CHNF$_REG_INFO object that specifies that hr.dcn_callback should receive change notifications. Note that to create the object you must have EXECUTE privileges on the DBMS_CHANGE_NOTIFICATION package.

Example 13–1 Creating a CHNF$_REG_INFO Object

```
DECLARE
  v_cn_addr SYS.CHNF$_REG_INFO;
BEGIN
  -- create the object
  v_cn_addr :=
    SYS.CHNF$_REG_INFO
    (
      'hr.dcn_callback',                    -- name of PL/SQL callback procedure
       DBMS_CHANGE_NOTIFICATION.QOS_ROWIDS, -- include rowids of modified objects
       0,                                   -- registration persists until unregistered
       0,                                   -- notify on all types of DML
       0
-- notify immediately (no transaction lag)
    );
  -- ... register objects ...
END;
/
```

See Also: "Configuring Database Change Notification: Scenario" on page 13-14

Creating a Registration with DBMS_CHANGE_NOTIFICATION

Use the subprograms in the DBMS_CHANGE_NOTIFICATION package to register queries for a specified notification recipient. For complete documentation for this package, refer to *Oracle Database PL/SQL Packages and Types Reference*. You can view the package contents in SQL*Plus by connecting as SYS and running the following command:

```
DESC SYS.DBMS_CHANGE_NOTIFICATION
```

Table 13–2 provides brief descriptions of the DBMS_CHANGE_NOTIFICATION subprograms.

Table 13–2 DBMS_CHANGE_NOTIFICATION Subprograms

Program Unit Signature	Description
NEW_REG_START (reg_info IN SYS.CHNF$_REG_INFO) RETURNS reg_id NUMBER	Marks the beginning of a registration block for inbound object reg_info. The function creates a NEW registration with the properties specified in the reg_info object type. A unique integer identifier called the registration_id is assigned to the registration by the database. The registration_id is returned to the client on return from the function. The application can use the registration_id to keep track of all registrations that were created by it. When a notification is generated for this registration, the registration_id will be part of the notification. After calling this function, you can execute the queries that you want to register and then end the registration boundary by calling REG_END. You cannot begin a new registration if a registration is currently in progress.
REG_END	Marks the end of the registration boundary that you started with NEW_REG_START or ENABLE_REG. The database does not register any newly executed queries after the call to REG_END.
ENABLE_REG (reg_id IN INTEGER)	Adds a database object to an existing registration_id. This interface is similar to NEW_REG_START, except that it accepts an existing registration_id to which to add objects. Subsequent execution of queries causes the objects referred to in the queries to be added to the registration. Invoke REG_END to terminate the registration.
DEREGISTER (reg_id IN INTEGER)	Disables the registration specified by its registration ID.

For an example of an object registration, suppose that the client requires notification whenever a row changes in the hr.employees table. Example 13–2 shows an anonymous PL/SQL block that registers this table with the hr.dcn_callback procedure. Note that you must have been granted the CHANGE NOTIFICATION privilege to execute this block.

Example 13–2 Registering the Employees Table for Change Notifications

```
DECLARE
  v_cn_recip       SYS.CHNF$_REG_INFO;
  v_regid          NUMBER;
  v_employee_id    hr.employees.manager_id%TYPE;
BEGIN
```

```
  v_cn_recip := SYS.CHNF$_REG_INFO('hr.dcn_callback',
                DBMS_CHANGE_NOTIFICATION.QOS_ROWIDS, 0, 0, 0);
  -- begin the registration boundary
  v_regid := DBMS_CHANGE_NOTIFICATION.NEW_REG_START(v_cn_recip);
    SELECT employee_id
      INTO   v_employee_id
    FROM   hr.employees       -- register the employees object
    WHERE  ROWNUM < 2;        -- write the query so that it returns a single row
  -- end the registration boundary
  DBMS_CHANGE_NOTIFICATION.REG_END;
  DBMS_OUTPUT.PUT_LINE('the registration id for this query is '||v_regid);
END;
/
```

In Example 13–2, the program registers the object itself, that is, the `hr.employees` table. The `WHERE` clause restricts the query to the first employee in the result set to avoid generating an error because the fetch returns multiple rows. The `DBMS_CHANGE_NOTIFICATION` package registers the object itself, which means that any change to the table—regardless of whether the change is to the row returned by the registered query—generates a notification.

> **See Also:** "Configuring Database Change Notification: Scenario" on page 13-14

Adding Objects to an Existing Registration

Suppose that later you decide to add a query against the `hr.departments` table to the registration ID for the `hr.employees` query. After you retrieve the registration ID either from the saved SQL*Plus output or a query of `USER_CHANGE_NOTIFICATION_REGS`, you can add this object with the code in Example 13–3 by substituting the numeric ID for *`reg_id`*.

Example 13–3 Adding an Object to an Existing Registration

```
DECLARE
  v_department_id     hr.departments.department_id%TYPE;
BEGIN
  -- begin registration boundary
  DBMS_CHANGE_NOTIFICATION.ENABLE_REG(reg_id);
    SELECT department_id
      INTO   v_department_id
    FROM   hr.departments
    WHERE  ROWNUM < 2; -- register this query
  -- end registration boundary
  DBMS_CHANGE_NOTIFICATION.REG_END;
END;
/
```

Querying Change Notification Registrations

You can query the following data dictionary views to obtain information about registered clients of the Database Change Notification feature:

- `DBA_CHANGE_NOTIFICATION_REGS`
- `USER_CHANGE_NOTIFICATION_REGS`

For example, you can obtain the registration ID for a client and the list of objects for which it receives notifications. To view registration-ids and table names for `HR`, you can do the following from SQL*Plus:

```
connect hr/hr;
SELECT regid, table_name FROM USER_CHANGE_NOTIFICATION_REGS;
```

> **See Also:** *Oracle Database Reference* for descriptions of `DBA_CHANGE_NOTIFICATION_REGS` and `USER_CHANGE_NOTIFICATION_REGS`

Interpreting a Database Change Notification

When a transaction commits, Oracle Database determines whether registered objects were modified in the transaction. If the database finds interested clients, it executes the callback procedure specified in the registration.

Interpreting a CHNF$_DESC Object

The details of a database change are exposed through descriptors that the database pass as arguments to a C callback or PL/SQL procedure. Specifically, Oracle Database passes an object of type `CHNF$_DESC`, which is the top-level change notification descriptor. You can view the type attributes in SQL*Plus by connecting as `SYS` and running the following command:

```
DESC SYS.CHNF$_DESC
```

Table 13–3 provides brief descriptions of the attributes of `CHNF$_DESC`.

Table 13–3 Attributes of SYS.CHNF$_DESC

Attribute	Specifies . . .
`REGISTRATION_ID`	The registration ID that was returned during registration.
`TRANSACTION_ID`	The ID for the transaction that made the change.
`DBNAME`	The name of the database in which the changed objects reside.
`EVENT_TYPE`	The database event that triggers a notification. For example, the attribute can contain the following constants, which correspond to different database events: ■ `EVENT_NONE` ■ `EVENT_STARTUP` (Instance startup) ■ `EVENT_SHUTDOWN` (Instance shutdown - last instance shutdown in the case of RAC) ■ `EVENT_SHUTDOWN_ANY` (Any instance shutdown in the case of RAC) ■ `EVENT_DEREG` (Registration has been removed) ■ `EVENT_OBJCHANGE` (Change to a registered table)
`NUMTABLES`	The number of tables that were modified.
`TABLE_DESC_ARRAY`	A `varray` of table change descriptors of type `CHNF$_TDESC`, which is described in Table 13–4. Each table descriptor corresponds to a table that was modified.

Interpreting a CHNF$_TDESC Object

The `CHNF$_DESC` type contains an attribute called `TABLE_DESC_ARRAY`, which holds an array of table descriptors of type `CHNF$_TDESC`. You can view the type attributes in SQL*Plus by connecting as `SYS` and running the following command:

```
DESC CHNF$_TDESC
```

Table 13–4 provides brief descriptions of the attributes of CHNF$_TDESC.

Table 13–4 Attributes of SYS.CHNF$_TDESC

Attribute	Specifies . . .
OPFLAGS	The type of operation performed on the modified table. For example, the attribute can contain the following constants, which correspond to different database operations: ■ ALL_ROWS signifies that either the entire table is modified, as in a DELETE *, or row-level granularity of information is not requested or not available in the notification, and the recipient must assume that the entire table has changed ■ UPDATEOP signifies an update ■ DELETEOP signifies a deletion ■ ALTEROP signifies an ALTER TABLE ■ DROPOP signifies a DROP TABLE ■ UNKNOWNOP signifies an unknown operation
TABLE_NAME	The name of the modified table.
NUMROWS	The number of modified rows.
ROW_DESC_ARRAY	A varray of row descriptors of type CHNF$_RDESC, which is described in Table 13–5. If ALL_ROWS was set in the opflags, then the desc_array member is NULL.

Interpreting a CHNF$_RDESC Object

If the ROWID option was chosen during registration, the CHNF$_TDESC type in turn holds an array of type CHNF$_RDESC, which contains the ROWIDs for the changed rows. Note: if ALL_ROWS was set in the opflags field of the CHNF$_TDESC object, then ROWID information is not available.

Table 13–5 provides brief descriptions of the attributes of CHNF$_RDESC.

Table 13–5 Attributes of SYS.CHNF$_RDESC

Attribute	Specifies . . .
OPFLAGS	The type of operation performed on the modified table. See the description of OPFLAGS in Table 13–4.
ROW_ID	The ROWID of the changed row.

Configuring Database Change Notification: Scenario

In this scenario, you are a developer who manages a Web application that provides employee data: name, location, phone number, and so forth. The application, which runs on Oracle Application Server, is heavily used and processes frequent queries of the hr.employees and hr.departments tables in the back-end database. Because these tables change relatively infrequently, the application can improve performance by caching table rows. Caching avoids a round trip to the back-end database as well as server-side execution latency.

You can use the DBMS_CHANGE_NOTIFICATION package to register a query based on hr.employees and hr.departments tables. To configure database change notification, you follow these steps:

1. Implement a mid-tier HTTP listener that listens for notifications and updates the mid-tier cache in response to a notification of a change to the `hr.employees` and `hr.departments` tables
2. Create a server-side PL/SQL stored procedure to process the change notifications, as described in "Creating a PL/SQL Callback Procedure" on page 13-15
3. Register the `hr.employees` and `hr.departments` tables, as described in "Registering the Query" on page 13-16

After you complete these steps, the server-side PL/SQL procedure defined in step 2 executes in response to changes to `hr.employees` or `hr.departments`. The callback procedure notifies the Web application of the tables changed. In response to the notification, the application refreshes the cache by querying the back-end database.

Creating a PL/SQL Callback Procedure

In this step, you write a server-side stored procedure to process change notifications. You first connect to the database as a user with `DBA` privileges and grant `EXECUTE` privileges to `hr`:

```
GRANT EXECUTE ON DBMS_CHANGE_NOTIFICATION TO HR;
GRANT CHANGE NOTIFICATION TO HR;
```

Enable the job_queue_processes parameter to receive notifications:

```
ALTER SYSTEM SET "JOB_QUEUE_PROCESSES"=4;
```

You may want to create database tables to hold the record of notification events received:

```
connect hr/hr;
Rem Create a table to record notification events
CREATE table nfevents(regid number, event_type number);
Rem Create a table to record changes to registered tables
create table nftablechanges(
       regid number,
       table_name varchar2(100),
       table_operation number);
Rem Create a table to record rowids of changed rows.
create table nfrowchanges(
       regid number,
       table_name varchar2(100),
       row_id varchar2(2000));
```

You then create the procedure `hr.chnf_callback`, as shown in Example 13–4.

Example 13–4 Server-Side PL/SQL Callback Procedure

```
CREATE OR REPLACE PROCEDURE chnf_callback(ntfnds IN SYS.CHNF$_DESC) IS
regid NUMBER;
tbname VARCHAR2(60);
event_type NUMBER;
numtables NUMBER;
operation_type NUMBER;
numrows NUMBER;
row_id VARCHAR2(2000);

BEGIN
  regid := ntfnds.registration_id;
```

```
  numtables := ntfnds.numtables;
  event_type := ntfnds.event_type;
  insert into nfevents values(regid, event_type);

  IF (event_type = DBMS_CHANGE_NOTIFICATION.EVENT_OBJCHANGE) THEN
    FOR i IN 1..numtables LOOP
      tbname := ntfnds.table_desc_array(i).table_name;
      operation_type := ntfnds.table_desc_array(I). Opflags;
      insert into nftablechanges values(regid, tbname, operation_type);
      /* Send the table name and operation_type to  client side listener
         using UTL_HTTP */
      /* If interested in the rowids, obtain them as follows */
      IF (bitand(operation_type, dbms_change_notification.ALL_ROWS) = 0)
      THEN
        numrows := ntfnds.table_desc_array(i).numrows;
      else
        numrows :=0;   /* ROWID INFO NOT AVAILABLE */
      END IF;

      /* The body of the loop is not executed when numrows is ZERO */
      FOR j IN 1..numrows LOOP
          Row_id := ntfnds.table_desc_array(i).row_desc_array(j).row_id;
          insert into nfrowchanges values(regid, tbname, Row_id);
          /* optionally Send out row_ids to client side listener using
             UTL_HTTP */
      END LOOP;

    END LOOP;
  END IF;
  commit;
END;
/
```

Registering the Query

After you have created the callback procedure, you register the query based on the tables for which you want to receive notifications. In Example 13–5, you pass in `hr.chnf_callback` as the name of the server-side PL/SQL procedure to be executed when the database generates a notification. Note that you must have the `CHANGE NOTIFICATION` privilege to create the procedure.

Example 13–5 Table Registration

```
CREATE OR REPLACE PROCEDURE hr.table_reg
IS
  v_regds          SYS.CHNF$_REG_INFO;
  v_regid          NUMBER;
  v_employee_id    NUMBER;
  v_department_id  NUMBER;
BEGIN
  v_regds := SYS.CHNF$_REG_INFO ('hr.chnf_callback',
                              DBMS_CHANGE_NOTIFICATION.QOS_ROWIDS,
                              0,
                              0,
                              0);
  v_regid :=  DBMS_CHANGE_NOTIFICATION.NEW_REG_START(v_regds);
    SELECT employee_id
      INTO   v_employee_id
    FROM   hr.employees     -- register employees object
    WHERE ROWNUM < 2;       -- return a single row to avoid multiple fetch error
```

```
    SELECT department_id
      INTO   v_department_id
    FROM   hr.departments   -- register departments object
    WHERE  ROWNUM < 2;      -- return a single row to avoid multiple fetch error
  DBMS_CHANGE_NOTIFICATION.REG_END;
END;
/

EXEC hr.table_reg
```

You can view the newly created registration by issuing the following query:

```
SQL> select regid, table_name from user_change_notification_regs;
     REGID TABLE_NAME
---------- ------------------------------------------------------------
        16 HR.EMPLOYEES
        16 HR.DEPARTMENTS
```

Once the registration is created as shown above, the server side PL/SQL procedure `chnf_callback`, as described above, is executed in response to any committed changes to the `HR.EMPLOYEES` or `HR.DEPARTMENTS` tables. As an example, let us assume that the following update is performed on the employees table:

```
UPDATE employees SET salary=salary*1.05 WHERE employee_id=203;
COMMIT;
```

Once the notification is processed, you will find rows which might look like the following in the `nfevents`, `nftablechanges`, and `nfrowchanges` tables:

```
SQL> select * from nfevents;
     REGID EVENT_TYPE
     ---------- ----------
     20045          6

SQL> select * from nftablechanges;
     REGID      TABLE_NAME         TABLE_OPERATION
     ----------------------------------------
     20045   HR.EMPLOYEES            4

SQL> select * from nfrowchanges;
     REGID  TABLE_NAME   ROW_ID
     ------------------------------------------
     20045 HR.EMPLOYEES   AAAKB/AABAAAJ8zAAF
```

Best Practices

For best performance of change notification, the following guidelines are presented.

Registered objects are few and mostly read-only and that modifications to those objects are the exception rather than the rule. If the object is extremely volatile, then it will cause a large number of invalidation notifications to be sent, and potentially a lot of storage in the invalidation queue on the server. If there are frequent and a large number of notifications, it can slow down OLTP throughput due to the overhead of generating the notifications.

It is also a good idea to keep the number of duplicate registrations on any given object low (ideally one) in order to avoid the same notification message being replicated to multiple recipients.

Troubleshooting

If you have created a registration and seem to not receive notifications or you are unable to create a registration, the following is a list of things to check for.

1. Is the `job_queue_processes` parameter set to a nonzero value? This parameter needs to be configured to a nonzero value in order to receive PL/SQL notifications via the handler.
2. Are the registrations being created as a NON-SYS user?
3. If you are attempting DML changes on the registered object, are you committing the transaction? Note that the notifications are transactional and will be generated when the transaction commits.
4. To check that the registrations on the objects have been successfully created in the database, you can query from the `USER_CHANGE_NOTIFICATION_REGS` or `DBA_CHANGE_NOTIFICATION_REGS` views. For example, to view all registrations and the registered objects for the current user, you can issue the following select:

   ```
   SELECT regid, table_name FROM user_change_notification_regs;
   ```

5. It maybe possible that there are run-time errors during the execution of the PL/SQL callback due to implementation errors in the callback. If so, they would be logged to the trace file of the `JOBQ` process that attempts to execute the procedure. The trace file would be usually named `<ORACLE_SID>_j*_<PID>.trc`. For example, if the ORACLE_SID is 'dbs1' and the process id of the `JOBQ` process is 12483, the trace file might be named 'dbs1_j000_12483.trc'.

   If there are run-time errors, then it will be reported to the `JOBQ` trace file. For example, let's say a registration is created with 'chnf_callback' as the notification handler and registration id 100. Let's say the 'chnf_callback' stored procedure was not DEFINED in the database. Then the `JOBQ` trace file might contain a message of the form:

   ```
   *********************************************************************
      Runtime error during execution of PL/SQL cbk chnf_callback for reg CHNF100.
      Error in PLSQL notification of msgid:
      Queue :
      Consumer Name :
      PLSQL function :chnf_callback
      Exception Occured, Error msg:
      ORA-00604: error occurred at recursive SQL level 2
      ORA-06550: line 1, column 7:
      PLS-00201: identifier 'CHNF_CALLBACK' must be declared
      ORA-06550: line 1, column 7:
      PL/SQL: Statement ignored
      *********************************************************************
   ```

6. If you are running into errors during the execution of the callback, consider creating a very simple version of the callback as shown below to verify that you are actually receiving notifications. The callback can be gradually evolved to add more application logic. For example, if the user is `HR` then you might consider creating a very simple version of the notification handler as follows:

   ```
   Rem create a table in the HR schema to hold a count of number of notifications
   received.
   Create table nfcount(cnt number);
   Insert into nfcount values(0);
   Commit;
   ```

```
CREATE OR REPLACE PROCEDURE chnf_callback (ntfnds IN SYS.CHNF$_DESC)
IS
BEGIN
  update nfcount set cnt = cnt+1;
  commit;
END;
/
```

The simple procedure created increments the count column of a table and commits. To verify that notifications are being published, you can query from the table `nfcount` to see if the `cnt` column is indeed going up when a change is made to a registered object and the transaction committed.

7. There maybe a time lag between the commit of a transaction and the notification received by the end user.

Part III

Advanced Topics for Application Developers

This part deals with application development scenarios that are either used by only a small minority of developers or of general interest but involve sophisticated technologies.

This part contains:

14

Calling External Procedures

In situations where a particular language does not provide the features you need, or when you want to reuse existing code written in another language, you can use code written in some other language by calling external procedures.

This chapter discusses the following topics:

Overview of Multi-Language Programs

Oracle Database lets you work in different languages:

- *PL/SQL*, as described in the *Oracle Database PL/SQL User's Guide and Reference*
- *C*, by means of the Oracle Call Interface (OCI), as described in the *Oracle Call Interface Programmer's Guide*
- *C* or *C++*, by means of the Pro*C/C++ precompiler, as described in the *Pro*C/C++ Programmer's Guide*
- *COBOL*, by means of the Pro*COBOL precompiler, as described in the *Pro*COBOL Programmer's Guide*
- *Visual Basic*, by means of Oracle Objects for OLE (OO4O), as described in *Oracle Objects for OLE Developer's Guide*.

- *Java*, by means of the JDBC Application Programmers Interface (API). Refer to *Oracle Database Java Developer's Guide*.

How should you choose between these different implementation possibilities? Each of these languages offers different advantages: ease of use, the availability of programmers with specific expertise, the need for portability, and the existence of legacy code are powerful determinants.

The choice may narrow depending on how your application needs to work with Oracle Database:

- PL/SQL is a powerful development tool, specialized for SQL transaction processing.
- Some computation-intensive tasks are executed most efficiently in a lower level language, such as C.
- The need for portability, together with the need for security, may influence you to select Java.

Most significantly, from the point of view of performance, you should note that only PL/SQL and Java methods run within the address space of the server. C/C++ methods are dispatched as external procedures, and run on the server machine but outside the address space of the database server. Pro*COBOL and Pro*C/C++ are precompilers, and Visual Basic accesses Oracle Database through the OCI, which is implemented in C.

Taking all these factors into account suggests that there may be a number of situations in which you may need to implement your application in more than one language. For instance, the introduction of Java running within the address space of the server suggest that you may want to import existing Java applications into the database, and then leverage this technology by calling Java functions from PL/SQL and SQL.

PL/SQL *external procedures* allow you to write C function calls as PL/SQL bodies. These C functions are callable directly from PL/SQL, and from SQL through PL/SQL procedure calls. The database provides a special-purpose interface, the call specification, that lets you call external procedures from other languages. While this service is designed for intercommunication between SQL, PL/SQL, C, and Java, it is accessible from any base language that can call these languages. For example, your procedure can be written in a language other than Java or C and still be usable by SQL or PL/SQL, as long as your procedure is callable by C. Therefore, if you have a candidate C++ procedure, you would use a C++ `extern "C"` statement in that procedure to make it callable by C.

This means that the strengths and capabilities of different languages are available to you, regardless of your programmatic environment. You are not restricted to one language with its inherent limitations. External procedures promote reusability and modularity because you can deploy specific languages for specific purposes.

What Is an External Procedure?

An **external procedure**, also sometimes referred to as an **external routine**, is a procedure stored in a dynamic link library (DLL), or libunit in the case of a Java class method. You register the procedure with the base language, and then call it to perform special-purpose processing.

For instance, when you work in PL/SQL, the language loads the library dynamically at runtime, and then calls the procedure as if it were a PL/SQL subprogram. These procedures participate fully in the current transaction and can call back to the database to perform SQL operations.

The procedures are loaded only when necessary, so memory is conserved. Because the decoupling of the call specification from its implementation body means that the procedures can be enhanced without affecting the calling programs.

External procedures let you:

- Isolate execution of client applications and processes from the database instance to ensure that any problems on the client side do not adversely impact the database.
- Move computation-bound programs from client to server where they execute faster (because they avoid the round-trips of network communication)
- Interface the database server with external systems and data sources
- Extend the functionality of the database server itself

Overview of The Call Specification for External Procedures

You publish external procedures through **call specifications**, which provide a superset of the `AS EXTERNAL` function through the `AS LANGUAGE` clause. `AS LANGUAGE` call specifications allow the publishing of external C procedures, but also Java class methods.

> **Note:** To support legacy applications, call specifications also allow you to publish with the `AS EXTERNAL` clause. For new application development, however, using the `AS LANGUAGE` clause is recommended.

In general, call specifications enable:

- Dispatching the appropriate C or Java target procedure
- Datatype conversions
- Parameter mode mappings
- Automatic memory allocation and cleanup
- Purity constraints to be specified, where necessary, for packaged functions called from SQL.
- Calling Java methods or C procedures from database triggers
- Location flexibility: you can put `AS LANGUAGE` call specifications in package or type specifications, or package (or type) bodies to optimize performance and hide implementation details

To use an already-existing program as an external procedure, load, publish, and then call it.

Loading External Procedures

To make your external C procedures or Java methods available to PL/SQL, you must first load them. The manner of doing this depends upon whether the procedure is written in C or Java.

Loading Java Class Methods

One way to load Java programs is to use the `CREATE JAVA` statement, which you can execute interactively from SQL*Plus. When implicitly invoked by the `CREATE JAVA`

statement, the Java Virtual Machine (JVM)] library manager loads Java binaries (.class files) and resources from local BFILEs or LOB columns into RDBMS libunits.

Suppose a compiled Java class is stored in the following operating system file:

```
/home/java/bin/Agent.class
```

Creating a class libunit in schema scott from file Agent.class requires two steps: First, create a directory object on the server's file system. The name of the directory object is an alias for the directory path leading to Agent.class.

To create the directory object, you must grant user scott the CREATE ANY DIRECTORY privilege, then execute the CREATE DIRECTORY statement, as follows:

```
CONNECT System/Manager
GRANT CREATE ANY DIRECTORY TO Scott IDENTIFIED BY Tiger;
CONNECT Scott/Tiger
CREATE DIRECTORY Bfile_dir AS '/home/java/bin';
```

You are ready to create the class libunit, as follows:

```
CREATE JAVA CLASS USING BFILE (Bfile_dir, 'Agent.class');
```

The name of the libunit is derived from the name of the class.

Alternatively, you can use the command-line utility LoadJava. This uploads Java binaries and resources into a system-generated database table, then uses the CREATE JAVA statement to load the Java files into RDBMS libunits. You can upload Java files from file systems, Java IDEs, intranets, or the Internet.

Loading External C Procedures

In order to set up your database configuration to use external procedures that are written in C, or can be called from C applications, you and your database administrator must take the following steps:

Note:

- This feature is available only on platforms that support dynamically linked libraries (DLLs) or dynamically loadable shared libraries such as Solaris `.so` libraries.
- The external procedure agent can call procedures in any library that complies with the calling standard used. The supported calling standard is C. Refer to "CALLING STANDARD" on page 14-10 for more information on the calling standard sub clause used with external procedures in PL/SQL.
- Define the C procedures using either the 1) K & R-style prototypes or 2) the ISO/ANSI prototypes without numeric datatypes that are less than full width (such as `float`, `short`, `char`). Other datatypes work in ISO/ANSI prototypes if they do not change size under "default argument promotions."

```
/* Supported K & R */
void C_findRoot(x)
 float x;
...

/* Supported ISO/ANSI */
void C_findRoot(double x)
...

/* Not supported ISO/ANSI */
void C_findRoot(float x)
...
```

Step 1 Set Up the Environment

Your database administrator must perform the following tasks to configure your database to use external procedures that are written in C, or can be called from C applications:

- Set configuration parameters for the agent, named `extproc` by default, in the configuration files `tnsnames.ora` and `listener.ora`. This establishes the connection for the external procedure agent when the database is started.
- Start a listener process exclusively for external procedures.

  The Listener sets a few required environment variables (such as `ORACLE_HOME`, `ORACLE_SID`, and `LD_LIBRARY_PATH`) for the external procedure agent. It can also define specific environment variables in the `ENVS` section of its `listener.ora` entry, and these variables are passed to the agent process. Otherwise, it provides the agent with a "clean" environment. The environment variables set for the agent are independent of those set for the client and server. Therefore, external procedures, which run in the agent process, cannot read environment variables set for the client or server processes.

Note: It is possible for you to set and read environment variables themselves by using the standard C procedures `setenv()` and `getenv()`, respectively. Environment variables, set this way, are specific to the agent process, which means that they can be read by all functions executed in that process, but not by any other process running on the same host.

- Determine whether the agent for your external procedure will run in *dedicated mode* (the default mode) or *multithreaded mode*. In dedicated mode, one "dedicated" agent is launched for each user. In multithreaded mode, a single *multithreaded agent* is launched. The multithreaded agent handles calls using different threads for different users. In a configuration where many users will call the external procedures, using a multithreaded agent is recommended to conserve system resources.

  If the agent will run in dedicated mode, additional configuration of the agent process is not necessary.

  If the agent will run in multithreaded mode, your database administrator must configure the database system to start the agent in multithreaded mode (as a multithreaded agent). This is done using the agent control utility `agtctl`. For example, start the agent using the agent control utility startup command:

  ```
  agtctl startup extproc agent_sid
  ```

  where *`agent_sid`* is the system identifier which this agent will service. An entry for this system identifier is typically added as an entry in the file `tnsnames.ora`. Details on the agent control utility are in the *Oracle Database Heterogeneous Connectivity Administrator's Guide*.

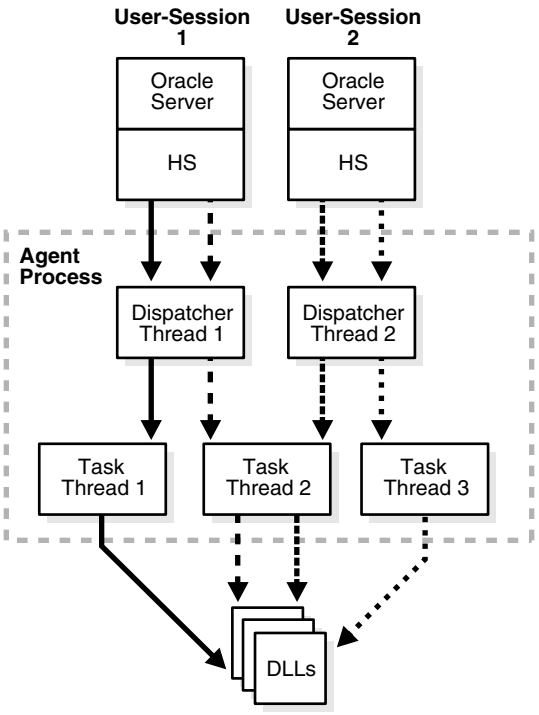
  Note:

  - If you use a multithreaded agent, the library you call must be thread safe—to avoid errors such as a corrupt call stack.
  - The database server, the agent process, and the listener process that spawns the agent process must all reside on the same host.
  - By default, the agent process runs on the same database instance as your main application. In situations where reliability is critical, you might want to run the agent process for the external procedure on a separate database instance (still on the same host), so that any problems in the agent do not affect the primary database server. To do so, specify the separate database instance using a database link.

Figure 14–1 illustrates the architecture of the multithreaded external procedure agent. User sessions 1 and 2 issue requests for callouts to functions in some DLLs. These requests get serviced through heterogeneous services to the multithreaded `extproc` agent. These requests get handled by the agent's dispatcher threads, which then pass them on to the task threads. The task thread that is actually handling a request is responsible for loading the respective DLL and calling the function therein.

- All requests from a user session get handled by the same dispatcher thread. For example, dispatcher 1 handles communication with user session 1, and dispatcher 2 handles communication with user session 2. This is the case for the lifetime of the session.
- The individual requests can, however, be serviced by different task threads. For example, task thread 1 could handle the request from user session 1 at one time, and handle the request from user session 2 at another time.

Figure 14–1 Multithreaded External Procedure Agent Architecture



See Also:

- *Oracle Database Heterogeneous Connectivity Administrator's Guide* for details on configuring the agent process for the external procedure to use multithreaded mode, architecture, and for additional details on multithreaded agents
- *Oracle Database Administrator's Guide*. for details on managing processes for external procedures

Step 2 Identify the DLL

In this context, a DLL is any dynamically loadable operating-system file that stores external procedures.

For security reasons, your DBA controls access to the DLL. Using the CREATE LIBRARY statement, the DBA creates a schema object called an alias library, which represents the DLL. Then, if you are an authorized user, the DBA grants you `EXECUTE` privileges on the **alias** library. Alternatively, the DBA may grant you `CREATE ANY LIBRARY` privileges, in which case you can create your own alias libraries using the following syntax:

```
CREATE LIBRARY [schema_name.]library_name
  {IS | AS} 'file_path'
  [AGENT 'agent_link'];
```

It is recommended that you specify the full path to the DLL, rather than just the DLL name. In the following example, you create alias library `c_utils`, which represents DLL `utils.so`:

```
CREATE LIBRARY C_utils AS '/DLLs/utils.so';
```

To allow flexibility in specifying the DLLs, you can specify the root part of the path as an environment variable using the notation `${VAR_NAME}`, and set up that variable in the `ENVS` section of the `listener.ora` entry.

In the following example, the agent specified by the name `agent_link` is used to run any external procedure in the library `C_Utils`. The environment variable `EP_LIB_HOME` is expanded by the agent to the appropriate path for that instance, such as `/usr/bin/dll`. Variable `EP_LIB_HOME` must be set in the file `listener.ora`, for the agent to be able to access it.

```
create or replace database link agent_link using 'agent_tns_alias';
create or replace library C_utils is
  '${EP_LIB_HOME}/utils.so' agent 'agent_link';
```

For security reasons, `EXTPROC`, by default, will only load DLLs that are in directory `$ORACLE_HOME/bin` or `$ORACLE_HOME/lib`. Also, only local sessions—that is, Oracle Database client processes that are running on the same machine—are allowed to connect to `EXTPROC`.

To load DLLs from other directories, the environment variable `EXTPROC_DLLS` should be set. The value for this environment variable is a colon- separated (`:`) list of DLL names qualified with the complete path. For example:

```
EXTPROC_DLLS=/private1/home/scott/dll/myDll.so:/private1/home/scott/dll/newDll.so
```

The preferred method to set this environment variable is through the `ENVS` parameter in the file `listener.ora`. Refer to the Oracle Net manual for more information on the `EXTPROC` feature.

Note the following:

- On a Windows system, you would specify the path using a drive letter and backslash characters (`\`) in the path.
- This technique is not applicable for VMS systems, where the `ENVS` section of listener.ora is not supported.

Step 3 Publish the External Procedure

You find or write a new external C procedure, then add it to the DLL. When the procedure is in the DLL, you publish it using the call specification mechanism described in the following section.

Publishing External Procedures

Oracle Database can only use external procedures that are published through a call specification, which maps names, parameter types, and return types for your Java class method or C external procedure to their SQL counterparts. It is written like any other PL/SQL stored subprogram except that, in its body, instead of declarations and a `BEGIN ... END` block, you code the `AS LANGUAGE` clause.

The `AS LANGUAGE` clause specifies:

- Which language the procedure is written in.
- For a Java method:
  - The signature of the Java method.
- For a C procedure:
  - The alias library corresponding to the DLL for a C procedure.

- The name of the C procedure in a DLL.
- Various options for specifying how parameters are passed.
- Which parameter (if any) holds the name of the external procedure agent, for running the procedure on a different machine.

You begin the declaration using the normal `CREATE OR REPLACE` syntax for a procedure, function, package specification, package body, type specification, or type body.

The call specification follows the name and parameter declarations. Its syntax is:

```
{IS | AS} LANGUAGE {C | JAVA}
```

> **Note:** Oracle Database uses a PL/SQL variant of the ANSI SQL92 External Procedure, but replaces the ANSI keyword `AS EXTERNAL` with this call specification syntax. This new syntax, first introduced for Java class methods, has been extended to C procedures.

This is then followed by either:

```
NAME  java_string_literal_name
```

Where *java_string_literal_name* is the signature of your Java method, or by:

```
LIBRARY library_name
[NAME c_string_literal_name]
[WITH CONTEXT]
[PARAMETERS (external_parameter[, external_parameter]...)];
```

Where `library_name` is the name of your alias library, `c_string_literal_name` is the name of your external C procedure, and `external_parameter` stands for:

```
{  CONTEXT
 | SELF [{TDO | property}]
 | {parameter_name | RETURN} [property] [BY REFERENCE] [external_datatype]}
```

`property` stands for:

```
{INDICATOR [{STRUCT | TDO}] | LENGTH | DURATION | MAXLEN | CHARSETID |
CHARSETFORM}
```

> **Note:** Unlike Java, C does not understand SQL types; therefore, the syntax is more intricate

The AS LANGUAGE Clause for Java Class Methods

The `AS LANGUAGE` clause is the interface between PL/SQL and a Java class method.

The AS LANGUAGE Clause for External C Procedures

The following subclauses tell PL/SQL where to locate the external C procedure, how to call it, and what to pass to it. Only the `LIBRARY` subclause is required.

LIBRARY

Specifies a local alias library. (You cannot use a database link to specify a remote library.) The library name is a PL/SQL identifier. Therefore, if you enclose the name in

double quotes, then it becomes case sensitive. (By default, the name is stored in upper case.) You must have EXECUTE privileges on the alias library.

NAME

Specifies the external C procedure to be called. If you enclose the procedure name in double quotes, then it becomes case sensitive. (By default, the name is stored in upper case.) If you omit this subclause, then the procedure name defaults to the upper-case name of the PL/SQL subprogram.

Note: The terms LANGUAGE and CALLING STANDARD apply only to the superseded AS EXTERNAL clause.

LANGUAGE

Specifies the third-generation language in which the external procedure was written. If you omit this subclause, then the language name defaults to C.

CALLING STANDARD

Specifies the calling standard under which the external procedure was compiled. The supported calling standard is C. If you omit this subclause, then the calling standard defaults to C.

WITH CONTEXT

Specifies that a context pointer will be passed to the external procedure. The context data structure is opaque to the external procedure but is available to service procedures called by the external procedure.

PARAMETERS

Specifies the positions and datatypes of parameters passed to the external procedure. It can also specify parameter properties, such as current length and maximum length, and the preferred parameter passing method (by value or by reference).

AGENT IN

Specifies which parameter holds the name of the agent process that should run this procedure. This is intended for situations where external procedure agents are run using multiple agent processes, to ensure robustness if the agent process of one external procedure fails. You can pass the name of the agent process (corresponding to the name of a database link), and if `tnsnames.ora` and `listener.ora` are set up properly across both instances, the external procedure is invoked on the other instance. Both instances must be on the same host.

This is similar to the AGENT clause of the CREATE LIBRARY statement; specifying the value at runtime through AGENT IN allows greater flexibility.

When the agent name is specified this way, it overrides any agent name declared in the alias library. If no agent name is specified, the default is the `extproc` agent on the same instance as the calling program.

Publishing Java Class Methods

Java classes and their methods are stored in RDBMS libunits in which you can load Java sources, binaries and resources using the LOADJAVA utility or the CREATEJAVA SQL statements. Libunits can be considered analogous to DLLs written, for example,

in C—although they map one-to-one with Java classes, whereas DLLs can contain more than one procedure.

The NAME-clause string uniquely identifies the Java method. The PL/SQL function or procedure and Java must correspond with regard to parameters. If the Java method takes no parameters, then you must code an empty parameter list for it.

When you load Java classes into the RDBMS, they are not published to SQL automatically. This is because the methods of many Java classes are called only from other Java classes, or take parameters for which there is no appropriate SQL type.

Suppose you want to publish the following Java method named J_calcFactorial, which returns the factorial of its argument:

```
package myRoutines.math;
public class Factorial {
   public static int J_calcFactorial (int n) {
      if (n == 1) return 1;
      else return n * J_calcFactorial(n - 1);
   }
}
```

The following call specification publishes Java method J_calcFactorial as PL/SQL stored function plsToJavaFac_func, using SQL*Plus:

```
CREATE OR REPLACE FUNCTION Plstojavafac_func (N NUMBER) RETURN NUMBER AS
   LANGUAGE JAVA
   NAME 'myRoutines.math.Factorial.J_calcFactorial(int) return int';
```

Publishing External C Procedures

In the following example, you write a PL/SQL standalone function named plsCallsCdivisor_func that publishes C function Cdivisor_func as an external function:

```
CREATE OR REPLACE FUNCTION Plscallscdivisor_func (
/* Find greatest common divisor of x and y: */
   x     BINARY_INTEGER,
   y     BINARY_INTEGER)
RETURN BINARY_INTEGER
AS LANGUAGE C
   LIBRARY C_utils
   NAME "Cdivisor_func"; /* Quotation marks preserve case. */
```

Locations of Call Specifications

For both Java class methods and external C procedures, call specifications can be specified in any of the following locations:

- Standalone PL/SQL Procedures and Functions
- PL/SQL Package Specifications
- PL/SQL Package Bodies
- Object Type Specifications
- Object Type Bodies

> **Note:** Under Oracle Database version 8.0, AS EXTERNAL call specifications could not be placed in package or type bodies.

We have already shown an example of call specification located in a standalone PL/SQL function. Here are some examples showing some of the other locations.

> **Note:** In the following examples, the AUTHID and SQL_NAME_RESOLVE clauses may or may not be required to fully stipulate a call specification.
>
> See the *Oracle Database PL/SQL User's Guide and Reference* and the *Oracle Database SQL Reference* for more information.

Example: Locating a Call Specification in a PL/SQL Package

```
CREATE OR REPLACE PACKAGE Demo_pack
AUTHID DEFINER
AS
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
END;
```

Example: Locating a Call Specification in a PL/SQL Package Body

```
CREATE OR REPLACE PACKAGE Demo_pack
   AUTHID CURRENT_USER
AS
   PROCEDURE plsToC_demoExternal_proc(x BINARY_INTEGER, y VARCHAR2, z DATE);
END;

CREATE OR REPLACE PACKAGE BODY Demo_pack
   SQL_NAME_RESOLVE CURRENT_USER
AS
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE JAVA
      NAME 'pkg1.class4.methodProc1(int,java.lang.String,java.sql.Date)';
END;
```

Example: Locating a Call Specification in an Object Type Specification

> **Note:** You may need to set up the following data structures for certain examples to work:
>
> ```
> CONN SYS/CHANGE_ON_INSTALL AS SYSDBA;
> GRANT CREATE ANY LIBRARY TO scott;
> CONNECT scott/tiger
> CREATE OR REPLACE LIBRARY SOMELIB AS '/tmp/lib.so';
> ```

```
CREATE OR REPLACE TYPE Demo_typ
AUTHID DEFINER
AS OBJECT
   (Attribute1   VARCHAR2(2000), SomeLib varchar2(20),
   MEMBER PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
```

```
    --  PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE)
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE, SELF)
);
```

Example: Locating a Call Specification in an Object Type Body

```
CREATE OR REPLACE TYPE Demo_typ
AUTHID CURRENT_USER
AS OBJECT
   (attribute1 NUMBER,
   MEMBER PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
);

CREATE OR REPLACE TYPE BODY Demo_typ
AS
   MEMBER PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
   AS LANGUAGE JAVA
      NAME 'pkg1.class4.J_demoExternal(int,java.lang.String,java.sql.Date)';
END;
```

Example: Java with AUTHID

Here is an example of a publishing a Java class method in a standalone

PL/SQL subprogram.

```
CREATE OR REPLACE PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y
VARCHAR2, z DATE)
   AUTHID CURRENT_USER
AS LANGUAGE JAVA
   NAME 'pkg1.class4.methodProc1(int,java.lang.String,java.sql.Date)';
```

Example: C with Optional AUTHID

Here is an example of `AS EXTERNAL` publishing a C procedure in a standalone PL/SQL program, in which the `AUTHID` clause is optional. This maintains compatibility with the external procedures of Oracle Database version 8.0.

```
CREATE OR REPLACE PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y
VARCHAR2, z DATE)
AS
   EXTERNAL
   LANGUAGE C
   NAME "C_demoExternal"
   LIBRARY SomeLib
   WITH CONTEXT
   PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
```

Example: Mixing Call Specifications in a Package

```
CREATE OR REPLACE PACKAGE Demo_pack
AUTHID DEFINER
AS
   PROCEDURE plsToC_InBodyOld_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToC_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToJ_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);

   PROCEDURE plsToJ_InSpec_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   IS LANGUAGE JAVA
      NAME 'pkg1.class4.J_InSpec_meth(int,java.lang.String,java.sql.Date)';
```

```
PROCEDURE C_InSpec_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
END;

CREATE OR REPLACE PACKAGE BODY Demo_pack
AS
PROCEDURE plsToC_InBodyOld_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS EXTERNAL
      LANGUAGE C
      NAME "C_InBodyOld"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);

PROCEDURE plsToC_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_InBody"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
PROCEDURE plsToJ_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   IS LANGUAGE JAVA
      NAME 'pkg1.class4.J_InBody_meth(int,java.lang.String,java.sql.Date)';
END;
```

Passing Parameters to External C Procedures with Call Specifications

Call specifications allows a mapping between PL/SQL and C datatypes. Refer to "Specifying Datatypes" for datatype mappings.

Passing parameters to an external C procedure is complicated by several circumstances:

- The available set of PL/SQL datatypes does not correspond one-to-one with the set of C datatypes.
- Unlike C, PL/SQL includes the RDBMS concept of nullity. Therefore, PL/SQL parameters can be `NULL`, whereas C parameters cannot.
- The external procedure might need the current length or maximum length of `CHAR`, `LONG RAW`, `RAW`, and `VARCHAR2` parameters.
- The external procedure might need character set information about `CHAR`, `VARCHAR2`, and `CLOB` parameters.
- PL/SQL might need the current length, maximum length, or null status of values returned by the external procedure.

In the following sections, you learn how to specify a parameter list that deals with these circumstances.

> **Note:** The maximum number of parameters that you can pass to a C external procedure is 128. However, if you pass float or double parameters by value, then the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each float or double passed by value as two parameters.

Specifying Datatypes

Do not pass parameters to an external procedure directly. Instead, pass them to the PL/SQL subprogram that published the external procedure. Therefore, you must specify PL/SQL datatypes for the parameters. PL/SQL datatypes map to default external datatypes, as shown in Table 14–1.

Table 14–1 Parameter Datatype Mappings

PL/SQL Datatype	Supported External Types	Default External Type
BINARY_INTEGER BOOLEAN PLS_INTEGER	[UNSIGNED] CHAR [UNSIGNED] SHORT [UNSIGNED] INT [UNSIGNED] LONG SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T	INT
NATURAL[1] NATURALN[1] POSITIVE[1] POSITIVEN[1] SIGNTYPE[1]	[UNSIGNED] CHAR [UNSIGNED] SHORT [UNSIGNED] INT [UNSIGNED] LONG SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T	UNSIGNED INT
FLOAT REAL	FLOAT	FLOAT
DOUBLE PRECISION	DOUBLE	DOUBLE
CHAR CHARACTER LONG NCHAR NVARCHAR2 ROWID VARCHAR VARCHAR2	STRING OCISTRING	STRING
LONG RAW RAW	RAW OCIRAW	RAW
BFILE BLOB CLOB NCLOB	OCILOBLOCATOR	OCILOBLOCATOR

Table 14–1 (Cont.) Parameter Datatype Mappings

PL/SQL Datatype	Supported External Types	Default External Type
NUMBER DEC[1] DECIMAL[1] INT[1] INTEGER[1] NUMERIC[1] SMALLINT[1]	OCINUMBER	OCINUMBER
DATE	OCIDATE	OCIDATE
TIMESTAMP TIMESTAMP WITH TIME ZONE TIMESTAMP WITH LOCAL TIME ZONE	OCIDateTime	OCIDateTime
INTERVAL DAY TO SECOND INTERVAL YEAR TO MONTH	OCIInterval	OCIInterval
composite object types: ADTs	dvoid	dvoid
composite object types: collections (varrays, nested tables)	OCICOLL	OCICOLL

[1] This PL/SQL type will only compile if you use `AS EXTERNAL` in your callspec.

External Datatype Mappings

Each external datatype maps to a C datatype, and the datatype conversions are performed implicitly. To avoid errors when declaring C prototype parameters, refer to Table 14–2, which shows the C datatype to specify for a given external datatype and PL/SQL parameter mode. For example, if the external datatype of an `OUT` parameter is `STRING`, then specify the datatype char * in your C prototype.

Table 14–2 External Datatype Mappings

External Datatype Corresponding to PL/SL Type	If Mode is IN or RETURN, Specify in C Prototype...	If Mode is IN by Reference or RETURN by Reference, Specify in C Prototype...	If Mode is IN OUT or OUT, Specify in C Prototype...
CHAR	char	char *	char *
UNSIGNED CHAR	unsigned char	unsigned char *	unsigned char *
SHORT	short	short *	short *
UNSIGNED SHORT	unsigned short	unsigned short *	unsigned short *
INT	int	int *	int *
UNSIGNED INT	unsigned int	unsigned int *	unsigned int *
LONG	long	long *	long *
UNSIGNED LONG	unsigned long	unsigned long *	unsigned long *
CHAR	char	char *	char *
UNSIGNED CHAR	unsigned char	unsigned char *	unsigned char *
SHORT	short	short *	short *
UNSIGNED SHORT	unsigned short	unsigned short *	unsigned short *
INT	int	int *	int *
UNSIGNED INT	unsigned int	unsigned int *	unsigned int *

Table 14–2 (Cont.) External Datatype Mappings

External Datatype Corresponding to PL/SL Type	If Mode is IN or RETURN, Specify in C Prototype...	If Mode is IN by Reference or RETURN by Reference, Specify in C Prototype...	If Mode is IN OUT or OUT, Specify in C Prototype...
LONG	long	long *	long *
UNSIGNED LONG	unsigned long	unsigned long *	unsigned long *
SIZE_T	size_t	size_t *	size_t *
SB1	sb1	sb1 *	sb1 *
UB1	ub1	ub1 *	ub1 *
SB2	sb2	sb2 *	sb2 *
UB2	ub2	ub2 *	ub2 *
SB4	sb4	sb4 *	sb4 *
UB4	ub4	ub4 *	ub4 *
FLOAT	float	float *	float *
DOUBLE	double	double *	double *
STRING	char *	char *	char *
RAW	unsigned char *	unsigned char *	unsigned char *
OCILOBLOCATOR	OCILobLocator *	OCILobLocator **	OCILobLocator **
OCINUMBER	OCINumber *	OCINumber *	OCINumber *
OCISTRING	OCIString *	OCIString *	OCIString *
OCIRAW	OCIRaw *	OCIRaw *	OCIRaw *
OCIDATE	OCIDate *	OCIDate *	OCIDate *
OCICOLL	OCIColl * or OCIArray * or OCITable *	OCIColl ** or OCIArray ** or OCITable **	OCIColl ** or OCIArray ** or OCITable **
OCITYPE	OCIType *	OCIType *	OCIType *
TDO	OCIType *	OCIType *	OCIType *
ADT (final types)	dvoid*	dvoid*	dvoid*
ADT (non-final types)	dvoid*	dvoid*	dvoid**

Composite object types are not self describing. Their description is stored in a **Type Descriptor Object** (TDO). Objects and indicator structs for objects have no predefined OCI datatype, but must use the datatypes generated by Oracle Database's **Object Type Translator** (OTT). The optional TDO argument for `INDICATOR`, and for composite objects, in general, has the C datatype, OCIType *.

`OCICOLL` for `REF` and collection arguments *is* optional and only exists for the sake of completeness. You cannot map `REF`s or collections onto any other datatype and vice versa.

BY VALUE/REFERENCE for IN and IN OUT Parameter Modes

If you specify BY VALUE, then scalar IN and RETURN arguments are passed by value (which is also the default). Alternatively, you may have them passed by reference by specifying BY REFERENCE.

By default, or if you specify BY REFERENCE, then scalar IN OUT, and OUT arguments are passed by reference. Specifying BY VALUE for IN OUT, and OUT arguments is not supported for C. The usefulness of the BY REFERENCE/VALUE clause is restricted to external datatypes that are, by default, passed by value. This is true for IN, and RETURN arguments of the following external types:

```
[UNSIGNED] CHAR
[UNSIGNED] SHORT
[UNSIGNED] INT
[UNSIGNED] LONG
SIZE_T
SB1
SB2
SB4
UB1
UB2
UB4
FLOAT
DOUBLE
```

All IN and RETURN arguments of external types not on this list, all IN OUT arguments, and all OUT arguments are passed by reference.

The PARAMETERS Clause

Generally, the PL/SQL subprogram that publishes an external procedure declares a list of formal parameters, as the following example shows:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE LIBRARY MathLib AS '/tmp/math.so';
```

```
CREATE OR REPLACE FUNCTION Interp_func (
/* Find the value of y at x degrees using Lagrange interpolation: */
   x    IN FLOAT,
   y    IN FLOAT)
RETURN FLOAT AS
   LANGUAGE C
   NAME "Interp_func"
   LIBRARY MathLib;
```

Each formal parameter declaration specifies a name, parameter mode, and PL/SQL datatype (which maps to the default external datatype). That might be all the information the external procedure needs. If not, then you can provide more information using the PARAMETERS clause, which lets you specify the following:

- Nondefault external datatypes
- The current or maximum length of a parameter
- NULL/NOT NULL indicators for parameters
- Character set IDs and forms

- The position of parameters in the list
- How IN parameters are passed (by value or by reference)

If you decide to use the PARAMETERS clause, keep in mind:

- For every formal parameter, there must be a corresponding parameter in the PARAMETERS clause.
- If you include the WITH CONTEXT clause, then you must specify the parameter CONTEXT, which shows the position of the context pointer in the parameter list.
- If the external procedure is a function, then you may specify the RETURN parameter, but it must be in the last position. If RETURN is not specified, the default external type is used.

Overriding Default Datatype Mapping

In some cases, you can use the PARAMETERS clause to override the default datatype mappings. For example, you can re-map the PL/SQL datatype BOOLEAN from external datatype INT to external datatype CHAR.

Specifying Properties

You can also use the PARAMETERS clause to pass additional information about PL/SQL formal parameters and function results to an external procedure. Do this by specifying one or more of the following properties:

```
INDICATOR [{STRUCT | TDO}]
LENGTH
DURATION
MAXLEN
CHARSETID
CHARSETFORM
SELF
```

Table 14–3 shows the allowed and the default external datatypes, PL/SQL datatypes, and PL/SQL parameter modes allowed for a given property. Notice that MAXLEN (used to specify data returned from C back to PL/SQL) cannot be applied to an IN parameter.

Table 14–3 Properties and Datatypes

Property	Allowed External Types (C)	Default External Type (C)	Allowed PL/SQL Types	Allowed PL/SQL Modes	Default PL/SQL Passing Method
INDICATOR	SHORT	SHORT	all scalars	IN	BY VALUE
				IN OUT	BY REFERENCE
				OUT	BY REFERENCE
				RETURN	BY REFERENCE

Table 14–3 (Cont.) Properties and Datatypes

Property	Allowed External Types (C)	Default External Type (C)	Allowed PL/SQL Types	Allowed PL/SQL Modes	Default PL/SQL Passing Method
LENGTH	[UNSIGNED] SHORT	INT	CHAR	IN	BY VALUE
	[UNSIGNED] INT		LONG RAW	IN OUT	BY REFERENCE
	[UNSIGNED] LONG		RAW	OUT	BY REFERENCE
			VARCHAR2	RETURN	BY REFERENCE
MAXLEN	[UNSIGNED] SHORT	INT	CHAR	IN OUT	BY REFERENCE
	[UNSIGNED] INT		LONG RAW	OUT	BY REFERENCE
	[UNSIGNED] LONG		RAW	RETURN	BY REFERENCE
			VARCHAR2		
CHARSETID	UNSIGNED SHORT	UNSIGNED INT	CHAR	IN	BY VALUE
CHARSETFORM	UNSIGNED INT		CLOB	IN OUT	BY REFERENCE
	UNSIGNED LONG		VARCHAR2	OUT	BY REFERENCE
				RETURN	BY REFERENCE

In the following example, the PARAMETERS clause specifies properties for the PL/SQL formal parameters and function result:

```
CREATE OR REPLACE FUNCTION plsToCparse_func  (
   x   IN BINARY_INTEGER,
   Y   IN OUT CHAR)
RETURN CHAR AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_parse"
   PARAMETERS (
      x,            -- stores value of x
      x INDICATOR,  -- stores null status of x
      y,            -- stores value of y
      y LENGTH,     -- stores current length of y
      y MAXLEN,     -- stores maximum length of y
      RETURN INDICATOR,
      RETURN);
```

With this PARAMETERS clause, the C prototype becomes:

```
char  *C_parse(x, x_ind, y, y_len, y_maxlen, retind)
int    x;
short  x_ind;
char  *y;
int   *y_len;
int   *y_maxlen;
short *retind;
```

A K&R prototype is needed because the indicator variable x_ind must be of datatype short and short should not be used in ISO/ANSI prototypes.

The additional parameters in the C prototype correspond to the INDICATOR (for x), LENGTH (of y), and MAXLEN (of y), as well as the INDICATOR for the function result in the PARAMETERS clause. The parameter RETURN corresponds to the C function identifier, which stores the result value.

INDICATOR

An INDICATOR is a parameter whose value indicates whether or not another parameter is NULL. PL/SQL does not need indicators, because the RDBMS concept of nullity is built into the language. However, an external procedure might need to know if a parameter or function result is NULL. Also, an external procedure might need to

signal the server that a returned value is actually a NULL, and should be treated accordingly.

In such cases, you can use the property INDICATOR to associate an indicator with a formal parameter. If the PL/SQL subprogram is a function, then you can also associate an indicator with the function result, as shown earlier.

To check the value of an indicator, you can use the constants OCI_IND_NULL and OCI_IND_NOTNULL. If the indicator equals OCI_IND_NULL, then the associated parameter or function result is NULL. If the indicator equals OCI_IND_NOTNULL, then the parameter or function result is not NULL.

For IN parameters, which are inherently read-only, INDICATOR is passed by value (unless you specify BY REFERENCE) and is read-only (even if you specify BY REFERENCE). For OUT, IN OUT, and RETURN parameters, INDICATOR is passed by reference by default.

The INDICATOR can also have a STRUCT or TDO option. Because specifying INDICATOR as a property of an object is not supported, and because arguments of objects have complete indicator structs instead of INDICATOR scalars, you must specify this by using the STRUCT option. You must use the type descriptor object (TDO) option for composite objects and collections,

LENGTH and MAXLEN

In PL/SQL, there is no standard way to indicate the length of a RAW or string parameter. However, in many cases, you want to pass the length of such a parameter to and from an external procedure. Using the properties LENGTH and MAXLEN, you can specify parameters that store the current length and maximum length of a formal parameter.

> **Note:** With a parameter of type RAW or LONG RAW, you must use the property LENGTH. Also, if that parameter is IN OUT and NULL or OUT and NULL, then you must set the length of the corresponding C parameter to zero.

For IN parameters, LENGTH is passed by value (unless you specify BY REFERENCE) and is read-only. For OUT, IN OUT, and RETURN parameters, LENGTH is passed by reference.

As mentioned earlier, MAXLEN does not apply to IN parameters. For OUT, IN OUT, and RETURN parameters, MAXLEN is passed by reference and is read-only.

CHARSETID and CHARSETFORM

Oracle Database provides globalization support, which lets you process single-byte and multibyte character data and convert between character sets. It also lets your applications run in different language environments.

By default, if the server and agent use the exact same $ORACLE_HOME value, the agent uses the same globalization support settings as the server (including any settings that have been specified with ALTER SESSION commands).

If the agent is running in a separate $ORACLE_HOME (even if the same location is specified by two different aliases or symbolic links), the agent uses the same globalization support settings as the server except for the character set; the default character set for the agent is defined by the NLS_LANG and NLS_NCHAR environment settings for the agent.

The properties CHARSETID and CHARSETFORM identify the nondefault character set from which the character data being passed was formed. With CHAR, CLOB, and VARCHAR2 parameters, you can use CHARSETID and CHARSETFORM to pass the character set ID and form to the external procedure.

For IN parameters, CHARSETID and CHARSETFORM are passed by value (unless you specify BY REFERENCE) and are read-only (even if you specify BY REFERENCE). For OUT, IN OUT, and RETURN parameters, CHARSETID and CHARSETFORM are passed by reference and are read-only.

The OCI attribute names for these properties are OCI_ATTR_CHARSET_ID and OCI_ATTR_CHARSET_FORM.

> **See Also:** *Oracle Call Interface Programmer's Guide* and the *Oracle Database Globalization Support Guide* for more information about using national language data with the OCI

Repositioning Parameters

Remember, each formal parameter of the external procedure must have a corresponding parameter in the PARAMETERS clause. Their positions can differ, because PL/SQL associates them by name, not by position. However, the PARAMETERS clause and the C prototype for the external procedure must have the same number of parameters, and they must be in the same order.

Using SELF

SELF is the always-present argument of an object type's member function or procedure, namely the object instance itself. In most cases, this argument is implicit and is not listed in the argument list of the PL/SQL procedure. However, SELF must be explicitly specified as an argument of the PARAMETERS clause.

For example, assume that a user wants to create a Person object, consisting of a person's name and date of birth, and then further a table of this object type. The user would eventually like to determine the age of each Person object in this table.

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CONNECT system/manager
GRANT CONNECT,RESOURCE,CREATE LIBRARY TO scott IDENTIFIED BY
tiger;
CONNECT scott/tiger
CREATE OR REPLACE LIBRARY agelib UNTRUSTED IS
  '/tmp/scott1.so';.
```

This example is only for Solaris; other libraries and include paths might be needed for other platforms.

In SQL*Plus, the Person object type can be created by:

```
CREATE OR REPLACE TYPE Person1_typ AS OBJECT
( Name      VARCHAR2(30),
  B_date    DATE,
  MEMBER FUNCTION calcAge_func RETURN NUMBER)
);
```

Normally, the member function would be implemented in PL/SQL, but for this example, we make it an external procedure. To realize this, the body of the member function is declared as follows:

```
CREATE OR REPLACE TYPE BODY Person1_typ AS
  MEMBER FUNCTION calcAge_func RETURN NUMBER
  AS LANGUAGE C
  NAME "age"
  LIBRARY agelib
  WITH CONTEXT
  PARAMETERS
  ( CONTEXT,
    SELF,
    SELF INDICATOR STRUCT,
    SELF TDO,
    RETURN INDICATOR
  );
END;
```

Notice that the `calcAge_func` member function does not take any arguments, but only returns a number. A member function is always invoked on an instance of the associated object type. The object instance itself always is an implicit argument of the member function. To refer to the implicit argument, the `SELF` keyword is used. This is incorporated into the external procedure syntax by supporting references to `SELF` in the parameters clause.

The matching table is created and populated.

```
CREATE TABLE Person_tab OF Person1_typ;

INSERT INTO Person_tab VALUES
   ('SCOTT', TO_DATE('14-MAY-85'));

INSERT INTO Person_tab VALUES
   ('TIGER', TO_DATE('22-DEC-71'));
```

Finally, we retrieve the information of interest from the table.

```
SELECT p.name, p.b_date, p.calcAge_func() FROM Person_tab p;

NAME                           B_DATE    P.CALCAGE_
------------------------------ --------- ----------
SCOTT                          14-MAY-85          0
TIGER                          22-DEC-71          0
```

The following is sample C code that implements the `external` member function and the Object-Type-Translator (OTT)-generated `struct` definitions:

```
#include <oci.h>

struct PERSON
{
    OCIString   *NAME;
    OCIDate      B_DATE;
};
typedef struct PERSON PERSON;

struct PERSON_ind
{
    OCIInd    _atomic;
    OCIInd    NAME;
```

```
    OCIInd    B_DATE;
};
typedef struct PERSON_ind PERSON_ind;

OCINumber *age (ctx, person_obj, person_obj_ind, tdo, ret_ind)
OCIExtProcContext *ctx;
PERSON         *person_obj;
PERSON_ind     *person_obj_ind;
OCIType        *tdo;
OCIInd         *ret_ind;
{
    sword      err;
    text       errbuf[512];
    OCIEnv    *envh;
    OCISvcCtx *svch;
    OCIError  *errh;
    OCINumber *age;
    int        inum = 0;
    sword      status;

    /* get OCI Environment */
    err = OCIExtProcGetEnv( ctx, &envh, &svch, &errh );

    /* initialize return age to 0 */
    age = (OCINumber *)OCIExtProcAllocCallMemory(ctx, sizeof(OCINumber));
    status = OCINumberFromInt(errh, &inum, sizeof(inum), OCI_NUMBER_SIGNED,
                              age);
    if (status != OCI_SUCCESS)
    {
      OCIExtProcRaiseExcp(ctx, (int)1476);
      return (age);
    }

    /* return NULL if the person object is null or the birthdate is null */
    if ( person_obj_ind->_atomic == OCI_IND_NULL ||
         person_obj_ind->B_DATE  == OCI_IND_NULL )
    {
        *ret_ind = OCI_IND_NULL;
        return (age);
    }

    /* The actual implementation to calculate the age is left to the reader,
       but an easy way of doing this is a callback of the form:
            select trunc(months_between(sysdate, person_obj->b_date) / 12)
            from dual;
    */
    *ret_ind = OCI_IND_NOTNULL;
    return (age);
}
```

Passing Parameters by Reference

In C, you can pass `IN` scalar parameters by value (the value of the parameter is passed) or by reference (a pointer to the value is passed). When an external procedure expects a pointer to a scalar, specify `BY REFERENCE` phrase to pass the parameter by reference:

```
CREATE OR REPLACE PROCEDURE findRoot_proc (
   x IN DOUBLE PRECISION)
AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_findRoot"
```

```
   PARAMETERS (
      x BY REFERENCE);
```

In this case, the C prototype would be:

```
void C_findRoot(double *x);
```

This is rather than the default, which would be used when there is no PARAMETERS clause:

```
void C_findRoot(double x);
```

WITH CONTEXT

By including the WITH CONTEXT clause, you can give an external procedure access to information about parameters, exceptions, memory allocation, and the user environment. The WITH CONTEXT clause specifies that a context pointer will be passed to the external procedure. For example, if you write the following PL/SQL function:

```
CREATE OR REPLACE FUNCTION getNum_func (
   x IN REAL)
RETURN BINARY_INTEGER AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_getNum"
   WITH CONTEXT
   PARAMETERS (
      CONTEXT,
      x BY REFERENCE,
      RETURN INDICATOR);
```

Then, the C prototype would be:

```
int C_getNum(
   OCIExtProcContext *with_context,
   float *x,
   short *retind);
```

The context data structure is opaque to the external procedure; but, is available to service procedures called by the external procedure.

If you also include the PARAMETERS clause, then you must specify the parameter CONTEXT, which shows the position of the context pointer in the parameter list. If you omit the PARAMETERS clause, then the context pointer is the first parameter passed to the external procedure.

Inter-Language Parameter Mode Mappings

PL/SQL supports the IN, IN OUT, and OUT parameter modes, as well as the RETURN clause for procedures returning values.

Executing External Procedures with the CALL Statement

Now that you have published your Java class method or external C procedure, you are ready to invoke it.

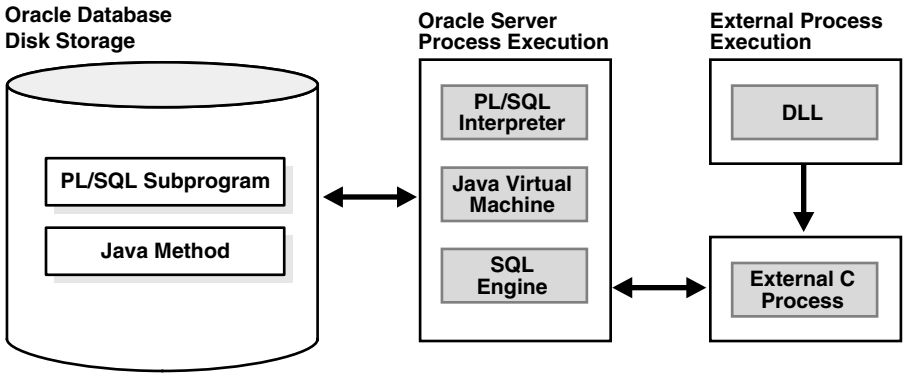
Do not call an external procedure directly. Instead, use the CALL statement to call the PL/SQL subprogram that published the external procedure. Refer to "CALL Statement Syntax".

Such calls, which you code in the same manner as a call to a regular PL/SQL procedure or function, can appear in the following:

- Anonymous blocks
- Standalone and packaged subprograms
- Methods of an object type
- Database triggers
- SQL statements (calls to packaged functions only).

Any PL/SQL block or subprogram executing on the server side, or on the client side, (for example, in a tool such as Oracle Forms) can call an external procedure. On the server side, the external procedure runs in a separate process address space, which safeguards your database. Figure 14–2 shows how Oracle Database and external procedures interact.

Figure 14–2 Oracle Database and External Procedures



Preconditions for External Procedures

Before calling external procedures, you should consider the privileges, permissions, and synonyms that exist in the execution environment.

Privileges of External Procedures

When external procedures are called through `CALL` specifications, they execute with *definer's privileges*, rather than invoker's privileges.

A program executing with invoker's privileges is not bound to a particular schema. It executes at the calling site and accesses database items (such as tables and views) with the caller's visibility and permissions. However, a program executing with definer's privileges is bound to the schema in which it is defined. It executes at the defining site, in the definer's schema, and accesses database items with the definer's visibility and permissions.

Managing Permissions

Note: You may need to set up the following data structures for certain examples to work:

```
CONNECT system/manager
GRANT CREATE ANY DIRECTORY to scott;
CONNECT scott/tiger
CREATE OR REPLACE DIRECTORY bfile_dir AS '/tmp';
CREATE OR REPLACE JAVA RESOURCE NAMED "appImages" USING BFILE
(bfile_dir,'bfile_audio');
```

To call external procedures, a user must have the `EXECUTE` privilege on the call specification and on any resources used by the procedure.

In SQL*Plus, you can use the `GRANT` and `REVOKE` data control statements to manage permissions. For example:

```
GRANT EXECUTE ON plsToJ_demoExternal_proc TO Public;
REVOKE EXECUTE ON plsToJ_demoExternal_proc FROM Public;
GRANT EXECUTE ON JAVA RESOURCE "appImages" TO Public;
GRANT EXECUTE ON plsToJ_demoExternal_proc TO Scott;
REVOKE EXECUTE ON plsToJ_demoExternal_proc FROM Scott;
```

See Also: *Oracle Database SQL Reference*

Creating Synonyms for External Procedures

For convenience, you or your DBA can create synonyms for external procedures using the `CREATE [PUBLIC] SYNONYM` statement. In the following example, your DBA creates a public synonym, which is accessible to all users. If `PUBLIC` is not specified, then the synonym is private and accessible only within its schema.

```
CREATE PUBLIC SYNONYM Rfac FOR Scott.RecursiveFactorial;
```

CALL Statement Syntax

Invoke the external procedure by means of the SQL `CALL` statement. You can execute the `CALL` statement interactively from SQL*Plus. The syntax is:

```
CALL [schema.][{object_type_name | package_name}]procedure_name[@dblink_name]
   [(parameter_list)] [INTO :host_variable][INDICATOR][:indicator_variable];
```

This is essentially the same as executing a procedure `myproc()` using a SQL statement of the form "`SELECT myproc(...) FROM dual`," except that the overhead associated with performing the `SELECT` is not incurred.

For example, here is an anonymous PL/SQL block that uses dynamic SQL to call `plsToC_demoExternal_proc`, which we published. PL/SQL passes three parameters to the external C procedure `C_demoExternal_proc`.

```
DECLARE
   xx NUMBER(4);
   yy VARCHAR2(10);
   zz DATE;
 BEGIN
    EXECUTE IMMEDIATE 'CALL plsToC_demoExternal_proc(:xxx, :yyy, :zzz)' USING
xx,yy,zz;
 END;
```

The semantics of the CALL statement is identical to the that of an equivalent BEGIN..END block.

> **Note:** CALL is the only SQL statement that cannot be put, by itself, in a PL/SQL BEGIN...END block. It can be part of an EXECUTE IMMEDIATE statement within a BEGIN...END block.

Calling Java Class Methods

Here is how you would call the J_calcFactorial class method published earlier. First, declare and initialize two SQL*Plus host variables, as follows:

```
VARIABLE x NUMBER
VARIABLE y NUMBER
EXECUTE :x := 5;
```

Call J_calcFactorial:

```
CALL
J_calcFactorial
(:x) INTO :y;
PRINT y
```

The result:

```
Y
------
   120
```

How the Database Server Calls External C Procedures

To call an external C procedure, PL/SQL must find the path of the appropriate DLL. The PL/SQL engine retrieves the path from the data dictionary, based on the library alias from the AS LANGUAGE clause of the procedure declaration.

Next, PL/SQL alerts a Listener process which, in turn, spawns a session-specific agent. By default, this agent is named extproc, although you can specify other names in the listener.ora file. The Listener hands over the connection to the agent, and PL/SQL passes to the agent the name of the DLL, the name of the external procedure, and any parameters.

Then, the agent loads the DLL and runs the external procedure. Also, the agent handles service calls (such as raising an exception) and callbacks to Oracle Database. Finally, the agent passes to PL/SQL any values returned by the external procedure.

> **Note:** Although some DLL caching takes place, there is no guarantee that your DLL will remain in the cache; therefore, do not store global variables in your DLL.

After the external procedure completes, the agent remains active throughout your Oracle Database session; when you log off, the agent is killed. Consequently, you incur the cost of launching the agent only once, no matter how many calls you make. Still, you should call an external procedure only when the computational benefits outweigh the cost.

Here, we call PL/SQL function `plsCallsCdivisor_func`, which we published previously, from an anonymous block. PL/SQL passes the two integer parameters to external function `Cdivisor_func`, which returns their greatest common divisor.

```
DECLARE
   g    BINARY_INTEGER;
   a    BINARY_INTEGER;
   b    BINARY_INTEGER;
CALL plsCallsCdivisor_func(a, b);
IF g IN (2,4,8) THEN ...
```

Handling Errors and Exceptions in Multi-Language Programs

The PL/SQL compiler raises compile time errors if an `AS EXTERNAL` call specification is found in a `TYPE` or `PACKAGE` specification.

C programs can raise exceptions through the `OCIExtproc`... functions.

Using Service Procedures with External C Procedures

When called from an external procedure, a **service routine** can raise exceptions, allocate memory, and invoke OCI handles for callbacks to the server. To use a service routine, you must specify the `WITH CONTEXT` clause, which lets you pass a context structure to the external procedure. The context structure is declared in header file `ociextp.h` as follows:

```
typedef struct OCIExtProcContext OCIExtProcContext;
```

> **Note:** `ociextp.h` is located in `$ORACLE_HOME/plsql/public` on UNIX.

OCIExtProcAllocCallMemory()

This service routine allocates *n* bytes of memory for the duration of the external procedure call. Any memory allocated by the function is freed automatically as soon as control returns to PL/SQL.

> **Note:** The external procedure does not need to (and should not) call the C function `free`() to free memory allocated by this service routine as this is handled automatically.

The C prototype for this function is as follows:

```
dvoid *OCIExtProcAllocCallMemory(
   OCIExtProcContext *with_context,
   size_t amount);
```

The parameters `with_context` and `amount` are the context pointer and number of bytes to allocate, respectively. The function returns an untyped pointer to the allocated memory. A return value of zero indicates failure.

In SQL*Plus, suppose you publish external function `plsToC_concat_func`, as follows:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CONNECT system/manager
DROP USER y CASCADE;
GRANT CONNECT,RESOURCE,CREATE LIBRARY TO y IDENTIFIED BY y;
CONNECT y/y
CREATE LIBRARY stringlib AS
'/private/varora/ilmswork/Cexamples/john2.so';
```

```
CREATE OR REPLACE FUNCTION plsToC_concat_func (
   str1 IN VARCHAR2,
   str2 IN VARCHAR2)
RETURN VARCHAR2 AS LANGUAGE C
NAME "concat"
LIBRARY stringlib
WITH CONTEXT
PARAMETERS (
CONTEXT,
str1   STRING,
str1   INDICATOR short,
str2   STRING,
str2   INDICATOR short,
RETURN INDICATOR short,
RETURN LENGTH short,
RETURN STRING);
```

When called, `C_concat` concatenates two strings, then returns the result:

```
select plsToC_concat_func('hello ', 'world') from dual;
PLSTOC_CONCAT_FUNC('HELLO','WORLD')
--------------------------------------------------------------------------------
hello world
```

If either string is `NULL`, the result is also `NULL`. As the following example shows, `C_concat` uses `OCIExtProcAllocCallMemory()` to allocate memory for the result string:

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <oci.h>
#include <ociextp.h>

char *concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l)
OCIExtProcContext *ctx;
char   *str1;
short  str1_i;
char   *str2;
short  str2_i;
short  *ret_i;
short  *ret_l;
{
  char *tmp;
  short len;
  /* Check for null inputs. */
  if ((str1_i == OCI_IND_NULL) || (str2_i == OCI_IND_NULL))
  {
      *ret_i = (short)OCI_IND_NULL;
```

```
      /* PL/SQL has no notion of a NULL ptr, so return a zero-byte string. */
      tmp = OCIExtProcAllocCallMemory(ctx, 1);
      tmp[0] = '\0';
      return(tmp);
  }
  /* Allocate memory for result string, including NULL terminator. */
  len = strlen(str1) + strlen(str2);
  tmp = OCIExtProcAllocCallMemory(ctx, len + 1);

  strcpy(tmp, str1);
  strcat(tmp, str2);

  /* Set NULL indicator and length. */
  *ret_i = (short)OCI_IND_NOTNULL;
  *ret_l = len;
  /* Return pointer, which PL/SQL frees later. */
  return(tmp);
}

#ifdef LATER
static void checkerr (/*_ OCIError *errhp, sword status _*/);

void checkerr(errhp, status)
OCIError *errhp;
sword status;
{
  text errbuf[512];
  sb4 errcode = 0;

  switch (status)
  {
  case OCI_SUCCESS:
    break;
  case OCI_SUCCESS_WITH_INFO:
    (void) printf("Error - OCI_SUCCESS_WITH_INFO\n");
    break;
  case OCI_NEED_DATA:
    (void) printf("Error - OCI_NEED_DATA\n");
    break;
  case OCI_NO_DATA:
    (void) printf("Error - OCI_NODATA\n");
    break;
  case OCI_ERROR:
    (void) OCIErrorGet((dvoid *)errhp, (ub4) 1, (text *) NULL, &errcode,
                       errbuf, (ub4) sizeof(errbuf), OCI_HTYPE_ERROR);
    (void) printf("Error - %.*s\n", 512, errbuf);
    break;
  case OCI_INVALID_HANDLE:
    (void) printf("Error - OCI_INVALID_HANDLE\n");
    break;
  case OCI_STILL_EXECUTING:
    (void) printf("Error - OCI_STILL_EXECUTE\n");
    break;
  case OCI_CONTINUE:
    (void) printf("Error - OCI_CONTINUE\n");
    break;
  default:
    break;
  }
}
```

```
char *concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l)
OCIExtProcContext *ctx;
char   *str1;
short  str1_i;
char   *str2;
short  str2_i;
short  *ret_i;
short  *ret_l;
{
  char *tmp;
  short len;
  /* Check for null inputs. */
  if ((str1_i == OCI_IND_NULL) || (str2_i == OCI_IND_NULL))
  {
      *ret_i = (short)OCI_IND_NULL;
      /* PL/SQL has no notion of a NULL ptr, so return a zero-byte string. */
      tmp = OCIExtProcAllocCallMemory(ctx, 1);
      tmp[0] = '\0';
      return(tmp);
  }
  /* Allocate memory for result string, including NULL terminator. */
  len = strlen(str1) + strlen(str2);
  tmp = OCIExtProcAllocCallMemory(ctx, len + 1);

  strcpy(tmp, str1);
  strcat(tmp, str2);

  /* Set NULL indicator and length. */
  *ret_i = (short)OCI_IND_NOTNULL;
  *ret_l = len;
  /* Return pointer, which PL/SQL frees later. */
  return(tmp);
}

/*=============================================================================*/
int main(char *argv, int argc)
{
  OCIExtProcContext *ctx;
  char           *str1;
  short          str1_i;
  char           *str2;
  short          str2_i;
  short          *ret_i;
  short          *ret_l;
  /* OCI Handles */
  OCIEnv        *envhp;
  OCIServer     *srvhp;
  OCISvcCtx     *svchp;
  OCIError      *errhp;
  OCISession    *authp;
  OCIStmt       *stmthp;
  OCILobLocator *clob, *blob;
  OCILobLocator *Lob_loc;

  /* Initialize and Logon */
  (void) OCIInitialize((ub4) OCI_DEFAULT, (dvoid *)0,
                       (dvoid * (*)(dvoid *, size_t)) 0,
                       (dvoid * (*)(dvoid *, dvoid *, size_t))0,
                       (void (*)(dvoid *, dvoid *)) 0 );
```

```
(void) OCIEnvInit( (OCIEnv **) &envhp,
                   OCI_DEFAULT, (size_t) 0,
                   (dvoid **) 0 );

(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &errhp, OCI_HTYPE_ERROR,
                  (size_t) 0, (dvoid **) 0);

/* Server contexts */
(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &srvhp, OCI_HTYPE_SERVER,
                  (size_t) 0, (dvoid **) 0);

/* Service context */
(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &svchp, OCI_HTYPE_SVCCTX,
                  (size_t) 0, (dvoid **) 0);

/* Attach to Oracle Database */
(void) OCIServerAttach( srvhp, errhp, (text *)"", strlen(""), 0);

/* Set attribute server context in the service context */
(void) OCIAttrSet ((dvoid *) svchp, OCI_HTYPE_SVCCTX,
                    (dvoid *)srvhp, (ub4) 0,
                   OCI_ATTR_SERVER, (OCIError *) errhp);

(void) OCIHandleAlloc((dvoid *) envhp,
                      (dvoid **)&authp, (ub4) OCI_HTYPE_SESSION,
                      (size_t) 0, (dvoid **) 0);

(void) OCIAttrSet((dvoid *) authp, (ub4) OCI_HTYPE_SESSION,
                (dvoid *) "samp", (ub4)4,
                (ub4) OCI_ATTR_USERNAME, errhp);

(void) OCIAttrSet((dvoid *) authp, (ub4) OCI_HTYPE_SESSION,
                (dvoid *) "samp", (ub4) 4,
                (ub4) OCI_ATTR_PASSWORD, errhp);

/* Begin a User Session */
checkerr(errhp, OCISessionBegin ( svchp,  errhp, authp, OCI_CRED_RDBMS,
                         (ub4) OCI_DEFAULT));

(void) OCIAttrSet((dvoid *) svchp, (ub4) OCI_HTYPE_SVCCTX,
                  (dvoid *) authp, (ub4) 0,
                  (ub4) OCI_ATTR_SESSION, errhp);

/* ----------------------User Logged In-----------------------------*/
printf ("user logged in \n");

/* allocate a statement handle */
checkerr(errhp, OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &stmthp,
         OCI_HTYPE_STMT, (size_t) 0, (dvoid **) 0));

checkerr(errhp, OCIDescriptorAlloc((dvoid *)envhp, (dvoid **) &Lob_loc,
                                   (ub4) OCI_DTYPE_LOB,
                                   (size_t) 0, (dvoid **) 0));

/* ------- subroutine called  here----------------------*/
printf ("calling concat...\n");
concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l);

return 0;
```

```
}

#endif
```

OCIExtProcRaiseExcp

This service routine raises a predefined exception, which must have a valid Oracle Database error number in the range 1..32767. After doing any necessary cleanup, your external procedure must return immediately. (No values are assigned to `OUT` or `IN OUT` parameters.) The C prototype for this function follows:

```
int OCIExtProcRaiseExcp(
   OCIExtProcContext *with_context,
   size_t errnum);
```

The parameters `with_context` and `error_number` are the context pointer and Oracle Database error number. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

In SQL*Plus, suppose you publish external procedure `plsTo_divide_proc`, as follows:

```
CREATE OR REPLACE PROCEDURE plsTo_divide_proc (
   dividend IN BINARY_INTEGER,
   divisor  IN BINARY_INTEGER,
   result   OUT FLOAT)
AS LANGUAGE C
   NAME "C_divide"
   LIBRARY MathLib
   WITH CONTEXT
   PARAMETERS (
      CONTEXT,
      dividend INT,
      divisor  INT,
      result   FLOAT);
```

When called, `C_divide` finds the quotient of two numbers. As the following example shows, if the divisor is zero, `C_divide` uses `OCIExtProcRaiseExcp()` to raise the predefined exception `ZERO_DIVIDE`:

```
void C_divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int    dividend;
int    divisor;
float  *result;
{
  /* Check for zero divisor. */
  if (divisor == (int)0)
  {
    /* Raise exception ZERO_DIVIDE, which is Oracle error 1476. */
    if (OCIExtProcRaiseExcp(ctx, (int)1476) == OCIEXTPROC_SUCCESS)
    {
      return;
    }
    else
    {
      /* Incorrect parameters were passed. */
      assert(0);
    }
  }
  *result = (float)dividend / (float)divisor;
```

```
}
```

OCIExtProcRaiseExcpWithMsg

This service routine raises a user-defined exception and returns a user-defined error message. The C prototype for this function follows:

```
int OCIExtProcRaiseExcpWithMsg(
   OCIExtProcContext *with_context,
   size_t  error_number,
   text   *error_message,
   size_t  len);
```

The parameters `with_context`, `error_number`, and `error_message` are the context pointer, Oracle Database error number, and error message text. The parameter `len` stores the length of the error message. If the message is a null-terminated string, then `len` is zero. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

In the previous example, we published external procedure `plsTo_divide_proc`. In the following example, you use a different implementation. With this version, if the divisor is zero, then `C_divide` uses `OCIExtProcRaiseExcpWithMsg()` to raise a user-defined exception:

```
void C_divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int    dividend;
int    divisor;
float  *result;
  /* Check for zero divisor. */
  if (divisor == (int)0)
  {
    /* Raise a user-defined exception, which is Oracle error 20100,
       and return a null-terminated error message. */
    if (OCIExtProcRaiseExcpWithMsg(ctx, (int)20100,
          "divisor is zero", 0) == OCIEXTPROC_SUCCESS)
    {
      return;
    }
    else
    {
      /*  Incorrect parameters were passed. */
      assert(0);
    }
  }
  *result = dividend / divisor;

}
```

Doing Callbacks with External C Procedures

Here is a function that is used to enable callbacks.

OCIExtProcGetEnv()

This service routine enables OCI callbacks to the database during an external procedure call. The environment handles obtained by using this function reuse the existing connection to go back to the database. If you need to establish a new connection to the database, you cannot use these handles; instead, you must create your own.

The C prototype for this function follows:

```
sword OCIExtProcGetEnv ( OCIExtProcContext *with_context,
   OCIEnv envh,
   OCISvcCtx svch,
   OCIError errh )
```

The parameter `with_context` is the context pointer, and the parameters `envh`, `svch`, and `errh` are the OCI environment, service, and error handles, respectively. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

Both external C procedures and Java class methods can call-back to the database to do SQL operations. For a working example, refer to "Demo Program" on page 14-39.

> **Note:** Callbacks are not necessarily a same-session phenomenon; you may execute an SQL statement in a different session through `OCIlogon`.

An external C procedure executing on Oracle Database can call a service routine to obtain OCI environment and service handles. With the OCI, you can use callbacks to execute SQL statements and PL/SQL subprograms, fetch data, and manipulate LOBs. Callbacks and external procedures operate in the same user session and transaction context, and so have the same user privileges.

In SQL*Plus, suppose you run the following script:

```
CREATE TABLE Emp_tab (empno NUMBER(10))

CREATE PROCEDURE plsToC_insertIntoEmpTab_proc (
   empno BINARY_INTEGER)
AS LANGUAGE C
   NAME "C_insertEmpTab"
   LIBRARY insert_lib
   WITH CONTEXT
   PARAMETERS (
      CONTEXT,
      empno LONG);
```

Later, you might call service routine `OCIExtProcGetEnv()` from external procedure `plsToC_insertIntoEmpTab_proc()`, as follows:

```
#include <stdio.h>
#include <stdlib.h>
#include <oratypes.h>
#include <oci.h>   /* includes ociextp.h */
...
void C_insertIntoEmpTab (ctx, empno)
OCIExtProcContext *ctx;
long empno;
{
  OCIEnv    *envhp;
  OCISvcCtx *svchp;
  OCIError  *errhp;
  int        err;
  ...
  err = OCIExtProcGetEnv(ctx, &envhp, &svchp, &errhp);
  ...
}
```

If you do not use callbacks, you do not need to include `oci.h`; instead, just include `ociextp.h`.

Object Support for OCI Callbacks

To execute object-related callbacks from your external procedures, the OCI environment in the `extproc` agent is fully initialized in object mode. You retrieve handles to this environment with the `OCIExtProcGetEnv`() procedure.

The object runtime environment lets you use static, as well as dynamic, object support provided by OCI. To utilize static support, use the OTT to generate C structs for the appropriate object types, and then use conventional C code to access the object attributes.

For those objects whose types are unknown at external procedure creation time, an alternative, dynamic, way of accessing objects is first to invoke `OCIDescribeAny`() to obtain attribute and method information about the type. Then, `OCIObjectGetAttr`() and `OCIObjectSetAttr`() can be called to retrieve and set attribute values.

Because the current external procedure model is stateless, `OCIExtProcGetEnv`() must be called in every external procedure that wants to execute callbacks, or invoke `OCIExtProc`...() service routines. After every external procedure invocation, the callback mechanism is cleaned up and all OCI handles are freed.

Restrictions on Callbacks

With callbacks, the following SQL commands and OCI procedures are not supported:

- Transaction control commands such as `COMMIT`
- Data definition commands such as `CREATE`
- The following object-oriented OCI procedures:

```
OCIObjectNew
OCIObjectPin
OCIObjectUnpin
OCIObjectPinCountReset
OCIObjectLock
OCIObjectMarkUpdate
OCIObjectUnmark
OCIObjectUnmarkByRef
OCIObjectAlwaysLatest
OCIObjectNotAlwaysLatest
OCIObjectMarkDeleteByRef
OCIObjectMarkDelete
OCIObjectFlush
OCIObjectFlushRefresh
OCIObjectGetTypeRef
OCIObjectGetObjectRef
OCIObjectExists
OCIObjectIsLocked
OCIObjectIsDirtied
OCIObjectIsLoaded
OCIObjectRefresh
OCIObjectPinTable
OCIObjectArrayPin
OCICacheFlush,
OCICacheFlushRefresh,
OCICacheRefresh
OCICacheUnpin
```

```
OCICacheFree
OCICacheUnmark
OCICacheGetObjects
OCICacheRegister
```

- Polling-mode OCI procedures such as `OCIGetPieceInfo`
- The following OCI procedures:

```
OCIEnvInit
OCIInitialize
OCIPasswordChange
OCIServerAttach
OCIServerDetach
OCISessionBegin
OCISessionEnd
OCISvcCtxToLda
OCITransCommit
OCITransDetach
OCITransRollback
OCITransStart
```

Also, with OCI procedure `OCIHandleAlloc`, the following handle types are not supported:

```
OCI_HTYPE_SERVER
OCI_HTYPE_SESSION
OCI_HTYPE_SVCCTX
OCI_HTYPE_TRANS
```

Debugging External Procedures

Usually, when an external procedure fails, its prototype is faulty. In other words, the prototype does not match the one generated internally by PL/SQL. This can happen if you specify an incompatible C datatype. For example, to pass an `OUT` parameter of type `REAL`, you must specify `float *`. Specifying `float`, `double *`, or any other C datatype will result in a mismatch.

In such cases, you might get:

```
lost RPC connection to external routine agent
```

This error, which means that agent `extproc` terminated abnormally because the external procedure caused a core dump. To avoid errors when declaring C prototype parameters, refer to the preceding tables.

Using Package DEBUG_EXTPROC

To help you debug external procedures, PL/SQL provides the utility package `DEBUG_EXTPROC`. To install the package, run the script `dbgextp.sql` which you can find in the PL/SQL demo directory. (For the location of the directory, refer to your Oracle Database Installation or User's Guide.)

To use the package, follow the instructions in `dbgextp.sql`. Your Oracle Database account must have `EXECUTE` privileges on the package and `CREATE LIBRARY` privileges.

Note: `DEBUG_EXTPROC` works only on platforms with debuggers that can attach to a running process.

Demo Program

Also in the PL/SQL demo directory is the script `extproc.sql`, which demonstrates the calling of an external procedure. The companion file `extproc.c` contains the C source code for the external procedure.

To run the demo, follow the instructions in `extproc.sql`. You must use the `SCOTT/TIGER` account, which must have `CREATE LIBRARY` privileges.

Guidelines for External C Procedures

Handling Global Variables

A global variable is declared outside of a function, and its value is shared by all functions of a program. In case of external procedures, this means that all functions in a DLL share the value of the global. The usage of global variables is discouraged for two reasons:

- *Threading:* In the non-threaded configuration of the agent process, there is only one function active at a time. However, in the case of multithreaded agents, multiple functions can be active at the same time. In that case, it is possible that two or more functions would try to access the global variable concurrently, with unsuccessful results.
- *DLL caching*: Global variables are also used to store data that is intended to persist beyond the lifetime of a function. For example, consider two functions *func1*() and *func2*() trying to pass data to each other. Because of the DLL caching feature, it is possible that after *func1*()'s completion, the DLL will be unloaded, which results in all global variables losing their values. When *func2*() is executed, the DLL is reloaded, and all globals are initialized to 0, which will be inconsistent with their values at the completion of *func1*().

Handling Static Variables

There are two types of static variables: external and internal. An external static variable is a special case of a global variable, so its usage is discouraged. Internal static variables are local to a particular function, but remain in existence rather than coming and going each time the function is activated. Therefore, they provide private, permanent storage within a single function. These variables are used to pass on data to subsequent invocations of the same function. But, because of the DLL caching feature mentioned previously, the DLL might be unloaded and reloaded between invocations, which means that the internal static variable would lose its value.

> **See Also:** Template `makefile` in the RDBMS subdirectory `/public` for help creating a dynamic link library

Guidelines for Call Specifications and CALL Statements

When calling external procedures:

- Never write to `IN` parameters or overflow the capacity of `OUT` parameters. (PL/SQL does no run time checks for these error conditions.)
- Never read an `OUT` parameter or a function result.
- Always assign a value to `IN OUT` and `OUT` parameters and to function results. Otherwise, your external procedure will not return successfully.

- If you include the WITH CONTEXT and PARAMETERS clauses, then you must specify the parameter CONTEXT, which shows the position of the context pointer in the parameter list.
- If you include the PARAMETERS clause, and if the external procedure is a function, then you must specify the parameter RETURN in the last position.
- For every formal parameter, there must be a corresponding parameter in the PARAMETERS clause. Also, make sure that the datatypes of parameters in the PARAMETERS clause are compatible with those in the C prototype, because no implicit conversions are done.
- With a parameter of type RAW or LONG RAW, you must use the property LENGTH. Also, if that parameter is IN OUT or OUT and null, then you must set the length of the corresponding C parameter to zero.

Restrictions on External C Procedures

The following restrictions apply to external procedures:

- This feature is available only on platforms that support DLLs.
- Only C procedures and procedures callable from C code are supported.
- You cannot pass PL/SQL cursor variables or records to an external procedure. For records, use instances of object types instead.
- In the LIBRARY subclause, you cannot use a database link to specify a remote library.
- The maximum number of parameters that you can pass to a external procedure is 128. However, if you pass float or double parameters by value, then the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each float or double passed by value as two parameters.

15

Developing Applications with Oracle XA

This chapter describes how to use the Oracle XA library. Typically, you use this library in applications that work with transaction monitors. The XA features are most useful in applications in which transactions interact with more than one database.

The chapter includes the following topics:

- X/Open Distributed Transaction Processing (DTP)
- Oracle XA Library Interface Subroutines
- Developing and Installing XA Applications
- Troubleshooting XA Applications
- XA Issues and Restrictions

See Also:

- *X/Open CAE Specification - Distributed Transaction Processing: The XA Specification*, X/Open Document Number XO/CAE/91/300, for an overview of XA, including basic architecture. Access at `http://www.opengroup.org/pubs/catalog/c193.htm`.
- *Oracle Call Interface Programmer's Guide* for background and reference information about the Oracle XA library.
- The Oracle Database platform-specific documentation for information on library linking filenames.
- README for changes, bugs, and restrictions in the Oracle XA library for your platform.

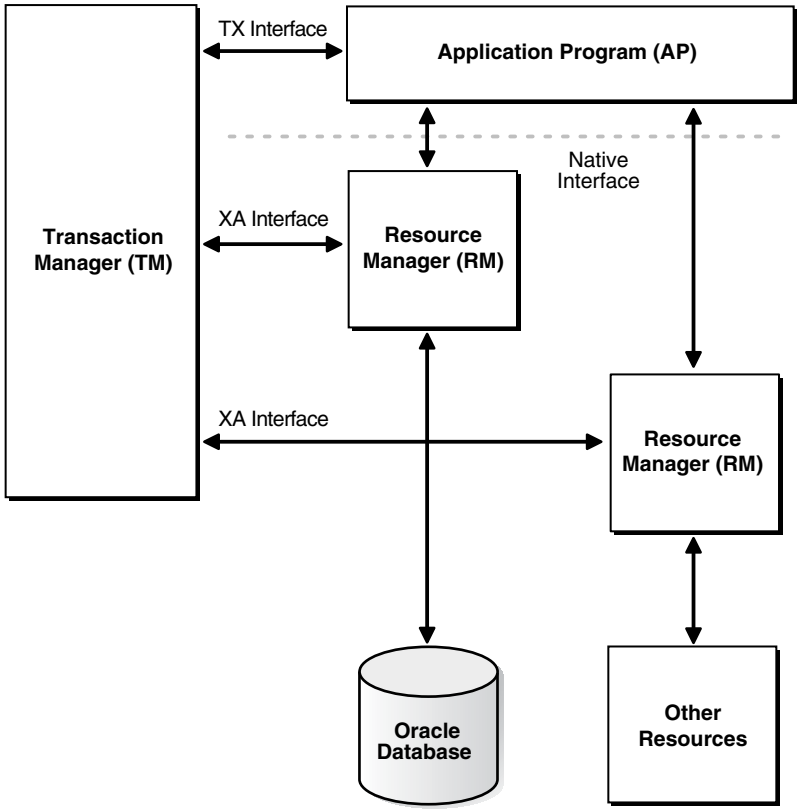
X/Open Distributed Transaction Processing (DTP)

The X/Open Distributed Transaction Processing (DTP) architecture defines a standard architecture or interface that enables multiple application programs (APs) to share resources provided by multiple, and possibly different, resource managers (RMs). It coordinates the work between APs and RMs into global transactions.

The Oracle XA library conforms to the X/Open software architecture's XA interface specification. The Oracle XA library is an external interface that enables a non-Oracle, client-side transaction manager (TM) to coordinate global transactions, thereby allowing inclusion of non-Oracle Database RMs in distributed transactions. For example, a client application can manage an Oracle Database transaction and a transaction in an NTFS file system as a single, global transaction.

Figure 15–1 illustrates a possible X/Open DTP model.

Figure 15–1 Possible DTP Model



DTP Terminology

This section introduces you to key terminology in distributed transaction processing.

Resource Manager (RM)

A resource manager controls a shared, recoverable resource that can be returned to a consistent state after a failure. Examples are relational databases, transactional queues, and transactional file systems. Oracle Database is an RM and uses its online redo log and undo segments to return to a consistent state after a failure.

Distributed Transaction

A distributed transaction, also called a **global transaction**, is a client transaction that involves updates to multiple distributed resources and requires an "all-or-none" semantics across distributed RMs.

Branch

A branch is a unit of work contained within one RM. Multiple branches make up one global transaction. In the case of Oracle Database, each branch maps to a local transaction inside the database server.

Transaction Manager (TM)

A transaction manager provides an API for specifying the boundaries of the transaction and manages commit and recovery. The TM implements a two-phase commit engine to provide an "all-or-none" semantics across distributed RMs.

An **external TM** is a middle-tier component that resides outside of Oracle Database. Normally, the database is its own internal TM. Using a standards-based TM enables Oracle Database to cooperate with other heterogeneous RMs in a single transaction.

Transaction Processing Monitor (TPM)

A TM is usually provided by a transaction processing monitor (TPM) vendor. A TPM coordinates the flow of transaction requests between the client processes that issue requests and the back-end servers that process them. Basically, a TPM coordinates transactions that require the services of several different types of back-end processes, such as application servers and RMs distributed over a network.

The TPM synchronizes any commits or rollbacks required to complete a distributed transaction. The TM portion of the TPM is responsible for controlling when distributed commits and rollbacks take place. Thus, if a distributed application program takes advantage of a TPM, then the TM portion of the TPM is responsible for controlling the two-phase commit protocol. The RMs enable the TMs to perform this task.

Because the TM controls distributed commits or rollbacks, it must communicate directly with Oracle Database (or any other RM) through the XA interface. It uses Oracle XA library subroutines, which are described in "XA Library Subroutines" on page 15-5, to tell Oracle Database how to process the transaction, based on its knowledge of all RMs in the transaction.

Two-Phase Commit Protocol

The Oracle XA library interface follows the two-phase commit protocol. The sequence of events is as follows:

1. In the prepare phase, the TM asks each RM to guarantee that it can commit any part of the transaction. If this is possible, then the RM records its prepared state and replies affirmatively to the TM. If it is not possible, then the RM may roll back any work, reply negatively to the TM, and forget about the transaction. The protocol allows the application, or any RM, to roll back the transaction unilaterally until the prepare phase completes.
2. In phase two, the TM records the commit decision and issues a commit or rollback to all RMs participating in the transaction. TM can issue a commit for an RM only if all RMs have replied affirmatively to phase one.

Application Program (AP)

An application program defines transaction boundaries and specifies actions that constitute a transaction. For example, an AP can be a precompiler or OCI program. The AP operates on the RM's resource through its native interface, for example, SQL.

TX Interface

An application program starts and completes all transaction control operations through the TM by means of an interface called **TX**. The AP does not directly use the XA interface. APs are not aware of branches that fork in the middle-tier: application threads do not explicitly join, leave, suspend, and resume branch work, instead the TM portion of the transaction processing monitor manages the branches of a global transaction for APs. Ultimately, APs call the TM to commit all-or-none.

Note: The naming conventions for the TX interface and associated subroutines are vendor-specific. For example, the `tx_open` call may be referred to as `tp_open` on your system. In some cases, the calls may be implicit, for example, at the entry to a transactional RPC. Refer to the documentation supplied with the transaction processing monitor for details.

Tight and Loose Coupling

Application threads are tightly coupled if the RM considers them as a single entity for all isolation semantic purposes. Tightly coupled branches must see changes in each other. Furthermore, an external client must either see all changes of a tightly coupled set or none of the changes. If application threads are not tightly coupled, then they are loosely coupled.

Dynamic and Static Registration

Oracle Database supports both dynamic and static registration. In dynamic registration, the RM executes an application callback before starting any work. In static registration, you must call `xa_start()` for each RM before starting any work, even if some RMs are not involved.

Required Public Information

As a resource manager, Oracle Database is required to publish the information described in Table 15–1.

Table 15–1 Required XA Features Published by Oracle Database

XA Feature	Oracle Database Details
`xa_switch_t` structures	The Oracle Database `xa_switch_t` structure name is `xaosw` for static registration and `xaoswd` for dynamic registration. These structures contain entry points and other information for the resource manager.
`xa_switch_t` resource manager	The Oracle Database resource manager name within the `xa_switch_t` structure is `Oracle_XA`.
Close string	The close string used by `xa_close()` is ignored and can be null.
Open string	The format of the open string used by `xa_open()` is described in detail in "Defining the xa_open() String" on page 15-7.
Libraries	Libraries needed to link applications using Oracle XA have platform-specific names. The procedure is similar to linking an ordinary precompiler or OCI program except that you may have to link any TPM-specific libraries. If you are not using `sqllib`, then link with `$ORACLE_HOME/rdbms/lib/xaonsl.o` or `$ORACLE_HOME/rdbms/lib32/xaonsl.o` (for 32 bit application on 64 bit platforms).
Requirements	None. The functionality to support XA is part of both Standard Edition and Enterprise Edition.

Oracle XA Library Interface Subroutines

The Oracle XA library subroutines enable a TM to instruct Oracle Database how to process transactions. Generally, the TM must open the resource by using `xa_open()`.

Typically, the opening of the resource results from the AP's call to `tx_open`. Some TMs may call `xa_open()` implicitly when the application begins.

Similarly, there is a close (using `xa_close()`) that occurs when the application is finished with the resource. The close may occur when the AP calls `tx_close` or when the application terminates.

The TM instructs the RMs to perform several other tasks, which include the following:

- Starting a new transaction and associating it with an ID
- Rolling back a transaction
- Preparing and committing a transaction

XA Library Subroutines

XA Library subroutines are described in Table 15–2.

Table 15–2 XA Library Subroutines

XA Subroutine	Description
`xa_open()`	Connects to the RM.
`xa_close()`	Disconnects from the RM.
`xa_start()`	Starts a new transaction and associates it with the given transaction ID (XID), or associates the process with an existing transaction.
`xa_end()`	Disassociates the process from the given XID.
`xa_rollback()`	Rolls back the transaction associated with the given XID.
`xa_prepare()`	Prepares the transaction associated with the given XID. This is the first phase of the two-phase commit protocol.
`xa_commit()`	Commits the transaction associated with the given XID. This is the second phase of the two-phase commit protocol.
`xa_recover()`	Retrieves a list of prepared, heuristically committed, or heuristically rolled back transactions.
`xa_forget()`	Forgets the heuristically completed transaction associated with the given XID.

In general, the AP does not need to worry about the subroutines in Table 15–2 except to understand the role played by the `xa_open()` string.

Extensions to the XA Interface

Oracle Database's XA interface includes some additional functions, which are described in Table 15–3.

Table 15–3 Additional Functions in the XA Interface for Oracle Database

Function	Description
`OCISvcCtx *xaoSvcCtx(text *dbname)`	Returns the OCI service handle for a given XA connection. The `dbname` parameter must be the same as the `DB` parameter passed in the `xa_open()` string. OCI applications can use this routing instead of the `sqlld2` calls to obtain the connection handle. Hence, OCI applications need not link with the `sqllib` library. The service handle can be converted to the Version 7 OCI logon data area (LDA) by using `OCISvcCtxToLda()` [Version 8 OCI]. Client applications must remember to convert the Version 7 LDA to a service handle by using `OCILdaToSvcCtx()` after completing the OCI calls.
`OCIEnv *xaoEnv(text *dbname)`	Returns the OCI environment handle for a given XA connection. The `dbname` parameter must be the same as the `DB` parameter passed in the `xa_open()` string.
`int xaosterr(OCISvcCtx *SvcCtx,sb4 error)`	Converts an Oracle Database error code to an XA error code (only applicable to dynamic registration). The first parameter is the service handle used to execute the work in the database. The second parameter is the error code that was returned from Oracle Database. Use this function to determine if the error returned from an OCI command was caused because the `xa_start()` failed. The function returns XA_OK if the error was not generated by the XA module or a valid XA error if the error was generated by the XA module.

Developing and Installing XA Applications

This section discusses developing and installing Oracle XA applications:

- Responsibilities of the DBA or System Administrator
- Responsibilities of the Application Developer
- Defining the xa_open() String
- Interfacing XA with Precompilers and OCI
- Managing Transaction Control with XA
- Migrating Precompiler or OCI Applications to TPM Applications
- Managing XA Library Thread Safety

Responsibilities of the DBA or System Administrator

The responsibilities of the DBA or system administrator are as follows:

1. Define the open string, with help from the application developer. This task is described in "Defining the xa_open() String" on page 15-7.
2. Make sure the `DBA_PENDING_TRANSACTIONS` view exists and grant the `SELECT` privilege to the view for all Oracle users specified in the `xa_open()` string.

   In Oracle Database version 7 client applications, all Oracle Database accounts used by Oracle XA library must have the `SELECT` privilege on the `V$XATRANS$` view. This view should have been created during the XA library installation. If necessary, you can manually create the view by running the SQL script `xaview.sql` as Oracle Database user `SYS`.

See Also: Your Oracle Database platform-specific documentation for the location of the `catxpend.sql` script

3. Using the open string information, install the RM into the TPM configuration. Follow the TPM vendor instructions.

   The DBA or system administrator should be aware that a TPM system starts the process that connects to Oracle Database. Refer to your TPM documentation to determine what environment exists for the process and what user ID it will have. Be sure that correct values are set for `$ORACLE_HOME` and `$ORACLE_SID` in this environment.

4. Grant the user ID write permission to the directory in which the system will write the XA trace file.

   See Also: "Defining the xa_open() String" on page 15-7 for information on how to specify an Oracle System Identifier (SID) or a trace directory that is different from the defaults

5. Start the relevant database instances to bring Oracle XA applications on-line. You should perform this task before starting any TPM servers.

Responsibilities of the Application Developer

The responsibilities of the application developer are as follows:

1. Define the open string with help from the DBA or system administrator, as explained in "Defining the xa_open() String" on page 15-7.
2. Develop the applications.

   Observe special restrictions on transaction-oriented SQL statements for precompilers.

   See Also: "Interfacing XA with Precompilers and OCI" on page 15-10

3. Link the application according to TPM vendor instructions.

Defining the xa_open() String

The open string is used by the transaction monitor to open the database. The maximum number of characters in an open string is 256.

This section covers:

- Syntax of the xa_open() String
- Required Fields for the xa_open() String
- Optional Fields for the xa_open() String

Syntax of the xa_open() String

You can define an open string with the syntax shown in Example 15–1.

Example 15–1 xa_open() String

```
ORACLE_XA{+required_fields...} [+optional_fields...]
```

The following strings shows sample parameter settings:

```
ORACLE_XA+DB=MANAGERS+SqlNet=SID1+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+DB=PAYROLL+SqlNet=SID2+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+SqlNet=SID3+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
```

The following sections describe valid parameters for the *required_fields* and *optional_fields* placeholders.

Note:

- You can enter the required fields and optional fields *in any order* when constructing the open string.
- All field names are case insensitive. Their values may or may not be case-sensitive depending on the platform.
- There is no way to use the plus character (+) as part of the actual information string.

Required Fields for the xa_open() String

The *required_fields* placeholder in Example 15–1 refers to any of the following name-value pairs described in Table 15–4.

Table 15–4 Required Fields for the xa_open() string

Syntax Element	Description
`Acc=P//`	Indicates that no explicit user or password information is provided and that the operating system authentication form will be used. For more information refer to *Oracle Database Administrator's Guide*.
`Acc=P/`*user*`/`*password*	Specifies the username and password for a valid Oracle Database account. For example, `Acc=P/hr/hr` indicates that the user is `hr` and the password is `hr`. As described in "Responsibilities of the DBA or System Administrator" on page 15-6, make sure that hr has the `SELECT` privilege on the `DBA_PENDING_TRANSACTIONS` table.
`SesTm=`*session_time_limit*	Specifies the maximum number of seconds allowed in a transaction between one service and the next, or between a service and the commit or rollback of the transaction, before the system aborts the transaction. For example, `SesTM=15` indicates that the session idle time limit is 15 seconds. For example, if the TPM uses remote procedure calls between the client and the servers, then `SesTM` applies to the time between the completion of one RPC and the initiation of the next RPC, or the `tx_commit`, or the `tx_rollback`. The value of `0` indicates no limit. Entering a value of `0` is strongly *discouraged*. It might tie up resources for a long time if something goes wrong. Also, if a child process has `SesTM=0`, then the `SesTM` setting is not effective after the parent process is terminated.

Optional Fields for the xa_open() String

The *optional_fields* placeholder in Example 15–1 refers to any of the following name-value pairs described in Table 15–5.

Table 15–5 Optional Fields in the xa_open() String

Syntax Element	Description
`NoLocal= true | false`	Specifies whether local transactions are allowed. The default value is `false`. If the application needs to disallow local transactions, then set the value to `true`.
`DB=`*`db_name`*	Indicates the name used by Oracle Database precompilers to identify the database. For example, `DB=payroll` indicates that the database name is payroll and that the application server program will use that name in `AT` clauses. Application programs that use only the default database for the Oracle Database precompiler (that is, they do not use the `AT` clause in their SQL statements) should omit the `DB=`*`db_name`* clause in the open string. Applications that use explicitly named databases should indicate that database name in their `DB=`*`db_name`* field. Oracle Database Version 7 OCI programs need to call the `sqlld2()` function to obtain the correct context for logon data area (`Lda_Def`), which is the equivalent of an OCI service context. Version 8 and higher OCI programs need to call the `xaoSvcCtx()` function to get the `OCISvcCtx` service context. The *`db_name`* is not the sid and is not used to locate the database to be opened. Rather, it correlates the database opened by this open string with the name used in the application program to execute SQL statements. The sid is set from either the environment variable `ORACLE_SID` of the TPM application server or the sid given in the Oracle Net clause in the open string. The Oracle Net clause is described later in this section. Some TPM vendors provide a way to name a group of servers that use the same open string. You may find it convenient to choose the same name both for that purpose and for db_name.
`LogDir=`*`log_dir`*	Specifies the path name on the local machine where the Oracle XA library error and tracing information should be logged. The default is `$ORACLE_HOME/rdbms/log` if `ORACLE_HOME` is set; otherwise, it specifies the current directory. For example, `LogDir=/xa_trace` indicates that the logging information is located under the `/xa_trace` directory. Ensure that the directory exists and the application server can write to it.
`Objects= true | false`	Specifies whether the application is initialized in object mode. The default value is false. If the application needs to use certain API calls that require object mode, such as `OCIRawAssignBytes()`, then set the value to `true`.
`MaxCur=`*`maximum_#_of_open_cursors`*	Specifies the number of cursors to be allocated when the database is opened. It serves the same purpose as the precompiler option `maxopencursors`. For example, `MaxCur=5` indicates that the precompiler should try to keep five open cursors cached. Note that this parameter overrides the precompiler option `maxopencursors` that you might have specified in your source code or at compile time.
`SqlNet=`*`db_link`*	Specifies the Oracle Net database link to use to log on to the system. This string should be an entry in `tnsnames.ora`. For example, the string `SqlNet=inst1_disp` might connect to a shared server at instance 1 if so defined in `tnsnames.ora`. You can use the `SqlNet` parameter to specify the `ORACLE_SID` in cases where you cannot control the server environment variable. You must also use it when the server needs to access more than one Oracle Database instance. To use the Oracle Net string without actually accessing a remote database, use the Pipe driver. For example, specify `SqlNet=localsid1`, where `localsid1` is an alias defined in the `tnsnames.ora` file.

Table 15–5 (Cont.) Optional Fields in the xa_open() String

Syntax Element	Description
`Loose_Coupling=true | false`	Specifies whether locks are shared. Oracle Database transaction branches within the same global transaction can be coupled tightly or loosely. If branches are loosely coupled, then they do not share locks. Set the value to `true` for loosely coupled branches. If branches are tightly coupled, then they share locks. Set the value to `false` for tightly coupled branches. The default value is `false`. However, if branches are landed on different RAC instances when running Oracle Real Application Clusters, they are loosely coupled even if the value is set to `false`. Refer to "Managing Transaction Branches in XA Applications" on page 15-19 for more information.
`SesWt=`*`session_wait_limit`*	Specifies the number of seconds Oracle Database waits for a transaction branch that is being used by another session before `XA_RETRY` is returned. The default value is 60 seconds.
`Threads=true | false`	Specifies whether the application is multithreaded. The default value is `false`. If the application is multithreaded, then the setting is `true`.

Interfacing XA with Precompilers and OCI

This section describes how to use the Oracle XA library with precompilers and Oracle Call Interface (OCI). It contains the following subsections:

- Using Precompilers with the Oracle XA Library
- Using OCI with the Oracle XA Library

Using Precompilers with the Oracle XA Library

When used in an Oracle XA application, cursors are valid only for the duration of the transaction. Explicit cursors should be opened after the transaction begins, and closed before the commit or rollback.

You have the following options when interfacing with precompilers:

- Using Precompilers with the Default Database
- Using Precompilers with a Named Database

The following examples use the precompiler Pro*C/C++.

Using Precompilers with the Default Database To interface to a precompiler with the default database, make certain that the `DB=`*db_name* field used in the open string is not present. The absence of this field indicates the default connection. Only one default connection is allowed for each process.

The following is an example of an open string identifying a default Pro*C/C++ connection.

```
ORACLE_XA+SqlNet=maildb+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/logs
```

Note that the `DB=`d*b_name* is absent, indicating an empty database ID string.

The syntax of a SQL statement would be:

```
EXEC SQL UPDATE Emp_tab SET Sal = Sal*1.5;
```

Using Precompilers with a Named Database To interface to a precompiler with a named database, include the DB=*db_name* field in the open string. Any database you refer to must reference the same *db_name* you specified in the corresponding open string.

An application may include the default database as well as one or more named databases.For example, suppose you want to update an employee's salary in one database, his department number (DEPTNO) in another, and his manager in a third database. You would configure the following open strings in the transaction manager:

Example 15–2 Sample Open String Configuration

```
ORACLE_XA+DB=MANAGERS+SqlNet=SID1+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+DB=PAYROLL+SqlNet=SID2+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+SqlNet=SID3+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
```

Note that there is no DB=*db_name* field in the last open string in Example 15–2.

In the application server program, you would enter declarations such as:

```
EXEC SQL DECLARE PAYROLL DATABASE;
EXEC SQL DECLARE MANAGERS DATABASE;
```

Again, the default connection (corresponding to the third open string that does not contain the DB field) needs no declaration.

When doing the update, you would enter statements similar to the following:

```
EXEC SQL AT PAYROLL UPDATE Emp_Tab SET Sal=4500 WHERE Empno=7788;
EXEC SQL AT MANAGERS UPDATE Emp_Tab SET Mgr=7566 WHERE Empno=7788;
EXEC SQL UPDATE Emp_Tab SET Deptno=30 WHERE Empno=7788;
```

There is no AT clause in the last statement because it is referring to the default database.

In Oracle Database precompilers release 1.5.3 or later, you can use a character host variable in the AT clause, as the following example shows:

```
EXEC SQL BEGIN DECLARE SECTION;
  DB_NAME1 CHARACTER(10);
  DB_NAME2 CHARACTER(10);
EXEC SQL END DECLARE SECTION;
    ...
SET DB_NAME1 = 'PAYROLL'
SET DB_NAME2 = 'MANAGERS'
    ...
EXEC SQL AT :DB_NAME1 UPDATE...
EXEC SQL AT :DB_NAME2 UPDATE...
```

> **Caution:** Do not have XA applications create connections other than the ones created through xa_open(). Any work performed on non-XA connections would be outside the global transaction and would have to be committed separately.

Using OCI with the Oracle XA Library

Oracle Call Interface applications that use the Oracle XA library should not call OCISessionBegin() to log on to the resource manager. Rather, the logon should be

done through the TPM. The applications can execute the function `xaoSvcCtx()` to obtain the service context structure when they need to access the resource manager.

In applications that need to pass the environment handle to OCI functions, you can also call `xaoEnv()` to find that handle.

Because an application server can have multiple concurrent open Oracle Database resource managers, it should call the function `xaoSvcCtx()` with the correct arguments to obtain the correct service context.

> **See Also:** *Oracle Call Interface Programmer's Guide* for more information about using the `OCISvcCtx` handle

Managing Transaction Control with XA

When you use the XA library, transactions are not controlled by the SQL statements that commit or roll back transactions. Rather, they are controlled by an API accepted by the TM that starts and stops transactions. You call the API that is provided by the transaction manager, including the TX interface listed in Table 15–6, but not the XA Library Subroutines listed in Table 15–2.

The TMs typically control the transactions through the XA interface. This interface includes the functions described in Table 15–2, " XA Library Subroutines".

Table 15–6 TX Interface Functions

TX Function	Description
`tx_open`	Logs into the resource manager(s)
`tx_close`	Logs out of the resource manager(s)
`tx_begin`	Starts a new transaction
`tx_commit`	Commits a transaction
`tx_rollback`	Rolls back the transaction

Most TPM applications use a client/server architecture in which an application client requests services and an application server provides them. The examples shown in "Examples of Precompiler Applications" on page 15-13 use such a client/server model. A service is a logical unit of work, which in the case of Oracle Database as the resource manager, comprises a set of SQL statements that perform a related unit of work.

For example, when a service named "credit" receives an account number and the amount to be credited, it executes SQL statements to update information in certain tables in the database. In addition, a service might request other services. For example, a "transfer fund" service might request services from a "credit" and "debit" service.

Typically, application clients request services from the application servers to perform tasks within a transaction. For some TPM systems, however, the application client itself can offer its own local services. As shown in "Examples of Precompiler Applications" on page 15-13, you can encode transaction control statements within either the client or the server.

To have more than one process participating in the same transaction, the TPM provides a communication API that enables transaction information to flow between the participating processes. Examples of communications APIs include RPC, pseudo-RPC functions, and send/receive functions.

Because the leading vendors support different communication functions, the examples that follow use the communication pseudo-function `tpm_service` to generalize the communications API.

X/Open includes several alternative methods for providing communication functions in their preliminary specification. At least one of these alternatives is supported by each of the leading TPM vendors.

Examples of Precompiler Applications

The following examples illustrate precompiler applications. Assume that the application server has already logged onto the RMs system, in a TPM-specific manner. Example 15–3 shows a transaction started by an application server.

Example 15–3 Transaction Started by an Application Server

```
/***** Client: *****/
tpm_service("ServiceName");              /*Request Service*/

/***** Server: *****/
ServiceName()
{
  <get service specific data>
  tx_begin();                              /* Begin transaction boundary */
  EXEC SQL UPDATE ....;

  /* This application server temporarily becomes */
  /* a client and requests another service. */

  tpm_service("AnotherService");
  tx_commit();                              /* Commit the transaction */
  <return service status back to the client>
}
```

Example 15–4 shows a transaction started by an application client.

Example 15–4 Transaction Started by an Application Client

```
/***** Client: *****/
tx_begin();                              /* Begin transaction boundary */
tpm_service("Service1");
tpm_service("Service2");
tx_commit();                             /* Commit the transaction */

/***** Server: *****/
Service1()
{
  <get service specific data>
  EXEC SQL UPDATE ....;
  <return service status back to the client>
}
Service2()
{
  <get service specific data>
  EXEC SQL UPDATE ....;
  ...
  <return service status back to client>
}
```

Migrating Precompiler or OCI Applications to TPM Applications

To migrate existing precompiler or OCI applications to a TPM application that uses the Oracle XA library, you must do the following:

1. Reorganize the application into a framework of "services" so that application clients request services from application servers. Some TPMs require the application to use the `tx_open and tx_close` functions, whereas other TPMs do the logon and logoff implicitly.

   If you do not specify the `SqlNet` parameter in your open string, then the application uses the default Oracle Net driver. Thus, be sure that the application server is brought up with the `ORACLE_HOME` and `ORACLE_SID` environment variables properly defined. This is accomplished in a TPM-specific fashion. Refer to your TPM vendor documentation for instructions on how to accomplish this.

2. Ensure that the application replaces the regular connect and disconnect statements. For example, replace the connect statements `EXEC SQL CONNECT` (for precompilers) or `OCISessionBegin(), OCIServerAttach()`, and `OCIEnvCreate()` (for OCI) with `tx_open()`. Replace the disconnect statements `EXEC SQL COMMIT/ROLLBACK WORK RELEASE` (for precompilers) or `OCISessionEnd()/OCIServerDetach` (for OCI) with `tx_close()`.

3. Ensure that the application replaces the regular commit or rollback statements for any global transactions and begins the transaction explicitly.

   For example, replace the `COMMIT/ROLLBACK` statements `EXEC SQL COMMIT/ROLLBACK WORK` (for precompilers), or `OCITransCommit()/OCITransRollback()` (for OCI) with `tx_commit()/tx_rollback()` and start the transaction by calling `tx_begin()`.

   > **Note:** The preceding is only true for global rather than local transactions. You should commit or roll back local transactions with the Oracle API.

4. Ensure that the application resets the fetch state before ending a transaction. In general, you should use `release_cursor=no`. Use `release_cursor=yes` only when you are certain that a statement will be executed only once.

Table 15–7 lists the TPM functions that replace regular Oracle Database commands when migrating precompiler or OCI applications to TPM applications.

Table 15–7 TPM Replacement Commands

Regular Oracle Database Commands	TPM Functions
`CONNECT` *`user/password`*	`tx_open` (possibly implicit)
implicit start of transaction	`tx_begin`
`SQL`	Service that executes the SQL
`COMMIT`	`tx_commit`
`ROLLBACK`	`tx_rollback`
disconnect	`tx_close` (possibly implicit)

Managing XA Library Thread Safety

If you use a transaction monitor that supports threads, then the Oracle XA library enables you to write applications that are thread safe. Nevertheless, you should keep certain issues in mind.

A **thread of control** (or thread) refers to the set of connections to resource managers. In an nonthreaded system, each process could be considered a thread of control because each process has its own set of connections to RMs and maintains its own independent resource manager table. In a threaded system, each thread has an autonomous set of connections to RMs and each thread maintains a *private* RM table. This private table must be allocated for each new thread and de-allocated when the thread terminates, even if the termination is abnormal.

Note: In Oracle Database, each thread that accesses the database must have its own connection.

Specifying Threading in the Open String

The `xa_open()` string provides the clause `Threads=`. You must specify this clause as `true` to enable the use of threads by the TM. The default is `false`. In most cases, the TM creates the threads; the application does not know when a new thread is created. Therefore, it is advisable to allocate a service context on the stack within each service that is written for a TM application. Before doing any Oracle Database-related calls in that service, you must call the `xaoSvcCtx` function to retrieve the initialized OCI service context. You can then use this context for OCI calls within the service.

Restrictions on Threading in XA

The following restrictions apply when using threads:

- Any Pro* or OCI code that executes as part of the application server process on the transaction monitor cannot be threaded unless the transaction monitor is explicitly told when each new application thread is started. This is typically accomplished by using a special C compiler provided by the TM vendor.
- The Pro* statements `EXEC SQL ALLOCATE` and `EXEC SQL USE` are not supported. Therefore, when threading is enabled, you cannot use embedded SQL statements across non-XA connections.
- If one thread in a process connects to Oracle Database through XA, then all other threads in the process that connect to Oracle Database must also connect through XA. You cannot connect through `EXEC SQL CONNECT` in one thread and through `xa_open()` in another thread.

Troubleshooting XA Applications

This section discusses how to find information in case of problems or system failure. It also discusses trace files and recovery of pending transactions. This section contains the following topics:

- Accessing XA Trace Files
- Managing In-Doubt or Pending Transactions
- Using SYS Account Tables to Monitor XA Transactions

Accessing XA Trace Files

The Oracle XA library logs any error and tracing information to its trace file. This information is useful in supplementing the XA error codes. For example, it can indicate whether an `xa_open()` failure is caused by an incorrect open string, failure to find the Oracle Database instance, or a logon authorization failure.

The name of the trace file is `xa_`*`db_namedate`*`.trc`, where `db_name` is the database name specified in the open string field `DB=`*`db_name`*, and `date` is the date when the information is logged to the trace file. If you do not specify `DB=`*`db_name`* in the open string, then it automatically defaults to the name `NULL`.

For example, xa_NULL06022005.trc indicates a trace file that was created on June 2, 2005. Its `DB` field was not specified in the open string when the resource manager was opened. The filename `xa_Finance12152004.trc` indicates a trace file was created on December 15, 2004. Its `DB` field was specified as "Finance" in the open string when the resource manager was opened.

> **Note:** Multiple Oracle XA library resource managers with the same `DB` field and `LogDir` field in their open strings log all trace information that occurs on the same day to the same trace file.

Suppose that a trace file contains the following contents:

```
1032.12345.2:  ORA-01017:  invalid username/password;  logon denied
1032.12345.2:  xaolgn:  XAER_INVAL;  logon denied
```

Table 15–8 explains the meaning of each element.

Table 15–8 Sample Trace File Contents

String	Description
`1032`	The time when the information is logged.
`12345`	The process ID (PID).
`2`	The resource manager ID.
`xaolgn`	The name of the module.
`XAER_INVAL`	The error returned as specified in the XA standard.
`ORA-01017`	The Oracle Database information that was returned.

The xa_open() String DbgFl

Normally, the XA trace file is opened only if an error is detected. The `xa_open()` string `DbgFl` provides a tracing facility to record additional detail about the XA library. By default, its value is zero. You can set it to any combination of the following values:

- `0x1`, which enables you to trace the entry and exit to each procedure in the XA interface. This value can be useful in seeing exactly which XA calls the TP Monitor is making and which transaction identifier it is generating.
- `0x2`, which enables you to trace the entry to and exit from other non-public XA library routines. This is generally of use only to Oracle Database developers.
- `0x4`, which enables you to trace various other "interesting" calls made by the XA library, such as specific calls to the OCI. This is generally of use only to Oracle Database developers.

Note: The flags are independent bits of an `ub4`, so to obtain printout from two or more flags, you must set a combined value of the flags.

Trace File Locations

The XA application determines a location for the trace file according to the following algorithm:

1. The `LogDir` directory specified in the open string.
2. If you do not specify `LogDir` in the open string, then the Oracle XA application attempts to create the trace file in the following directory (if the Oracle home is accessible):
   - `%ORACLE_HOME%\rdbms\trace` on Windows
   - `$ORACLE_HOME/rdbms/log` on UNIX
3. If the Oracle XA application cannot determine where the Oracle home is located, then the application creates the trace file in the current working directory.

Managing In-Doubt or Pending Transactions

In-doubt or pending transactions are transactions that have been prepared but not yet committed to the database. In general, the TM provided by the TPM system should resolve any failure and recovery of in-doubt or pending transactions. The DBA may have to override an in-doubt transaction if the following situations occur:

- It is locking data that is required by other transactions.
- It is not resolved in a reasonable amount of time.

Refer to the TPM documentation for more information about overriding in-doubt transactions in such circumstances and about how to decide whether the in-doubt transaction should be committed or rolled back.

Using SYS Account Tables to Monitor XA Transactions

The following views under the Oracle Database `SYS` account contain transactions generated by regular Oracle Database applications and Oracle XA applications:

- `DBA_PENDING_TRANSACTIONS`
- `V$GLOBAL_TRANSACTION`
- `DBA_2PC_PENDING`
- `DBA_2PC_NEIGHBORS`

For transactions generated by Oracle XA applications, the following column information applies specifically to the `DBA_2PC_NEIGHBORS` table:

- The `DBID` column is always `xa_orcl`
- The `DBUSER_OWNER` column is always *db_name*`xa.oracle.com`

Remember that the *db_name* is always specified as `DB=`*db_name* in the open string. If you do not specify this field in the open string, then the value of this column is `NULLxa.oracle.com` for transactions generated by Oracle XA applications.

For example, you could use the following SQL statement to obtain more information about in-doubt transactions generated by Oracle XA applications.

```
SELECT *
FROM DBA_2PC_PENDING p, DBA_2PC_NEIGHBORS n
WHERE p.LOCAL_TRAN_ID = n.LOCAL_TRAN_ID
AND n.DBID = 'xa_orcl';
```

Alternatively, if you know the format `ID` used by the transaction processing monitor, then you can use `DBA_PENDING_TRANSACTIONS` or `V$GLOBAL_TRANSACTION`. Whereas `DBA_PENDING_TRANSACTIONS` gives a list of prepared transactions, `V$GLOBAL_TRANSACTION` provides a list of all active global transactions.

XA Issues and Restrictions

This section contains the following topics:

- Using Database Links in XA Applications
- Managing Transaction Branches in XA Applications
- Using XA with Oracle Real Application Clusters
- SQL-Based XA Restrictions
- Miscellaneous Restrictions

Using Database Links in XA Applications

Oracle XA applications can access other Oracle Database instances through database links with the following restrictions:

- They must use the shared server configuration.

  The transaction processing monitors (TPMs) use shared servers to open the connection to an Oracle Database A. Then the operating system network connection required for the database link is opened by the dispatcher instead of a dedicated server process. This allows different services or threads to operate on the transaction.

  If this restriction is not satisfied, then when you use database links within an XA transaction, it creates an operating system network connection between the dedicated server process and the other Oracle Database B. Because this network connection cannot be moved from one dedicated server process to another, you cannot detach from this dedicated server process of database A. Then when you access the database B through a database link, you receive an ORA-24777 error.

- The other database being accessed should be another *Oracle Database*.

Assuming that these restrictions are satisfied, Oracle Database allows such links and propagates the transaction protocol (prepare, rollback, and commit) to the other Oracle Database instances.

If using the shared server configuration is not possible, then access the remote database through the Pro*C/C++ application by using `EXEC SQL AT` syntax.

The `init.ora` parameter `OPEN_LINKS_PER_INSTANCE` specifies the number of open database link connections that can be migrated. These `dblink` connections are used by XA transactions so that the connections are cached after a transaction is committed. Another transaction is free to use the database link connection provided the user that created the connection is the same as the user who created the transaction. This parameter is different from the `init.ora` parameter `OPEN_LINKS`, which specifies the maximum number of concurrent open connections (including

database links) to remote databases in one session. The `OPEN_LINKS` parameter is not applicable to XA applications.

Managing Transaction Branches in XA Applications

Oracle Database transaction branches within the same global transaction can be coupled tightly or loosely. If the transaction branches are **tightly coupled**, then they share locks. Consequently, pre-`COMMIT` updates in one transaction branch are visible in other branches that belong to the same global transaction. In loosely coupled transaction branches, the branches do not share locks and do not see updates in other branches.

In a tightly coupled branch, Oracle Database obtains the DX lock before executing any statement. Because the system does not obtain a lock before executing the statement, loosely coupled transaction branches result in greater concurrency. The disadvantage is that all transaction branches must go through the two phases of commit, that is, the system cannot use XA one-phase optimization.

Table 15–9 summarizes the trade-offs between tightly coupled branches and loosely coupled branches.

Table 15–9 Tightly and Loosely Coupled Transaction Branches

Attribute	Tightly Coupled Branches	Loosely Coupled Branches
Two Phase Commit	Read-only optimization	Two phases
	[prepare for all branches, commit for last branch]	[prepare and commit for all branches]
Serialization	Database call	None

Using XA with Oracle Real Application Clusters

This section contains the following topics:

- Managing Transaction Branches on Oracle Real Application Clusters (RAC)
- Managing Instance Recovery in Real Application Clusters
- Global Uniqueness of XIDs in Real Application Clusters

Managing Transaction Branches on Oracle Real Application Clusters (RAC)

Oracle Database permits different instances to operate on different transaction branches in RAC. For example, Node 1 can operate on branch A while Node 2 operates on branch B. If transaction branches are on different instances, then they are loosely coupled and do not share locks. In this case, Oracle Database treats different units of work in different application threads as separate entities that do not share resources.

A different case is when multiple instances operate on a single transaction branch. For example, assume that a single transaction lands on Node 1 and Node 2 as follows:

Node 1

1. `xa_start()`
2. SQL operations
3. `xa_end()` (SUSPEND)

Node 2

1. `xa_start()` (RESUME)
2. `xa_prepare()`
3. `xa_commit()`
4. `xa_end()`

In the previous sequence, Oracle Database returns an error because Node 2 should not resume a branch that is physically located on a different node (Node 1).

The way to achieve tight coupling in RAC is to use **DTP services**, that is, services whose cardinality (one) ensures that all tightly-coupled branches land on the same instance—whether or not load balancing is enabled. Mid-tier components address Oracle Database by means of a common logical database service name that maps to a single RAC instance at any point in time. An intermediate name resolver for the database service hides the physical characteristics of the database instance. DTP services enable all participants of a tightly-coupled global transaction to create branches on one instance.

For example, when you use a DTP service, the following sequence of actions occurs on the same instance:

1. `xa_start()`
2. SQL operations
3. `xa_end()` (SUSPEND)
4. `xa_start()` (RESUME)
5. SQL operations
6. `xa_prepare()`
7. `xa_commit()` or `xa_rollback()`

Moreover, multiple tightly-coupled branches land on the same instance if each addresses the Oracle RM with the same DTP service.

To leverage all instances in the cluster, create multiple DTP services, with one or more on each node that hosts distributed transactions. All branches of a global distributed transaction exist on the same instance. Thus, you can leverage all instances and nodes of a RAC cluster to balance the load of many distributed XA transactions, thereby maximizing application throughput.

> **See Also:** *Oracle Database Oracle Clusterware and Oracle Real Application Clusters Administration and Deployment Guide* to learn how to manage distributed transactions in a Real Application Clusters configuration.

Managing Instance Recovery in Real Application Clusters

Prior to Oracle Database 10g Release 2 (10.2), the onus of detecting failure and triggering failover and failback in RAC was on the TM. In order to ensure information about in-doubt transactions is propagated to DBA_2PC_PENDING, TM was required to invoke `xa_recover()` before TM can proceed to resolve the in-doubt transactions. If an instance failed, then the XA client library could not fail over to another instance until it had run the `SYS.DBMS_SYSTEM.DIST_TXN_SYNC` procedure to ensure that the undo segments of the failed instance were recovered. In the current release there is no such requirement to invoke `xa_recover()` in cases where the TM has enough information about in-flight transactions.

Note: In releases subsequent to Oracle Database 9*i* Release 2, `xa_recover()` is required to wait for distributed DML to complete on remote sites.

Using DTP services in RAC has the following benefits:

- Automates instance failure detection.
- Automates instance failover and failback. When an instance fails, the DTP service hosted on this instance fails over to another instance. The failover forces clients to reconnect; nevertheless, the logical names for the service remain the same. Failover is automatic and does not require an administrator intervention. The administrator can induce failback by a service relocate command, but all failback-related recovery is automatically handled within the database server.
- Enables Oracle Database rather than the client to drive instance recovery. The database does not require mid-tier TM involvement to determine the state of transactions prepared by other instances.

See Also: *Oracle Database Oracle Clusterware and Oracle Real Application Clusters Administration and Deployment Guide* to learn how to manage instance recovery

Global Uniqueness of XIDs in Real Application Clusters

The TM must maintain the global uniqueness of transaction IDs (XIDs). According to the XA specification, the RM must accept XIDs from the TM. XA on RAC cannot determine whether a given XID is unique throughout the cluster.

For example, suppose that there is an XID `Fmt(x).Tx(1).Br(1)` on RAC instance 1 and another XID `Fmt(x).Tx(1).Br(1)` on RAC instance 2. Each of these can start a branch and execute SQL even though the XID is not unique across RAC instances.

SQL-Based XA Restrictions

This section describes restrictions concerning the following SQL operations:

- Rollbacks and Commits
- DDL Statements
- Session State
- EXEC SQL

Rollbacks and Commits

Because the transaction manager is responsible for coordinating and monitoring the progress of the global transaction, the application should not contain any Oracle Database-specific statement that independently rolls back or commits a global transaction. However, you can use rollbacks and commits in a local transaction.

Do not use `EXEC SQL ROLLBACK WORK` for precompiler applications when you are in the middle of a global transaction. Similarly, an OCI application should not execute `OCITransRollback()`, or the Version 7 equivalent `orol()`. You can roll back a global transaction by calling `tx_rollback()`.

Similarly, a precompiler application should not have the `EXEC SQL COMMIT WORK` statement in the middle of a global transaction. An OCI application should not execute

OCITransCommit() or the Version 7 equivalent ocom(). For example, use tx_commit() or tx_rollback() to end a global transaction.

DDL Statements

Because a DDL SQL statement, such as CREATE TABLE, implies an implicit commit, the Oracle XA application cannot execute any DDL SQL statements.

Session State

Oracle Database does not guarantee that session state will be valid between TPM services. For example, if a TPM service updates a session variable (such as a global package variable), then another TPM service that executes as part of the same global transaction may not see the change. Use savepoints only within a TPM service. The application must not refer to a savepoint that was created in another TPM service. Similarly, an application must not attempt to fetch from a cursor that was executed in another TPM service.

EXEC SQL

Do not use the EXEC SQL command to connect or disconnect. That is, do not use EXEC SQL CONNECT, EXEC SQL COMMIT WORK RELEASE or EXEC SQL ROLLBACK WORK RELEASE.

Miscellaneous Restrictions

Note the following restrictions:

- Oracle Database does not support association migration (a means whereby a transaction manager may resume a suspended branch association in another branch).
- The optional XA feature asynchronous XA calls is not supported.
- Set the TRANSACTIONS initialization parameter to the expected number of concurrent global transactions. The initialization parameter OPEN_LINKS_PER_INSTANCE specifies the number of open database link connections that can be migrated. These database link connections are used by XA transactions so that the connections are cached after a transaction is committed.

  See Also: "Using Database Links in XA Applications" on page 15-18

- The maximum number of xa_open() calls for each thread is 32.
- When building an XA application based on TP-monitor, ensure that the TP-monitors libraries (that define the symbols ax_reg and ax_unreg) are placed in the link line before Oracle Database's client shared library. If your platform does not support shared libraries or if your linker is not sensitive to ordering of libraries in the link line, use Oracle Database's non-shared client library. These link restrictions are applicable only when using XA's dynamic registration (Oracle XA switch xaoswd).

16

Developing Applications on the Publish-Subscribe Model

Because the database is the most significant resource of information within the enterprise, Oracle created a publish-subscribe solution for enterprise information delivery and messaging to complement this role. Topics in this chapter include:

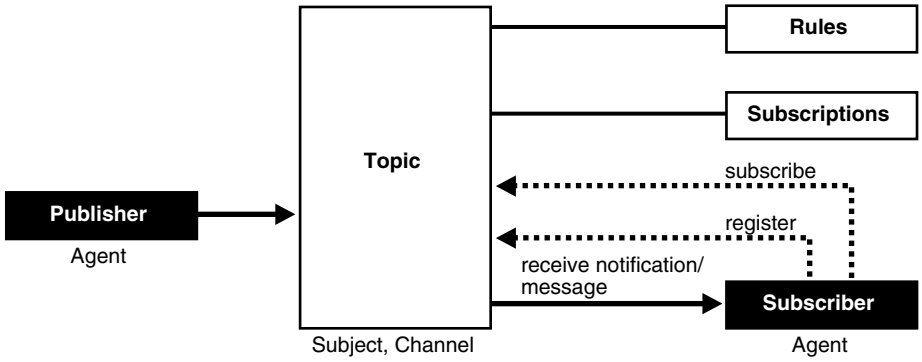
Introduction to Publish-Subscribe

Networking technologies and products enable a high degree of connectivity across a large number of computers, applications, and users. In these environments, it is important to provide asynchronous communications for the class of distributed systems that operate in a loosely-coupled and autonomous fashion, and which require operational immunity from network failures. This requirement has been filled by various middleware products that are characterized as messaging, message-oriented middleware (MOM), message queuing, or publish-subscribe.

Applications that communicate through a publish and subscribe paradigm require the sending applications (publishers) to publish messages without explicitly specifying recipients or having knowledge of intended recipients. Similarly, receiving applications (subscribers) must receive only those messages that the subscriber has registered an interest in.

This decoupling between senders and recipients is usually accomplished by an intervening entity between the publisher and the subscriber, which serves as a level of indirection. This intervening entity is a queue that represents a subject or channel. Figure 16–1 illustrates publish and subscribe functionality.

Figure 16–1 Oracle Publish-Subscribe Functionality



A subscriber subscribes to a queue by expressing interest in messages enqueued to that queue and by using a subject- or content-based rule as a filter. This results in a set of rule-based subscriptions associated with a given queue.

At runtime, publishers post messages to various queues. The queue (in other words, the delivery mechanisms of the underlying infrastructure) then delivers messages that match the various subscriptions to the appropriate subscribers.

Publish-Subscribe Architecture

Oracle Database includes the following features to support database-enabled publish-subscribe messaging:

- Database Events
- Advanced Queuing
- Client Notification

Database Events

Database events support declarative definitions for publishing database events, detection, and run-time publication of such events. This feature enables active publication of information to end-users in an event-driven manner, to complement the traditional pull-oriented approaches to accessing information.

> **See Also:** "Responding to System Events through Triggers" on page 9-37

Advanced Queuing

Oracle Advanced Queuing (AQ) supports a queue-based publish-subscribe paradigm. Database queues serve as a durable store for messages, along with capabilities to allow publish and subscribe based on queues. A rules-engine and subscription service dynamically route messages to recipients based on expressed interest. This allows decoupling of addressing between senders and receivers to complement the existing explicit sender-receiver message addressing.

> **See Also:** *Oracle Streams Advanced Queuing User's Guide and Reference*

Client Notification

Client notifications support asynchronous delivery of messages to interested subscribers. This enables database clients to register interest in certain queues, and it enables these clients to receive notifications when publications on such queues occur.

Asynchronous delivery of messages to database clients is in contrast to the traditional polling techniques used to retrieve information.

See Also: *Oracle Call Interface Programmer's Guide*

Publish-Subscribe Concepts

This section describes various concepts related to publish-subscribe.

queue

A queue is an entity that supports the notion of named subjects of interest. Queues can be characterized as:

non-persistent queue (lightweight queue)

The underlying queue infrastructure pushes the messages published to connected clients in a lightweight, at-best-once, manner.

persistent queue

Queues serve as durable containers for messages. Messages are delivered in a deferred and reliable mode.

agent

Publishers and subscribers are internally represented as agents. There is a distinction between an agent and a client.

An **agent** is a persistent logical subscribing entity that expresses interest in a queue through a subscription. An agent has properties, such as an associated subscription, an address, and a delivery mode for messages. In this context, an agent is an electronic proxy for a publisher or subscriber.

A **client** is a transient physical entity. The attributes of a client include the physical process where the client programs run, the node name, and the client application logic. There could be several clients acting on behalf of a single agent. Also, the same client, if authorized, can act on behalf of multiple agents.

rule on a queue

A rule on a queue is specified as a conditional expression using a predefined set of operators on the message format attributes or on the message header attributes. Each queue has an associated message content format that describes the structure of the messages represented by that queue. The message format may be unstructured (`RAW`) or it may have a well-defined structure (ADT). This allows both subject- or content-based subscriptions.

subscriber

Subscribers (agents) may specify subscriptions on a queue using a rule. Subscribers are durable and are stored in a catalog.

database event publication framework

The database represents a significant source for publishing information. An event framework is proposed to allow declarative definition of database event publication. As these pre-defined events occur, the framework detects and publishes such events. This allows active delivery of information to end-users in an event-driven manner as part of the publish-subscribe capability.

registration

Registration is the process of associated delivery information by a given client, acting on behalf of an agent. There is an important distinction between the subscription and registration related to the agent/client separation.

Subscription indicates an interest in a particular queue by an agent. It does not specify where and how delivery must occur. Delivery information is a physical property that is associated with a client, and it is a transient manifestation of the logical agent (the subscriber). A specific client process acting on behalf of an agent registers delivery information by associating a host and port, indicating *where* the delivery should be done, and a callback, indicating *how* there delivery should be done.

publishing a message

Publishers publish messages to queues by using the appropriate queuing interfaces. The interfaces may depend on which model the queue is implemented on. For example, an enqueue call represents the publishing of a message.

rules engine

When a message is posted or published to a given queue, a rules engine extracts the set of candidate rules from all rules defined on that queue that match the published message.

subscription services

Corresponding to the list of candidate rules on a given queue, the set of subscribers that match the candidate rules can be evaluated. In turn, the set of agents corresponding to this subscription list can be determined and notified.

posting

The queue notifies all registered clients of the appropriate published messages. This concept is called **posting**. When the queue needs to notify all interested clients, it posts the message to all registered clients.

receive a message

A subscriber may receive messages through any of the following mechanisms:

- A client process acting on behalf of the subscriber specifies a callback using the registration mechanism. The posting mechanism then asynchronously invokes the callback when a message matches the subscriber's subscription. The message content may be passed to the callback function (non-persistent queues only).
- A client process acting on behalf of the subscriber specifies a callback using the registration mechanism. The posting mechanism then asynchronously invokes the callback function, but without the full message content. This serves as a notification to the client, which subsequently retrieves the message content in a pull fashion (persistent queues only).
- A client process acting on behalf of the subscriber simply retrieves messages from the queue in a periodic, or some other appropriate, manner. While the messages are deferred, there is no asynchronous delivery to the end-client.

Examples of a Publish-Subscribe Mechanism

Note: You may need to set up data structures, similar to the following, for certain examples to work:

```
CONNECT system/manager
DROP USER pubsub CASCADE;
CREATE USER pubsub IDENTIFIED BY pubsub;
GRANT CONNECT, RESOURCE TO pubsub;
GRANT EXECUTE ON DBMS_AQ to pubsub;
GRANT EXECUTE ON DBMS_AQADM to pubsub;
GRANT AQ_ADMINISTRATOR_ROLE TO pubsub;
CONNECT pubsub/pubsub
```

Scenario: This example shows how system events, client notification, and AQ work together to implement publish-subscribe.

- Create under the user schema, `pubsub`, with all objects necessary to support a publish-subscribe mechanism. In this particular code, the Agent `snoop` subscribe to messages that are published at logon events. Note that the user `pubsub` needs `AQ_ADMINISTRATOR_ROLE` privileges to use AQ functionality.

```
Rem ------------------------------------------------------
REM create queue table for persistent multiple consumers:
Rem ------------------------------------------------------

CONNECT pubsub/pubsub;

Rem  Create or replace a queue table
BEGIN
DBMS_AQADM.CREATE_QUEUE_TABLE(
   Queue_table        =>  'Pubsub.Raw_msg_table',
   Multiple_consumers =>   TRUE,
   Queue_payload_type =>  'RAW',
   Compatible         =>  '8.1');
END;
/
Rem ------------------------------------------------------
Rem  Create a persistent queue for publishing messages:
Rem ------------------------------------------------------

Rem  Create a queue for logon events
begin
BEGIN
   DBMS_AQADM.CREATE_QUEUE(
         Queue_name     =>   'Pubsub.Logon',
         Queue_table    =>   'Pubsub.Raw_msg_table',
         Comment        =>   'Q for error triggers');
END;
/

Rem ------------------------------------------------------
Rem  Start the queue:
Rem ------------------------------------------------------

BEGIN
   DBMS_AQADM.START_QUEUE('pubsub.logon');
END;
/
```

```
Rem ------------------------------------------------------
Rem  define new_enqueue for convenience:
Rem ------------------------------------------------------

CREATE OR REPLACE PROCEDURE New_enqueue(
               Queue_name      IN VARCHAR2,
               Payload         IN RAW ,
               Correlation     IN VARCHAR2 := NULL,
               Exception_queue IN VARCHAR2 := NULL)
AS

Enq_ct     DBMS_AQ.Enqueue_options_t;
Msg_prop   DBMS_AQ.Message_properties_t;
Enq_msgid  RAW(16);
Userdata   RAW(1000);

BEGIN
   Msg_prop.Exception_queue := Exception_queue;
   Msg_prop.Correlation := Correlation;
   Userdata := Payload;

DBMS_AQ.ENQUEUE(Queue_name, Enq_ct, Msg_prop, Userdata, Enq_msgid);
END;
/

Rem ------------------------------------------------------
Rem  add subscriber with rule based on current user name,
Rem  using correlation_id
Rem ------------------------------------------------------


DECLARE
Subscriber Sys.Aq$_agent;
BEGIN
   Subscriber := sys.aq$_agent('SNOOP', NULL, NULL);
DBMS_AQADM.ADD_SUBSCRIBER(
    Queue_name         => 'Pubsub.logon',
    Subscriber         => subscriber,
    Rule               => 'CORRID = ''SCOTT'' ');
END;
/

Rem ------------------------------------------------------
Rem  create a trigger on logon on database:
Rem ------------------------------------------------------


Rem  create trigger on after logon:
CREATE OR REPLACE TRIGGER pubsub.Systrig2
   AFTER LOGON
   ON DATABASE
   BEGIN
      New_enqueue('Pubsub.Logon', HEXTORAW('9999'), Dbms_standard.login_user);
   END;
/
```

- After subscriptions are created, the next step is for the client to register for notification using callback functions. This is done using the Oracle Call Interface (OCI). The following code performs necessary steps for registration. The initial

steps of allocating and initializing session handles are omitted here for sake of clarity.

```
ub4 namespace = OCI_SUBSCR_NAMESPACE_AQ;

/* callback function for notification of logon of user 'scott' on database: */

ub4 notifySnoop(ctx, subscrhp, pay, payl, desc, mode)
dvoid *ctx;
OCISubscription *subscrhp;
dvoid *pay;
ub4 payl;
dvoid *desc;
ub4 mode;
{
    printf("Notification : User Scott Logged on\n");
}

int main()
{
    OCISession *authp = (OCISession *) 0;
    OCISubscription *subscrhpSnoop = (OCISubscription *)0;

    /*************************************************
       Initialize OCI Process/Environment
       Initialize Server Contexts
       Connect to Server
       Set Service Context
    *************************************************/

    /* Registration Code Begins */

    /* Each call to initSubscriptionHn allocates
           and Initialises a Registration Handle */


    initSubscriptionHn(    &subscrhpSnoop,    /* subscription handle */
        "ADMIN:PUBSUB.SNOOP", /* subscription name */
                  /* <agent_name>:<queue_name> */
        (dvoid*)notifySnoop); /* callback function */

     /*************************************************
       The Client Process does not need a live Session for Callbacks
       End Session and Detach from Server
     *************************************************/

    OCISessionEnd ( svchp,  errhp, authp, (ub4) OCI_DEFAULT);

    /* detach from server */
    OCIServerDetach( srvhp, errhp, OCI_DEFAULT);

    while (1)     /* wait for callback */
        sleep(1);

}

void initSubscriptionHn (subscrhp,
subscriptionName,
func)

OCISubscription **subscrhp;
```

```
char* subscriptionName;
dvoid * func;
{

    /* allocate subscription handle: */

    (void) OCIHandleAlloc((dvoid *) envhp, (dvoid **)subscrhp,
        (ub4) OCI_HTYPE_SUBSCRIPTION,
        (size_t) 0, (dvoid **) 0);

    /* set subscription name in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) subscriptionName,
        (ub4) strlen((char *)subscriptionName),
        (ub4) OCI_ATTR_SUBSCR_NAME, errhp);

    /* set callback function in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) func, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_CALLBACK, errhp);

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) 0, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_CTX, errhp);

    /* set namespace in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) &namespace, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_NAMESPACE, errhp);

    checkerr(errhp, OCISubscriptionRegister(svchp, subscrhp, 1, errhp,

        OCI_DEFAULT));
}
```

If user `SCOTT` logs on to the database, the client is notified, and the call back function `notifySnoop` is called.

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