Oracle® Database

PL/SQL User's Guide and Reference

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Oracle Database PL/SQL User’s Guide and Reference 10*g* Release 2 (10.2)

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Preface

This guide explains the concepts behind the PL/SQL language and shows, with examples, how to use various language features.

This Preface contains these topics:

- Audience
- Documentation Accessibility
- Structure
- PL/SQL Sample Programs
- Related Documents
- Conventions

Audience

PL/SQL, Oracle's procedural extension of SQL, is an advanced fourth-generation programming language (4GL). It offers software-engineering features such as data encapsulation, overloading, collection types, exceptions, and information hiding. PL/SQL also supports rapid prototyping and development through tight integration with SQL and the Oracle database.

Anyone developing PL/SQL-based applications for Oracle should read this book. This book is intended for programmers, systems analysts, project managers, database administrators, and others who need to automate database operations. People developing applications in other languages can also produce mixed-language applications with parts written in PL/SQL.

To use this guide effectively, you need a working knowledge of the Oracle database, the SQL language, and basic programming constructs such as `IF-THEN` comparisons, loops, procedures, and functions.

Documentation Accessibility

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Screen readers may not always correctly read the code examples in this document. The conventions for writing code require that closing braces should appear on an otherwise empty line; however, some screen readers may not always read a line of text that consists solely of a bracket or brace.

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Structure

This document contains:

Chapter 1, "Overview of PL/SQL"

Summarizes the main features of PL/SQL and their advantages. Introduces the basic concepts behind PL/SQL and the general appearance of PL/SQL programs.

Chapter 2, "Fundamentals of the PL/SQL Language"

Focuses on the small-scale aspects of PL/SQL, such as lexical units, scalar datatypes, user-defined subtypes, data conversion, expressions, assignments, block structure, declarations, and scope.

Chapter 3, "PL/SQL Datatypes"

Discusses PL/SQL's predefined datatypes, which include integer, floating-point, character, Boolean, date, collection, reference, and LOB types. Also discusses user-defined subtypes and data conversion.

Chapter 4, "Using PL/SQL Control Structures"

Shows how to control the flow of execution through a PL/SQL program. Describes conditional, iterative, and sequential control, with control structures such as `IF-THEN-ELSE`, `CASE`, and `WHILE-LOOP`.

Chapter 5, "Using PL/SQL Collections and Records"

Discusses the composite datatypes `TABLE`, `VARRAY`, and `RECORD`. You learn how to reference and manipulate whole collections of data and group data of different types together.

Chapter 6, "Performing SQL Operations from PL/SQL"

Shows how PL/SQL supports the SQL commands, functions, and operators for manipulating Oracle data. Also shows how to process queries and transactions.

Chapter 7, "Performing SQL Operations with Native Dynamic SQL"

Shows how to build SQL statements and queries at run time.

Chapter 8, "Using PL/SQL Subprograms"

Shows how to write and call procedures and functions. It discusses related topics such as parameters, overloading, and different privilege models for subprograms.

Chapter 9, "Using PL/SQL Packages"

Shows how to bundle related PL/SQL types, items, and subprograms into a package. Packages define APIs that can be reused by many applications.

Chapter 10, "Handling PL/SQL Errors"

Shows how to detect and handle PL/SQL errors using exceptions and handlers.

Chapter 11, "Tuning PL/SQL Applications for Performance"

Discusses how to improve performance for PL/SQL-based applications.

Chapter 12, "Using PL/SQL With Object Types"

Discusses how to manipulate objects through PL/SQL.

Chapter 13, "PL/SQL Language Elements"

Shows the syntax of statements, parameters, and other PL/SQL language elements. Also includes usage notes and links to examples in the book.

Appendix A, "Obfuscating PL/SQL Source Code"

Describes how to use the standalone `wrap` utility and subprograms of the `DBMS_DDL` package to obfuscate PL/SQL source code, enabling you to deliver PL/SQL applications without exposing your source code.

Appendix B, "How PL/SQL Resolves Identifier Names"

Explains how PL/SQL resolves references to names in potentially ambiguous SQL and procedural statements.

Appendix C, "PL/SQL Program Limits"

Explains the compile-time and runtime limits imposed by PL/SQL.

Appendix D, "PL/SQL Reserved Words and Keywords"

Lists the words that are reserved for use by PL/SQL.

PL/SQL Sample Programs

You can install the PL/SQL sample programs from the Oracle Database Companion CD. The demos are installed in the PL/SQL demo directory, typically `ORACLE_HOME/plsql/demo`. For the exact location of the directory, see the Oracle installation guide for your system. These samples are typically older ones based on the `SCOTT` schema, with its `EMP` and `DEPT` tables.

Most examples in this book have been made into complete programs that you can run under the `HR` sample schema, with its `EMPLOYEES` and `DEPARTMENTS` tables.

The Oracle Technology Network Web site has a PL/SQL section with many sample programs to download, at `http://www.oracle.com/technology/tech/pl_sql/`. These programs demonstrate many language features, particularly the most recent ones. You can use some of the programs to compare performance of PL/SQL across database releases.

For examples of calling PL/SQL from other languages, see *Oracle Database Java Developer's Guide* and *Pro*C/C++ Programmer's Guide*.

Related Documents

For more information, see these Oracle resources:

- For additional information on PL/SQL, see the Oracle Technology Network (OTN), at `http://www.oracle.com/technology/tech/pl_sql/`.

  If you want to access information for a specific topic on OTN, such as "PL/SQL best practices", enter the appropriate phrase in the search field on the OTN main page at `http://www.oracle.com/technology/`.

  For articles on technical topics, see "Technical Articles Index" on OTN, at `http://www.oracle.com/technology/pub/articles/index.html`.
- For various aspects of PL/SQL programming, in particular details for triggers and stored procedures, see *Oracle Database Application Developer's Guide - Fundamentals*.
- For information about PL/SQL packages provided with the Oracle database, see *Oracle Database PL/SQL Packages and Types Reference*.
- For information on object-oriented programming using both PL/SQL and SQL features, see *Oracle Database Application Developer's Guide - Object-Relational Features*. For information about programming with large objects (LOBs), see *Oracle Database Application Developer's Guide - Large Objects*.
- For SQL information, see the *Oracle Database SQL Reference* and *Oracle Database Administrator's Guide*. For basic Oracle concepts, see *Oracle Database Concepts*.

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

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

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`http://www.oracle.com/technology/books/10g_books.html`

Conventions

This section describes the conventions used in the text and code examples of this documentation set. It describes:

- Conventions in Text
- Conventions in Code Examples

Conventions in Text

We use various conventions in text to help you more quickly identify special terms. The following table describes those conventions and provides examples of their use.

Convention	Meaning	Example
Bold	Bold typeface indicates terms that are defined in the text or terms that appear in a glossary, or both.	When you specify this clause, you create an **index-organized table**.
Italics	Italic typeface indicates book titles or emphasis.	*Oracle Database Concepts* Ensure that the recovery catalog and target database do *not* reside on the same disk.
`UPPERCASE monospace (fixed-width) font`	Uppercase monospace typeface indicates elements supplied by the system. Such elements include parameters, privileges, datatypes, Recovery Manager keywords, SQL keywords, SQL*Plus or utility commands, packages and methods, as well as system-supplied column names, database objects and structures, usernames, and roles.	You can specify this clause only for a `NUMBER` column. You can back up the database by using the `BACKUP` command. Query the `TABLE_NAME` column in the `USER_TABLES` data dictionary view. Use the `DBMS_STATS.GENERATE_STATS` procedure.
`lowercase monospace (fixed-width) font`	Lowercase monospace typeface indicates executable programs, filenames, directory names, and sample user-supplied elements. Such elements include computer and database names, net service names and connect identifiers, user-supplied database objects and structures, column names, packages and classes, usernames and roles, program units, and parameter values. *Note:* Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.	Enter `sqlplus` to start SQL*Plus. The password is specified in the `orapwd` file. Back up the datafiles and control files in the `/disk1/oracle/dbs` directory. The `department_id`, `department_name`, and `location_id` columns are in the `hr.departments` table. Set the `QUERY_REWRITE_ENABLED` initialization parameter to `true`. Connect as `oe` user. The `JRepUtil` class implements these methods.
`lowercase italic monospace (fixed-width) font`	Lowercase italic monospace font represents placeholders or variables.	You can specify the *`parallel_clause`*. Run *`old_release`*`.SQL` where *`old_release`* refers to the release you installed prior to upgrading.

Conventions in Code Examples

Code examples illustrate SQL, PL/SQL, SQL*Plus, or other command-line statements. They are displayed in a monospace (fixed-width) font and separated from normal text as shown in this example:

```
SELECT USERNAME FROM DBA_USERS WHERE USERNAME = 'MIGRATE';
```

The following table describes typographic conventions used in code examples and provides examples of their use.

Convention	Meaning	Example
[ ]	Anything enclosed in brackets is optional.	DECIMAL (*digits* [, *precision*])
{ }	Braces are used for grouping items.	{ENABLE | DISABLE}
|	A vertical bar represents a choice of two options.	{ENABLE | DISABLE} [COMPRESS | NOCOMPRESS]

Convention	Meaning	Example

`. . .`	Ellipsis points mean repetition in syntax descriptions.
	In addition, ellipsis points can mean an omission in code examples or text.
		`CREATE TABLE ... AS` *`subquery`*`;`
		`SELECT` *`col1`*`,` *`col2`*`, ... ,` *`coln`* `FROM employees;`

Other symbols	You must use symbols other than brackets ([ ]), braces ({ }), vertical bars (|), and ellipsis points (...) exactly as shown.	`acctbal NUMBER(11,2);`
		`acct    CONSTANT NUMBER(4) := 3;`

`Italics`	Italicized text indicates placeholders or variables for which you must supply particular values.	`CONNECT SYSTEM/`*`system_password`*
		`DB_NAME =` *`database_name`*

`UPPERCASE`	Uppercase typeface indicates elements supplied by the system. We show these terms in uppercase in order to distinguish them from terms you define. Unless terms appear in brackets, enter them in the order and with the spelling shown. Because these terms are not case sensitive, you can use them in either UPPERCASE or lowercase.	`SELECT last_name, employee_id FROM employees;`
		`SELECT * FROM USER_TABLES;`
		`DROP TABLE hr.employees;`

`lowercase`	Lowercase typeface indicates user-defined programmatic elements, such as names of tables, columns, or files.
	Note: Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.
		`SELECT last_name, employee_id FROM employees;`
		`sqlplus hr/hr`
		`CREATE USER mjones IDENTIFIED BY ty3MU9;`

What's New in PL/SQL?

This section describes new features of PL/SQL release 10*g*, and provides pointers to additional information.

The following sections describe the new features in PL/SQL:

- New Features in PL/SQL for Oracle Database 10g Release 2 (10.2)
- New Features in PL/SQL for Oracle Database 10g Release 1 (10.1)

See Also:

- Information and examples related to new PL/SQL features on the PL/SQL home page on Oracle Technology Network (OTN):

  `http://www.oracle.com/technology/tech/pl_sql/`
- Oracle By Example - Using Oracle Database 10g PL/SQL New Features on the Oracle Technology Network (OTN, including bulk binding enhancements and debugging PL/SQL with JDeveloper:

  `http://www.oracle.com/technology/obe/obe10gdb/develop/plsql/plsql.htm`

New Features in PL/SQL for Oracle Database 10g Release 2 (10.2)

These are the new features for Oracle Database 10*g* Release 2 (10.2).

Conditional Compilation

This feature enables you to selectively include code depending on the values of the conditions evaluated during compilation. For example, conditional compilation enables you to determine which PL/SQL features in a PL/SQL application are used for specific database releases. The latest PL/SQL features in an application can be run on a new database release while at the same time those features can be conditionalized so that the same application is compatible with a previous database release. Conditional compilation is also useful when you want to execute debugging procedures in a development environment, but want to turn off the debugging routines in a production environment. See "Conditional Compilation" on page 2-30.

Dynamic Wrap

`DBMS_DDL` wrap subprograms obfuscate (hide) dynamically generated PL/SQL code units in an Oracle database so that implementation details are hidden from users. See Appendix A, "Obfuscating PL/SQL Source Code".

PLS_INTEGER Datatype Update

The range of the PLS_INTEGER datatype is -2147483648 to 2147483647, represented in 32 bits. See "PLS_INTEGER Datatype" on page 3-4.

New Features in PL/SQL for Oracle Database 10g Release 1 (10.1)

These are the new features for Oracle Database 10*g* Release 1 (10.1).

Improved Performance

PL/SQL performance is improved across the board. Most improvements are automatic, with no action required from you. Global optimization of PL/SQL code is controlled by the PLSQL_OPTIMIZE_LEVEL initialization parameter. The default optimization level improves performance for a broad range of PL/SQL operations. Most users should never need to change the default optimization level.

Performance improvements include better integer performance, reuse of expression values, simplification of branching code, better performance for some library calls, and elimination of unreachable code.

The new datatypes BINARY_FLOAT and BINARY_DOUBLE can improve performance in number-crunching applications, such as processing scientific data.

Native compilation is easier and more integrated, with fewer initialization parameters to set, less compiler configuration, the object code is stored in the database, and compatibility with Oracle Real Application Clusters environments.

The FORALL statement can handle associative arrays and nested tables with deleted elements. You can now use this performance construct in more situations than before, and avoid the need to copy elements from one collection to another.

Enhancements to PL/SQL Native Compilation

The configuration of initialization parameters and the command setup for native compilation has been simplified. The only required parameter is PLSQL_NATIVE_LIBRARY_DIR. The parameters related to the compiler, linker, and make utility have been obsoleted. Native compilation is turned on and off by a separate initialization parameter, PLSQL_CODE_TYPE, rather than being one of several options in the PLSQL_COMPILER_FLAGS parameter, which is now deprecated.

The $ORACLE_HOME/plsql/spnc_commands file contains the commands and options for compiling and linking, rather than a makefile. The spnc_commands file. A new script, dbmsupgnv.sql, has been provided to recompile all the PL/SQL modules in a database as NATIVE. The dbmsupgin.sql script recompiles all the PL/SQL modules in a database as INTERPRETED.

A package body and its specification do not need to be compiled with the same setting for native compilation. For example, a package body can be compiled natively while the package specification is compiled interpreted, or vice versa.

Natively compiled subprograms are stored in the database, and the corresponding shared libraries are extracted automatically as needed. You do not need to worry about backing up the shared libraries, cleaning up old shared libraries, or what happens if a shared library is deleted accidentally.

Any errors that occur during native compilation are reflected in the USER_ERRORS dictionary view and by the SQL*Plus command SHOW ERRORS.

See "Compiling PL/SQL Code for Native Execution" on page 11-22.

FORALL Support for Non-Consecutive Indexes

You can use the `INDICES OF` and `VALUES OF` clauses with the `FORALL` statement to iterate over non-consecutive index values. For example, you can delete elements from a nested table, and still use that nested table in a `FORALL` statement. See "Using the FORALL Statement" on page 11-9.

New IEEE Floating-Point Types

New datatypes `BINARY_FLOAT` and `BINARY_DOUBLE` represent floating-point numbers in IEEE 754 format. These types are useful for scientific computation where you exchange data with other programs and languages that use the IEEE 754 standard for floating-point. Because many computer systems support IEEE 754 floating-point operations through native processor instructions, these types are efficient for intensive computations involving floating-point data.

Support for these types includes numeric literals such as `1.0f` and `3.141d`, arithmetic operations including square root and remainder, exception handling, and special values such as not-a-number (NaN) and infinity.

The rules for overloading subprograms are enhanced, so that you can write math libraries with different versions of the same function operating on `PLS_INTEGER`, `NUMBER`, `BINARY_FLOAT`, and `BINARY_DOUBLE` parameters. See "PL/SQL Number Types" on page 3-2.

Change to the BINARY_INTEGER Datatype

Staring with Oracle 10*g* release 1, the `BINARY_INTEGER` datatype was changed to be identical to `PLS_INTEGER` so the datatypes can be used interchangeably. See "BINARY_INTEGER Datatype" on page 3-2.

Note: Prior to Oracle 10*g* release 1, `PLS_INTEGER` was more efficient than `BINARY_INTEGER`, so you might prefer to use the `PLS_INTEGER` datatype if your code will be run under older database releases. However, the `PLS_INTEGER` datatype has a different overflow behavior than the `BINARY_INTEGER` datatype in releases prior to Oracle 10*g* release 1. Prior to Oracle 10*g* release 1, when a calculation with two `BINARY_INTEGER` datatypes overflowed the magnitude range of `BINARY_INTEGER`, the result was assigned to a `NUMBER` datatype and no overflow exception was raised. See "PLS_INTEGER Datatype" on page 3-4.

Improved Overloading

You can now overload subprograms that accept different kinds of numeric arguments, to write math libraries with specialized versions of each subprogram for different datatypes. See "Guidelines for Overloading with Numeric Types" on page 8-10.

Nested Table Enhancements

Nested tables defined in PL/SQL have many more operations than previously. You can compare nested tables for equality, test whether an element is a member of a nested table, test whether one nested table is a subset of another, perform set operations such as union and intersection, and much more. See "Assigning Collections" on page 5-12 and "Comparing Collections" on page 5-16.

Compile-Time Warnings

Oracle can issue warnings when you compile subprograms that produce ambiguous results or use inefficient constructs. You can selectively enable and disable these warnings through the `PLSQL_WARNINGS` initialization parameter and the `DBMS_WARNING` package. See "Overview of PL/SQL Compile-Time Warnings" on page 10-17.

Quoting Mechanism for String Literals

Instead of doubling each single quote inside a string literal, you can specify your own delimiter character for the literal, and then use single quotes inside the string. See "String Literals" on page 2-6.

Implicit Conversion Between CLOB and NCLOB

You can implicitly convert from `CLOB` to `NCLOB` or from `NCLOB` to `CLOB`. Because this can be an expensive operation, it might help maintainability to continue using the `TO_CLOB` and `TO_NCLOB` functions.

Regular Expressions

If you are familiar with UNIX-style regular expressions, you can use them while performing queries and string manipulations. You use the `REGEXP_LIKE` operator in SQL queries, and the `REGEXP_INSTR`, `REGEXP_REPLACE`, and `REGEXP_SUBSTR` functions anywhere you would use `INSTR`, `REPLACE`, and `SUBSTR`. See "Summary of PL/SQL Built-In Functions" on page 2-38 and "Do Not Duplicate Built-in String Functions" on page 11-5.

Flashback Query Functions

The functions `SCN_TO_TIMESTAMP` and `TIMESTAMP_TO_SCN` let you translate between a date and time, and the system change number that represents the database state at a point in time. See Example 3–2, "Using the SCN_TO_TIMESTAMP and TIMESTAMP_TO_SCN Functions" on page 3-14. See "Summary of PL/SQL Built-In Functions" on page 2-38.

1 Overview of PL/SQL

This chapter introduces the main features of the PL/SQL language. It shows how PL/SQL meets the challenges of database programming, and how you can reuse techniques that you know from other programming languages.

This chapter contains these topics:

- Advantages of PL/SQL
- Understanding the Main Features of PL/SQL
- PL/SQL Architecture

See Also:

- Additional information and code samples for PL/SQL on the Oracle Technology Network (OTN), at:

  `http://www.oracle.com/technology/tech/pl_sql/`

- Information for a specific topic on OTN, such as "PL/SQL best practices", by entering the appropriate phrase in the search field on the OTN main page at:

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

Advantages of PL/SQL

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

- Tight Integration with SQL
- Better Performance
- Higher Productivity
- Full Portability
- Tight Security
- Access to Pre-defined Packages
- Support for Object-Oriented Programming
- Support for Developing Web Applications and Pages

Tight Integration with SQL

SQL has become the standard database language because it is flexible, powerful, and easy to learn. A few English-like commands such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE` make it easy to manipulate the data stored in a relational database.

PL/SQL lets you use all the SQL data manipulation, cursor control, and transaction control commands, as well as all the SQL functions, operators, and pseudocolumns. This extensive SQL support lets you manipulate Oracle data flexibly and safely. Also, PL/SQL fully supports SQL datatypes, reducing the need to convert data passed between your applications and the database.

The PL/SQL language is tightly integrated with SQL. You do not have to translate between SQL and PL/SQL datatypes; a `NUMBER` or `VARCHAR2` column in the database is stored in a `NUMBER` or `VARCHAR2` variable in PL/SQL. This integration saves you both learning time and processing time. Special PL/SQL language features let you work with table columns and rows without specifying the datatypes, saving on maintenance work when the table definitions change.

Running a SQL query and processing the result set is as easy in PL/SQL as opening a text file and processing each line in popular scripting languages. Using PL/SQL to access metadata about database objects and handle database error conditions, you can write utility programs for database administration that are reliable and produce readable output about the success of each operation. Many database features, such as triggers and object types, make use of PL/SQL. You can write the bodies of triggers and methods for object types in PL/SQL.

PL/SQL supports both static and dynamic SQL. The syntax of static SQL statements is known at precompile time and the preparation of the static SQL occurs before runtime, where as the syntax of dynamic SQL statements is not known until runtime. Dynamic SQL is a programming technique that makes your applications more flexible and versatile. Your programs can build and process SQL data definition, data control, and session control statements at run time, without knowing details such as table names and `WHERE` clauses in advance. For information on the use of static SQL with PL/SQL, see Chapter 6, "Performing SQL Operations from PL/SQL". For information on the use of dynamic SQL, see Chapter 7, "Performing SQL Operations with Native Dynamic SQL". For additional information about dynamic SQL, see *Oracle Database Application Developer's Guide - Fundamentals*.

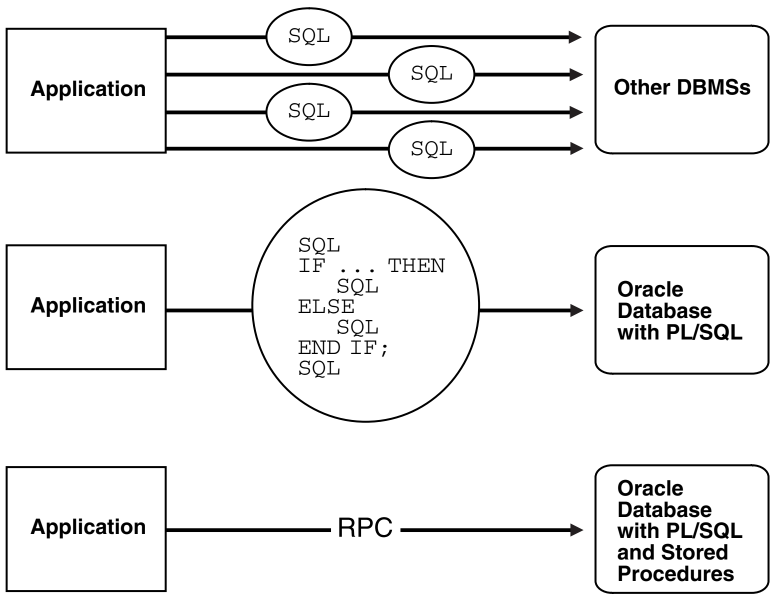
Better Performance

Without PL/SQL, Oracle must process SQL statements one at a time. Programs that issue many SQL statements require multiple calls to the database, resulting in significant network and performance overhead.

With PL/SQL, an entire block of statements can be sent to Oracle at one time. This can drastically reduce network traffic between the database and an application. As Figure 1–1 shows, you can use PL/SQL blocks and subprograms to group SQL statements before sending them to the database for execution. PL/SQL also has language features to further speed up SQL statements that are issued inside a loop.

PL/SQL stored procedures are compiled once and stored in executable form, so procedure calls are efficient. Because stored procedures execute in the database server, a single call over the network can start a large job. This division of work reduces network traffic and improves response times. Stored procedures are cached and shared among users, which lowers memory requirements and invocation overhead.

Figure 1–1 PL/SQL Boosts Performance



Higher Productivity

PL/SQL lets you write very compact code for manipulating data. In the same way that scripting languages such as Perl can read, transform, and write data from files, PL/SQL can query, transform, and update data in a database. PL/SQL saves time on design and debugging by offering a full range of software-engineering features, such as exception handling, encapsulation, data hiding, and object-oriented datatypes.

PL/SQL extends tools such as Oracle Forms. With PL/SQL in these tools, you can use familiar language constructs to build applications. 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. After you learn PL/SQL with one Oracle tool, you can transfer your knowledge to other tools.

Full Portability

Applications written in PL/SQL can run on any operating system and platform where the Oracle database runs. With PL/SQL, you can write portable program libraries and reuse them in different environments.

Tight Security

PL/SQL stored procedures move application code from the client to the server, where you can protect it from tampering, hide the internal details, and restrict who has access. For example, you can grant users access to a procedure that updates a table, but not grant them access to the table itself or to the text of the `UPDATE` statement. Triggers written in PL/SQL can control or record changes to data, making sure that all changes obey your business rules.

For information on wrapping, or hiding, the source of a PL/SQL unit, see Appendix A, "Obfuscating PL/SQL Source Code".

Access to Pre-defined Packages

Oracle provides product-specific packages that define APIs you can call from PL/SQL to perform many useful tasks. These packages include `DBMS_ALERT` for using database triggers, `DBMS_FILE` for reading and writing operating system (OS) text files, `DBMS_HTTP` for making hypertext transfer protocol (HTTP) callouts, `DBMS_OUTPUT` for display output from PL/SQL blocks and subprograms, and `DBMS_PIPE` for communicating over named pipes. For additional information on these packages, see "Overview of Product-Specific Packages" on page 9-9.

For complete information on the packages supplied by Oracle, see *Oracle Database PL/SQL Packages and Types Reference*.

Support for Object-Oriented Programming

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.

By encapsulating operations with data, object types let you move data-maintenance code out of SQL scripts and PL/SQL blocks into methods. Also, object types hide implementation details, so that you can change the details without affecting client programs. See Chapter 12, "Using PL/SQL With Object Types".

In addition, object types allow for realistic data modeling. Complex real-world entities and relationships map directly into object types. This direct mapping helps your programs better reflect the world they are trying to simulate. For information on object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*.

Support for Developing Web Applications and Pages

You can use PL/SQL to develop Web applications and Server Pages (PSPs). For an overview of the use of PL/SQL with the Web, see "Using PL/SQL to Create Web Applications and Server Pages" on page 2-38.

Understanding the Main Features of PL/SQL

PL/SQL combines the data-manipulating power of SQL with the processing power of procedural languages. You can control program flow with statements like `IF` and `LOOP`. As with other procedural programming languages, you can declare variables, define procedures and functions, and trap runtime errors.

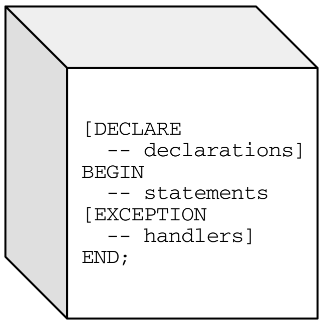
PL/SQL lets you break complex problems down into easily understandable procedural code, and reuse this code across multiple applications. When a problem can be solved through plain SQL, you can issue SQL commands directly inside your PL/SQL programs, without learning new APIs. PL/SQL's data types correspond with SQL's column types, making it easy to interchange PL/SQL variables with data inside a table.

Understanding PL/SQL Block Structure

The basic units (procedures, functions, and anonymous blocks) that make up a PL/SQL program are logical blocks, which can be nested inside one another. A block groups related declarations and statements. You can place declarations close to where they are used, such as inside a large subprogram. The declarations are local to the block and cease to exist when the block completes, helping to avoid cluttered namespaces for variables and procedures. For a syntax description of the block structure, see "Block Declaration" on page 13-8.

As Figure 1–2 shows, a PL/SQL block has three basic parts: a declarative part (DECLARE), an executable part (BEGIN .. END), and an exception-handling (EXCEPTION) part that handles error conditions. Only the executable part is required. The optional declarative part is written first, where you define types, variables, and similar items. These items are manipulated in the executable part. Exceptions raised during execution can be dealt with in the exception-handling part. For an example of PL/SQL block structure, see Example 1–3 on page 1-6.

Figure 1–2 Block Structure



```
[DECLARE
  -- declarations]
BEGIN
  -- statements
[EXCEPTION
  -- handlers]
END;
```

You can nest blocks in the executable and exception-handling parts of a PL/SQL block or subprogram but not in the declarative part. You can define local subprograms in the declarative part of any block. You can call local subprograms only from the block in which they are defined.

Understanding PL/SQL Variables and Constants

PL/SQL lets you declare variables and constants, then use them in SQL and procedural statements anywhere an expression can be used. You must declare a constant or variable before referencing it in any other statements. For additional information, see "Declarations" on page 2-8.

Declaring Variables

Variables can have any SQL datatype, such as `CHAR`, `DATE`, or `NUMBER`, or a PL/SQL-only datatype, such as `BOOLEAN` or `PLS_INTEGER`. For example, assume that you want to declare variables for part data, such as `part_no` to hold 6-digit numbers and `in_stock` to hold the Boolean value `TRUE` or `FALSE`. You declare these and related part variables as shown in Example 1–1. Note that there is a semi-colon (;) at the end of each line in the declaration section.

Example 1–1 Declaring Variables in PL/SQL

```
DECLARE
  part_no    NUMBER(6);
  part_name  VARCHAR2(20);
  in_stock   BOOLEAN;
  part_price NUMBER(6,2);
  part_desc  VARCHAR2(50);
```

You can also declare nested tables, variable-size arrays (varrays for short), and records using the `TABLE`, `VARRAY`, and `RECORD` composite datatypes. See Chapter 5, "Using PL/SQL Collections and Records".

Assigning Values to a Variable

You can assign values to a variable in three ways. The first way uses the assignment operator (`:=`), a colon followed by an equal sign, as shown in Example 1–2. You place the variable to the left of the operator and an expression, including function calls, to the right. Note that you can assign a value to a variable when it is declared.

Example 1–2 Assigning Values to Variables With the Assignment Operator

```
DECLARE
   wages          NUMBER;
   hours_worked   NUMBER := 40;
   hourly_salary  NUMBER := 22.50;
   bonus          NUMBER := 150;
   country        VARCHAR2(128);
   counter        NUMBER := 0;
   done           BOOLEAN;
   valid_id       BOOLEAN;
   emp_rec1       employees%ROWTYPE;
   emp_rec2       employees%ROWTYPE;
   TYPE commissions IS TABLE OF NUMBER INDEX BY PLS_INTEGER;
   comm_tab       commissions;
BEGIN
   wages := (hours_worked * hourly_salary) + bonus;
   country := 'France';
   country := UPPER('Canada');
   done := (counter > 100);
   valid_id := TRUE;
   emp_rec1.first_name := 'Antonio';
   emp_rec1.last_name := 'Ortiz';
   emp_rec1 := emp_rec2;
   comm_tab(5) := 20000 * 0.15;
END;
/
```

The second way to assign values to a variable is by selecting (or fetching) database values into it. In Example 1–3, 10% of an employee's salary is selected into the `bonus` variable. Now you can use the `bonus` variable in another computation or insert its value into a database table.

Example 1–3 Assigning Values to Variables by SELECTing INTO

```
DECLARE
  bonus  NUMBER(8,2);
  emp_id NUMBER(6) := 100;
BEGIN
  SELECT salary * 0.10 INTO bonus FROM employees
    WHERE employee_id = emp_id;
END;
/
```

The third way to assign a value to a variable is by passing it as an `OUT` or `IN OUT` parameter to a subprogram, and then assigning the value inside the subprogram. Example 1–4 passes the `sal` variable to a subprogram, and the subprogram updates the variable.

In the example, `DBMS_OUTPUT.PUT_LINE` is used to display output from the PL/SQL program. For more information, see "Inputting and Outputting Data with PL/SQL" on page 1-15. For information on the `DBMS_OUTPUT` package, see "About the DBMS_OUTPUT Package" on page 9-9.

Example 1–4 Assigning Values to Variables as Parameters of a Subprogram

```
REM SERVEROUTPUT must be set to ON to display output with DBMS_OUTPUT
SET SERVEROUTPUT ON FORMAT WRAPPED
DECLARE
  new_sal NUMBER(8,2);
  emp_id  NUMBER(6) := 126;
  PROCEDURE adjust_salary(emp_id NUMBER, sal IN OUT NUMBER) IS
    emp_job VARCHAR2(10);
    avg_sal NUMBER(8,2);
    BEGIN
      SELECT job_id INTO emp_job FROM employees WHERE employee_id = emp_id;
      SELECT AVG(salary) INTO avg_sal FROM employees WHERE job_id = emp_job;
      DBMS_OUTPUT.PUT_LINE ('The average salary for ' || emp_job
                           || ' employees: ' || TO_CHAR(avg_sal));
      sal := (sal + avg_sal)/2; -- adjust sal value which is returned
    END;
BEGIN
  SELECT AVG(salary) INTO new_sal FROM employees;
  DBMS_OUTPUT.PUT_LINE ('The average salary for all employees: '
                       || TO_CHAR(new_sal));
  adjust_salary(emp_id, new_sal); -- assigns a new value to new_sal
  DBMS_OUTPUT.PUT_LINE ('The adjusted salary for employee ' || TO_CHAR(emp_id)
                       || ' is ' || TO_CHAR(new_sal)); -- sal has new value
END;
/
```

Bind Variables

When you embed an INSERT, UPDATE, DELETE, or SELECT SQL statement directly in your PL/SQL code, PL/SQL turns the variables in the WHERE and VALUES clauses into bind variables automatically. Oracle can reuse these SQL statement each time the same code is executed. To run similar statements with different variable values, you can save parsing overhead by calling a stored procedure that accepts parameters, then issues the statements with the parameters substituted in the appropriate places.

You do need to specify bind variables with dynamic SQL, in clauses like WHERE and VALUES where you normally use variables. Instead of concatenating literals and variable values into a single string, replace the variables with the names of bind variables (prefixed by a colon) and specify the corresponding PL/SQL variables with the USING clause. Using the USING clause, instead of concatenating the variables into the string, reduces parsing overhead and lets Oracle reuse the SQL statements. For example:

```
'DELETE FROM employees WHERE employee_id = :id' USING emp_id;
```

For an example of the use of bind variables, see Example 7–1 on page 7-3.

Declaring Constants

Declaring a constant is like declaring a variable except that you must add the keyword CONSTANT and immediately assign a value to the constant. No further assignments to the constant are allowed. The following example declares a constant:

```
credit_limit CONSTANT NUMBER := 5000.00;
```

See "Constants" on page 2-9.

Processing Queries with PL/SQL

Processing a SQL query with PL/SQL is like processing files with other languages. For example, a Perl program opens a file, reads the file contents, processes each line, then closes the file. In the same way, a PL/SQL program issues a query and processes the rows from the result set as shown in Example 1–5.

Example 1–5 Processing Query Results in a LOOP

```
BEGIN
  FOR someone IN (SELECT * FROM employees WHERE employee_id < 120 )
  LOOP
    DBMS_OUTPUT.PUT_LINE('First name = ' || someone.first_name ||
                         ', Last name = ' || someone.last_name);
  END LOOP;
END;
/
```

You can use a simple loop like the one shown here, or you can control the process precisely by using individual statements to perform the query, retrieve data, and finish processing.

Declaring PL/SQL Subprograms

Subprograms are named PL/SQL blocks that can be called with a set of parameters. PL/SQL has two types of subprograms: procedures and functions. The following is an example of a declaration of a PL/SQL procedure:

```
DECLARE
  in_string  VARCHAR2(100) := 'This is my test string.';
  out_string VARCHAR2(200);
  PROCEDURE double ( original IN VARCHAR2, new_string OUT VARCHAR2 ) AS
    BEGIN
      new_string := original || original;
    END;
```

For example of a subprogram declaration in a package, see Example 1–13 on page 1-14. For more information on subprograms, see "What Are Subprograms?" on page 8-1.

You can create standalone subprograms with SQL statements that are stored in the database. See Subprograms: Procedures and Functions on page 1-13.

Declaring Datatypes for PL/SQL Variables

As part of the declaration for each PL/SQL variable, you declare its datatype. Usually, this datatype is one of the types shared between PL/SQL and SQL, such as `NUMBER` or `VARCHAR2`. For easier maintenance of code that interacts with the database, you can also use the special qualifiers `%TYPE` and `%ROWTYPE` to declare variables that hold table columns or table rows. For more information on datatypes, see Chapter 3, "PL/SQL Datatypes".

%TYPE

The `%TYPE` attribute provides the datatype of a variable or database column. This is particularly useful when declaring variables that will hold database values. For example, assume there is a column named `last_name` in a table named `employees`. To declare a variable named `v_last_name` that has the same datatype as column `title`, use dot notation and the `%TYPE` attribute, as follows:

```
v_last_name employees.last_name%TYPE;
```

Declaring v_last_name with %TYPE has two advantages. First, you need not know the exact datatype of last_name. Second, if you change the database definition of last_name, perhaps to make it a longer character string, the datatype of v_last_name changes accordingly at run time.

For more information on %TYPE, see "Using the %TYPE Attribute" on page 2-10 and "%TYPE Attribute" on page 13-119.

%ROWTYPE

In PL/SQL, records are used to group data. A record consists of a number of related fields in which data values can be stored. The %ROWTYPE attribute provides a record type that represents a row in a table. The record can store an entire row of data selected from the table or fetched from a cursor or cursor variable. See "Cursors" on page 1-16.

Columns in a row and corresponding fields in a record have the same names and datatypes. In the following example, you declare a record named dept_rec. Its fields have the same names and datatypes as the columns in the departments table.

```
DECLARE
  dept_rec departments%ROWTYPE; -- declare record variable
```

You use dot notation to reference fields, as the following example shows:

```
v_deptid := dept_rec.department_id;
```

If you declare a cursor that retrieves the last name, salary, hire date, and job class of an employee, you can use %ROWTYPE to declare a record that stores the same information as shown in Example 1–6. When you execute the FETCH statement, the value in the last_name column of the employees table is assigned to the last_name field of employee_rec, the value in the salary column is assigned to the salary field, and so on.

Example 1–6 Using %ROWTYPE with an Explicit Cursor

```
DECLARE
  CURSOR c1 IS
    SELECT last_name, salary, hire_date, job_id FROM employees
       WHERE employee_id = 120;
-- declare record variable that represents a row fetched from the employees table
   employee_rec c1%ROWTYPE;
BEGIN
-- open the explicit cursor and use it to fetch data into employee_rec
  OPEN c1;
  FETCH c1 INTO employee_rec;
  DBMS_OUTPUT.PUT_LINE('Employee name: ' || employee_rec.last_name);
END;
/
```

For more information on %ROWTYPE, see "Using the %ROWTYPE Attribute" on page 2-11 and "%ROWTYPE Attribute" on page 13-104.

Understanding PL/SQL Control Structures

Control structures are the most important PL/SQL extension to SQL. Not only does PL/SQL let you manipulate Oracle data, it lets you process the data using conditional, iterative, and sequential flow-of-control statements such as IF-THEN-ELSE, CASE, FOR-LOOP, WHILE-LOOP, EXIT-WHEN, and GOTO. For additional information, see Chapter 4, "Using PL/SQL Control Structures".

Conditional Control

Often, it is necessary to take alternative actions depending on circumstances. The IF-THEN-ELSE statement lets you execute a sequence of statements conditionally. The IF clause checks a condition, the THEN clause defines what to do if the condition is true and the ELSE clause defines what to do if the condition is false or null. Example 1–7 shows the use of IF-THEN-ELSE to determine the salary raise an employee receives based on the current salary of the employee.

To choose among several values or courses of action, you can use CASE constructs. The CASE expression evaluates a condition and returns a value for each case. The case statement evaluates a condition and performs an action, such as an entire PL/SQL block, for each case. See Example 1–7.

Example 1–7   Using the IF-THEN_ELSE and CASE Statement for Conditional Control

```
DECLARE
   jobid      employees.job_id%TYPE;
   empid      employees.employee_id%TYPE := 115;
   sal        employees.salary%TYPE;
   sal_raise  NUMBER(3,2);
BEGIN
  SELECT job_id, salary INTO jobid, sal from employees WHERE employee_id = empid;
  CASE
    WHEN jobid = 'PU_CLERK' THEN
        IF sal < 3000 THEN sal_raise := .12;
          ELSE sal_raise := .09;
        END IF;
    WHEN jobid = 'SH_CLERK' THEN
        IF sal < 4000 THEN sal_raise := .11;
          ELSE sal_raise := .08;
        END IF;
    WHEN jobid = 'ST_CLERK' THEN
        IF sal < 3500 THEN sal_raise := .10;
          ELSE sal_raise := .07;
        END IF;
    ELSE
     BEGIN
       DBMS_OUTPUT.PUT_LINE('No raise for this job: ' || jobid);
     END;
  END CASE;
  UPDATE employees SET salary = salary + salary * sal_raise
    WHERE employee_id = empid;
  COMMIT;
END;
/
```

A sequence of statements that uses query results to select alternative actions is common in database applications. Another common sequence inserts or deletes a row only if an associated entry is found in another table. You can bundle these common sequences into a PL/SQL block using conditional logic.

Iterative Control

LOOP statements let you execute a sequence of statements multiple times. You place the keyword LOOP before the first statement in the sequence and the keywords END

LOOP after the last statement in the sequence. The following example shows the simplest kind of loop, which repeats a sequence of statements continually:

```
LOOP
  -- sequence of statements
END LOOP;
```

The FOR-LOOP statement lets you specify a range of integers, then execute a sequence of statements once for each integer in the range. In Example 1–8 the loop inserts 100 numbers, square roots, squares, and the sum of squares into a database table:

Example 1–8 Using the FOR-LOOP

```
CREATE TABLE sqr_root_sum (num NUMBER, sq_root NUMBER(6,2),
                           sqr NUMBER, sum_sqrs NUMBER);
DECLARE
   s PLS_INTEGER;
BEGIN
  FOR i in 1..100 LOOP
    s := (i * (i + 1) * (2*i +1)) / 6; -- sum of squares
    INSERT INTO sqr_root_sum VALUES (i, SQRT(i), i*i, s );
  END LOOP;
END;
/
```

The WHILE-LOOP statement associates a condition with a sequence of statements. Before each iteration of the loop, the condition is evaluated. If the condition is true, the sequence of statements is executed, then control resumes at the top of the loop. If the condition is false or null, the loop is bypassed and control passes to the next statement.

In Example 1–9, you find the first employee who has a salary over $15000 and is higher in the chain of command than employee 120:

Example 1–9 Using WHILE-LOOP for Control

```
CREATE TABLE temp (tempid NUMBER(6), tempsal NUMBER(8,2), tempname VARCHAR2(25));
DECLARE
   sal            employees.salary%TYPE := 0;
   mgr_id         employees.manager_id%TYPE;
   lname          employees.last_name%TYPE;
   starting_empid employees.employee_id%TYPE := 120;
BEGIN
   SELECT manager_id INTO mgr_id FROM employees
      WHERE employee_id = starting_empid;
   WHILE sal <= 15000 LOOP -- loop until sal > 15000
      SELECT salary, manager_id, last_name INTO sal, mgr_id, lname
         FROM employees WHERE employee_id = mgr_id;
   END LOOP;
   INSERT INTO temp VALUES (NULL, sal, lname); -- insert NULL for tempid
   COMMIT;
EXCEPTION
   WHEN NO_DATA_FOUND THEN
      INSERT INTO temp VALUES (NULL, NULL, 'Not found'); -- insert NULLs
      COMMIT;
END;
/
```

The EXIT-WHEN statement lets you complete a loop if further processing is impossible or undesirable. When the EXIT statement is encountered, the condition in the WHEN clause is evaluated. If the condition is true, the loop completes and control passes to the next statement. In Example 1–10, the loop completes when the value of `total` exceeds 25,000:

Example 1–10 Using the EXIT-WHEN Statement

```
DECLARE
  total   NUMBER(9) := 0;
  counter NUMBER(6) := 0;
BEGIN
  LOOP
    counter := counter + 1;
    total := total + counter * counter;
    -- exit loop when condition is true
    EXIT WHEN total > 25000;
  END LOOP;
  DBMS_OUTPUT.PUT_LINE('Counter: ' || TO_CHAR(counter) || ' Total: ' ||
TO_CHAR(total));
END;
/
```

Sequential Control

The `GOTO` statement lets you branch to a label unconditionally. The label, an undeclared identifier enclosed by double angle brackets, must precede an executable statement or a PL/SQL block. When executed, the `GOTO` statement transfers control to the labeled statement or block, as shown in Example 1–11.

Example 1–11 Using the GOTO Statement

```
DECLARE
  total   NUMBER(9) := 0;
  counter NUMBER(6) := 0;
BEGIN
  <<calc_total>>
    counter := counter + 1;
    total := total + counter * counter;
    -- branch to print_total label when condition is true
    IF total > 25000 THEN GOTO print_total;
      ELSE GOTO calc_total;
    END IF;
  <<print_total>>
  DBMS_OUTPUT.PUT_LINE('Counter: ' || TO_CHAR(counter) || ' Total: ' ||
TO_CHAR(total));
END;
/
```

Understanding Conditional Compilation

Using conditional compilation, you can customize the functionality in a compiled PL/SQL application by conditionalizing functionality rather than removing any source code. For example, conditional compilation enables you to determine which PL/SQL features in a PL/SQL application are used for specific database releases. The latest PL/SQL features in an application can be run on a new database release while at the same time those features can be conditionalizing so that the same application is compatible with a previous database release. Conditional compilation is also useful when you want to execute debugging procedures in a development environment, but want to turn off the debugging routines in a production environment. See "Conditional Compilation" on page 2-30.

Writing Reusable PL/SQL Code

PL/SQL lets you break an application down into manageable, well-defined modules. PL/SQL meets this need with program units, which include blocks, subprograms, and packages. You can reuse program units by loading them into the database as triggers, stored procedures, and stored functions. For additional information, see Chapter 8, "Using PL/SQL Subprograms" and Chapter 9, "Using PL/SQL Packages".

Subprograms: Procedures and Functions

There are two types of subprograms called procedures and functions, which can accept parameters and be invoked (called). See "What Are Subprograms?" on page 8-1.

The SQL `CREATE PROCEDURE` statement lets you create standalone procedures that are stored in the database. For information, see `CREATE PROCEDURE` in *Oracle Database SQL Reference*. The SQL `CREATE FUNCTION` statement lets you create standalone functions that are stored in an Oracle database. For information, see `CREATE FUNCTION` in *Oracle Database SQL Reference*. These stored (schema level) subprograms can be accessed from SQL.

As shown in Example 1–12, a subprogram is like a miniature program, beginning with a header followed by an optional declarative part, an executable part, and an optional exception-handling part.

Example 1–12 Creating a Stored Subprogram

```
-- including OR REPLACE is more convenient when updating a subprogram
CREATE OR REPLACE PROCEDURE award_bonus (emp_id NUMBER, bonus NUMBER) AS
   commission        REAL;
   comm_missing EXCEPTION;
BEGIN  -- executable part starts here
   SELECT commission_pct / 100 INTO commission FROM employees
    WHERE employee_id = emp_id;
   IF commission IS NULL THEN
      RAISE comm_missing;
   ELSE
      UPDATE employees SET salary = salary + bonus*commission
      WHERE employee_id = emp_id;
   END IF;
EXCEPTION  -- exception-handling part starts here
   WHEN comm_missing THEN
      DBMS_OUTPUT.PUT_LINE('This employee does not receive a commission.');
      commission := 0;
   WHEN OTHERS THEN
      NULL; -- for other exceptions do nothing
END award_bonus;
/
CALL award_bonus(150, 400);
```

When called, this procedure accepts an employee Id and a bonus amount. It uses the Id to select the employee's commission percentage from a database table and, at the same time, convert the commission percentage to a decimal amount. Then, it checks the commission amount. If the commission is null, an exception is raised; otherwise, the employee's salary is updated.

Packages: APIs Written in PL/SQL

PL/SQL lets you bundle logically related types, variables, cursors, and subprograms into a package, a database object that is a step above regular stored procedures. The packages defines a simple, clear, interface to a set of related procedures and types that can be accessed by SQL statements.

Packages usually have two parts: a specification and a body. The specification defines the application programming interface; it declares the types, constants, variables, exceptions, cursors, and subprograms. The body fills in the SQL queries for cursors and the code for subprograms.

To create package specs, use the SQL statement `CREATE PACKAGE`. A `CREATE PACKAGE BODY` statement defines the package body. For information on the `CREATE PACKAGE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE PACKAGE BODY` SQL statement, see *Oracle Database SQL Reference*.

In Example 1–13, the `emp_actions` package contain two procedures that update the `employees` table and one function that provides information.

Example 1–13 Creating a Package and Package Body

```
CREATE OR REPLACE PACKAGE emp_actions AS  -- package specification
   PROCEDURE hire_employee (employee_id NUMBER, last_name VARCHAR2,
     first_name VARCHAR2, email VARCHAR2, phone_number VARCHAR2,
    hire_date DATE, job_id VARCHAR2, salary NUMBER, commission_pct NUMBER,
    manager_id NUMBER, department_id NUMBER);
   PROCEDURE fire_employee (emp_id NUMBER);
   FUNCTION num_above_salary (emp_id NUMBER) RETURN NUMBER;
END emp_actions;
/
CREATE OR REPLACE PACKAGE BODY emp_actions AS  -- package body
-- code for procedure hire_employee
   PROCEDURE hire_employee (employee_id NUMBER, last_name VARCHAR2,
      first_name VARCHAR2, email VARCHAR2, phone_number VARCHAR2, hire_date DATE,
      job_id VARCHAR2, salary NUMBER, commission_pct NUMBER,
      manager_id NUMBER, department_id NUMBER) IS
   BEGIN
      INSERT INTO employees VALUES (employee_id, last_name, first_name, email,
       phone_number, hire_date, job_id, salary, commission_pct, manager_id,
       department_id);
   END hire_employee;
-- code for procedure fire_employee
   PROCEDURE fire_employee (emp_id NUMBER) IS
   BEGIN
      DELETE FROM employees WHERE employee_id = emp_id;
   END fire_employee;
-- code for function num_above salary
   FUNCTION num_above_salary (emp_id NUMBER) RETURN NUMBER IS
      emp_sal NUMBER(8,2);
      num_count NUMBER;
   BEGIN
      SELECT salary INTO emp_sal FROM employees WHERE employee_id = emp_id;
      SELECT COUNT(*) INTO num_count FROM employees WHERE salary > emp_sal;
      RETURN num_count;
   END num_above_salary;
END emp_actions;
/
```

Applications that call these procedures only need to know the names and parameters from the package specification. You can change the implementation details inside the package body without affecting the calling applications.

To call the procedures of the `emp_actions` package created in Example 1–13, you can execute the statements in Example 1–14. The procedures can be executed in a `BEGIN` ..

END block or with the SQL CALL statement. Note the use of the package name as a prefix to the procedure name.

Example 1–14 Calling a Procedure in a Package

```
CALL emp_actions.hire_employee(300, 'Belden', 'Enrique', 'EBELDEN',
   '555.111.2222', '31-AUG-04', 'AC_MGR', 9000, .1, 101, 110);

BEGIN
  DBMS_OUTPUT.PUT_LINE( 'Number of employees with higher salary: ' ||
                        TO_CHAR(emp_actions.num_above_salary(120)));
  emp_actions.fire_employee(300);
END;
/
```

Packages are stored in the database, where they can be shared by many applications. Calling a packaged subprogram for the first time loads the whole package and caches it in memory, saving on disk I/O for subsequent calls. Thus, packages enhance reuse and improve performance in a multiuser, multi-application environment. For information on packages, see Chapter 9, "Using PL/SQL Packages".

If a subprogram does not take any parameters, you can include an empty set of parentheses or omit the parentheses, both in PL/SQL and in functions called from SQL queries. For calls to a method that takes no parameters, an empty set of parentheses is optional within PL/SQL scopes but required within SQL scopes.

Inputting and Outputting Data with PL/SQL

Most PL/SQL input and output is through SQL statements, to store data in database tables or query those tables. All other PL/SQL I/O is done through APIs that interact with other programs. For example, the DBMS_OUTPUT package has procedures such as PUT_LINE. To see the result outside of PL/SQL requires another program, such as SQL*Plus, to read and display the data passed to DBMS_OUTPUT.

SQL*Plus does not display DBMS_OUTPUT data unless you first issue the SQL*Plus command SET SERVEROUTPUT ON as follows:

```
SET SERVEROUTPUT ON
```

For information on the SEVEROUTPUT setting, see the "SQL*Plus Command Reference" chapter in *SQL*Plus User's Guide and Reference*.

Other PL/SQL APIs for processing I/O are:

- HTF and HTP for displaying output on a web page
- DBMS_PIPE for passing information back and forth between PL/SQL and operating-system commands
- UTL_FILE for reading and writing operating-system files
- UTL_HTTP for communicating with web servers
- UTL_SMTP for communicating with mail servers

See "Overview of Product-Specific Packages" on page 9-9. Although some of these APIs can accept input as well as output, there is no built-in language facility for accepting data directly from the keyboard. For that, you can use the PROMPT and ACCEPT commands in SQL*Plus.

Understanding PL/SQL Data Abstraction

Data abstraction lets you work with the essential properties of data without being too involved with details. After you design a data structure, you can focus on designing algorithms that manipulate the data structure.

Cursors

A cursor is a name for a specific private SQL area in which information for processing the specific statement is kept. PL/SQL uses both implicit and explicit cursors. PL/SQL implicitly declares a cursor for all SQL data manipulation statements on a set of rows, 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. For example, Example 1–6 on page 1-9 declares an explicit cursor.

For information on managing cursors with PL/SQL, see "Managing Cursors in PL/SQL" on page 6-6.

Collections

PL/SQL collection types let you declare high-level datatypes similar to arrays, sets, and hash tables found in other languages. In PL/SQL, array types are known as varrays (short for variable-size arrays), set types are known as nested tables, and hash table types are known as associative arrays. Each kind of collection is an ordered group of elements, all of the same type. Each element has a unique subscript that determines its position in the collection. When declaring collections, you use a `TYPE` definition. See "Defining Collection Types and Declaring Collection Variables" on page 5-6.

To reference an element, use subscript notation with parentheses, as shown in Example 1–15.

Example 1–15 Using a PL/SQL Collection Type

```
DECLARE
  TYPE staff_list IS TABLE OF employees.employee_id%TYPE;
  staff staff_list;
  lname employees.last_name%TYPE;
  fname employees.first_name%TYPE;
BEGIN
   staff := staff_list(100, 114, 115, 120, 122);
   FOR i IN staff.FIRST..staff.LAST LOOP
     SELECT last_name, first_name INTO lname, fname FROM employees
       WHERE employees.employee_id = staff(i);
     DBMS_OUTPUT.PUT_LINE ( TO_CHAR(staff(i)) || ': ' || lname || ', ' || fname );
   END LOOP;
END;
/
```

Collections can be passed as parameters, so that subprograms can process arbitrary numbers of elements.You can use collections to move data into and out of database tables using high-performance language features known as bulk SQL.

For information on collections, see Chapter 5, "Using PL/SQL Collections and Records".

Records

Records are composite data structures whose fields can have different datatypes. You can use records to hold related items and pass them to subprograms with a single parameter. When declaring records, you use a `TYPE` definition. See "Defining and Declaring Records" on page 5-29.

Example 1–16 shows how are records are declared.

Example 1–16 Declaring a Record Type

```
DECLARE
   TYPE timerec IS RECORD (hours SMALLINT, minutes SMALLINT);
   TYPE meetin_typ IS RECORD (
      date_held DATE,
      duration  timerec,  -- nested record
      location  VARCHAR2(20),
      purpose   VARCHAR2(50));
BEGIN
-- NULL does nothing but allows unit to be compiled and tested
  NULL;
END;
/
```

You can use the `%ROWTYPE` attribute to declare a record that represents a row in a table or a row from a query result set, without specifying the names and types for the fields.

For information on records, see Chapter 5, "Using PL/SQL Collections and Records".

Object Types

PL/SQL supports object-oriented programming through object types. An object type encapsulates a data structure along with the functions and procedures needed to manipulate the data. The variables that form the data structure are known as attributes. The functions and procedures that manipulate the attributes are known as methods.

Object types reduce complexity by breaking down a large system into logical entities. This lets you create software components that are modular, maintainable, and reusable. Object-type definitions, and the code for the methods, are stored in the database. Instances of these object types can be stored in tables or used as variables inside PL/SQL code. Example 1–17 shows an object type definition for a bank account.

Example 1–17 Defining an Object Type

```
CREATE TYPE bank_account AS OBJECT (
  acct_number NUMBER(5),
  balance     NUMBER,
  status      VARCHAR2(10),
  MEMBER PROCEDURE open (SELF IN OUT NOCOPY bank_account, amount IN NUMBER),
  MEMBER PROCEDURE close (SELF IN OUT NOCOPY bank_account, num IN NUMBER,
                         amount OUT NUMBER),
  MEMBER PROCEDURE deposit (SELF IN OUT NOCOPY bank_account, num IN NUMBER,
                           amount IN NUMBER),
  MEMBER PROCEDURE withdraw (SELF IN OUT NOCOPY bank_account, num IN NUMBER,
                            amount IN NUMBER),
  MEMBER FUNCTION curr_bal  (num IN NUMBER) RETURN NUMBER );
/
```

For information on object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*. For information on the use of PL/SQL with objects, see Chapter 12, "Using PL/SQL With Object Types".

Understanding PL/SQL Error Handling

PL/SQL makes it easy to detect and process error conditions known as exceptions. When an error occurs, an exception is raised: normal execution stops and control transfers to special exception-handling code, which comes at the end of any PL/SQL block. Each different exception is processed by a particular exception handler.

PL/SQL's exception handling is different from the manual checking you might be used to from C programming, where you insert a check to make sure that every operation succeeded. Instead, the checks and calls to error routines are performed automatically, similar to the exception mechanism in Java programming.

Predefined exceptions are raised automatically for certain common error conditions involving variables or database operations. For example, if you try to divide a number by zero, PL/SQL raises the predefined exception `ZERO_DIVIDE` automatically.

You can declare exceptions of your own, for conditions that you decide are errors, or to correspond to database errors that normally result in ORA- error messages. When you detect a user-defined error condition, you execute a `RAISE` statement. See the exception `comm_missing` in Example 1–12 on page 1-13. In the example, if the commission is null, the exception `comm_missing` is raised.

By default, you put an exception handler at the end of a subprogram to handle exceptions that are raised anywhere inside the subprogram. To continue executing from the spot where an exception happens, enclose the code that might raise an exception inside another `BEGIN-END` block with its own exception handler. For example, you might put separate `BEGIN-END` blocks around groups of SQL statements that might raise `NO_DATA_FOUND`, or around arithmetic operations that might raise `DIVIDE_BY_ZERO`. By putting a `BEGIN-END` block with an exception handler inside a loop, you can continue executing the loop even if some loop iterations raise exceptions. See Example 5–38 on page 5-27.

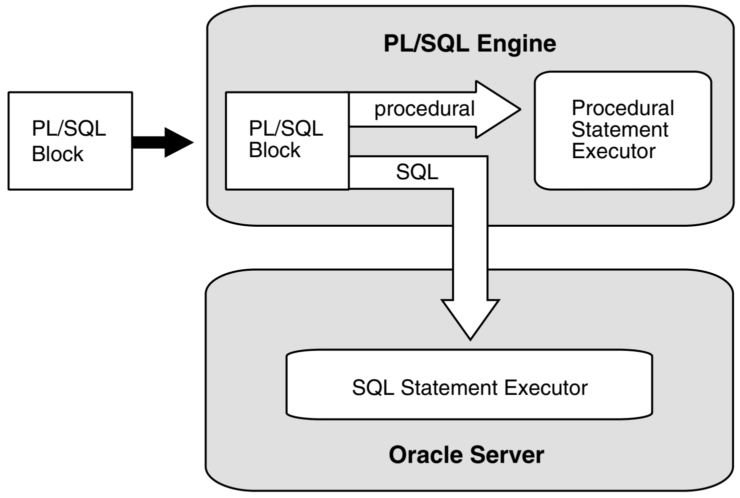
For information on PL/SQL errors, see "Overview of PL/SQL Runtime Error Handling" on page 10-1. For information on PL/SQL warnings, see "Overview of PL/SQL Compile-Time Warnings" on page 10-17.

PL/SQL Architecture

The PL/SQL compilation and run-time system is an engine that compiles and executes PL/SQL blocks and subprograms. The engine can be installed in an Oracle server or in an application development tool such as Oracle Forms.

In either environment, the PL/SQL engine accepts as input any valid PL/SQL block or subprogram. Figure 1–3 shows the PL/SQL engine processing an anonymous block. The PL/SQL engine executes procedural statements but sends SQL statements to the SQL engine in the Oracle database.

Figure 1–3 PL/SQL Engine



In the Oracle Database Server

Typically, the Oracle database server processes PL/SQL blocks and subprograms.

Anonymous Blocks

Anonymous PL/SQL blocks can be submitted to interactive tools such as SQL*Plus and Enterprise Manager, or embedded in an Oracle Precompiler or OCI program. At run time, the program sends these blocks to the Oracle database, where they are compiled and executed.

Stored Subprograms

Subprograms can be compiled and stored in an Oracle database, ready to be executed. Once compiled, it is a schema object known as a stored procedure or stored function, which can be referenced by any number of applications connected to that database.

The SQL `CREATE PROCEDURE` statement lets you create standalone procedures that are stored in the database. For information, see `CREATE PROCEDURE` in *Oracle Database SQL Reference*. The SQL `CREATE FUNCTION` statement lets you create standalone functions that are stored in an Oracle database. For information, see `CREATE FUNCTION` in *Oracle Database SQL Reference*.

Subprograms are stored in a compact compiled form. When called, they are loaded and processed immediately. Subprograms take advantage of shared memory, so that only one copy of a subprogram is loaded into memory for execution by multiple users.

Stored subprograms defined within a package are known as packaged subprograms. Those defined independently are called standalone subprograms. Subprograms nested inside other subprograms or within a PL/SQL block are known as local subprograms, which cannot be referenced by other applications and exist only inside the enclosing block.

Stored subprograms are the key to modular, reusable PL/SQL code. Wherever you might use a JAR file in Java, a module in Perl, a shared library in C++, or a DLL in Visual Basic, you should use PL/SQL stored procedures, stored functions, and packages.

You can call stored subprograms from a database trigger, another stored subprogram, an Oracle Precompiler or OCI application, or interactively from SQL*Plus or

Enterprise Manager. You can also configure a web server so that the HTML for a web page is generated by a stored subprogram, making it simple to provide a web interface for data entry and report generation.

Example 1–18 shows how you can call the stored subprogram in Example 1–12 from SQL*Plus using the CALL statement or using a BEGIN ... END block.

Example 1–18 Techniques for Calling a Standalone Procedure From SQL*Plus

```
CALL award_bonus(179, 1000);

BEGIN
  award_bonus(179, 10000);
END;
/
-- using named notation
BEGIN award_bonus(emp_id=>179, bonus=>10000); END;
/
```

Using the BEGIN .. END block is recommended in several situations. Calling the subprogram from a BEGIN .. END block allows named or mixed notation for parameters which the CALL statement does not support. For information on named parameters, see "Using Positional, Named, or Mixed Notation for Subprogram Parameters" on page 8-7. In addition, using the CALL statement can suppress an ORA-01403: no data found error that has not been handled in the PL/SQL subprogram.

For additional examples on calling PL/SQL procedures, see Example 8–5, "Subprogram Calls Using Positional, Named, and Mixed Notation" on page 8-7 and "Passing Schema Object Names As Parameters" on page 7-8. For information on the use of the CALL statement, see *Oracle Database SQL Reference*

Database Triggers

A database trigger is a stored subprogram associated with a database table, view, or event. The trigger can be called once, when some event occurs, or many times, once for each row affected by an INSERT, UPDATE, or DELETE statement. The trigger can be called after the event, to record it or take some followup action. Or, the trigger can be called before the event to prevent erroneous operations or fix new data so that it conforms to business rules. In Example 1–19 the table-level trigger fires whenever salaries in the employees table are updated, such as the processing in Example 1–7 on page 1-10. For each update, the trigger writes a record to the emp_audit table.

Example 1–19 Creating a Database Trigger

```
CREATE TABLE emp_audit ( emp_audit_id NUMBER(6), up_date DATE,
                         new_sal NUMBER(8,2), old_sal NUMBER(8,2) );

CREATE OR REPLACE TRIGGER audit_sal
   AFTER UPDATE OF salary ON employees FOR EACH ROW
BEGIN
-- bind variables are used here for values
   INSERT INTO emp_audit VALUES( :old.employee_id, SYSDATE,
                                 :new.salary, :old.salary );
END;
/
```

The executable part of a trigger can contain procedural statements as well as SQL data manipulation statements. Besides table-level triggers, there are instead-of triggers for views and system-event triggers for schemas. For more information on triggers, see *Oracle Database Concepts* and *Oracle Database Application Developer's Guide - Fundamentals*. For information on the `CREATE TRIGGER` SQL statement, see *Oracle Database SQL Reference*.

In Oracle Tools

An application development tool that contains the PL/SQL engine can process PL/SQL blocks and subprograms. The tool passes the blocks to its local PL/SQL engine. The engine executes all procedural statements inside the application and sends only SQL statements to the database. Most of the work is done inside the application, not on the database server. If the block contains no SQL statements, the application executes the entire block. This is useful if your application can benefit from conditional and iterative control.

Frequently, Oracle Forms applications use SQL statements to test the value of field entries or to do simple computations. By using PL/SQL instead, you can avoid calls to the database. You can also use PL/SQL functions to manipulate field entries.

2

Fundamentals of the PL/SQL Language

The previous chapter provided an overview of PL/SQL. This chapter focuses on the detailed aspects of the language. Like other programming languages, PL/SQL has a character set, reserved words, punctuation, datatypes, and fixed syntax rules.

This chapter contains these topics:

Character Sets and Lexical Units

PL/SQL programs are written as lines of text using a specific set of characters:

- Upper- and lower-case letters `A` .. `Z` and `a` .. `z`
- Numerals `0` .. `9`
- Symbols `( ) + - * / < > = ! ~ ^ ; : . ' @ % , " # $ & _ | { } ? [ ]`
- Tabs, spaces, and carriage returns

PL/SQL keywords are not case-sensitive, so lower-case letters are equivalent to corresponding upper-case letters except within string and character literals.

A line of PL/SQL text contains groups of characters known as lexical units:

- Delimiters (simple and compound symbols)
- Identifiers, which include reserved words
- Literals
- Comments

To improve readability, you can separate lexical units by spaces. In fact, you must separate adjacent identifiers by a space or punctuation. The following line is not allowed because the reserved words `END` and `IF` are joined:

`IF x > y THEN high := x; ENDIF;` -- not allowed, must be `END IF`

You cannot embed spaces inside lexical units except for string literals and comments. For example, the following line is not allowed because the compound symbol for assignment (`:=`) is split:

`count : = count + 1;` -- not allowed, must be `:=`

To show structure, you can split lines using carriage returns, and indent lines using spaces or tabs. This formatting makes the first `IF` statement more readable.

```
IF x>y THEN max:=x;ELSE max:=y;END IF;
```

The following is easier to read:

```
IF x > y THEN
  max := x;
ELSE
  max := y;
END IF;
```

Delimiters

A delimiter is a simple or compound symbol that has a special meaning to PL/SQL. For example, you use delimiters to represent arithmetic operations such as addition and subtraction. Table 2–1 contains a list of PL/SQL delimiters.

Table 2–1 PL/SQL Delimiters

Symbol	Meaning
`+`	addition operator
`%`	attribute indicator
`'`	character string delimiter
`.`	component selector
`/`	division operator
`(`	expression or list delimiter
`)`	expression or list delimiter
`:`	host variable indicator
`,`	item separator
`*`	multiplication operator
`"`	quoted identifier delimiter
`=`	relational operator
`<`	relational operator
`>`	relational operator
`@`	remote access indicator
`;`	statement terminator
`-`	subtraction/negation operator
`:=`	assignment operator
`=>`	association operator
`||`	concatenation operator

Table 2–1 (Cont.) PL/SQL Delimiters

Symbol	Meaning
`**`	exponentiation operator
`<<`	label delimiter (begin)
`>>`	label delimiter (end)
`/*`	multi-line comment delimiter (begin)
`*/`	multi-line comment delimiter (end)
`..`	range operator
`<>`	relational operator
`!=`	relational operator
`~=`	relational operator
`^=`	relational operator
`<=`	relational operator
`>=`	relational operator
`--`	single-line comment indicator

Identifiers

You use identifiers to name PL/SQL program items and units, which include constants, variables, exceptions, cursors, cursor variables, subprograms, and packages. Some examples of identifiers follow:

```
X
t2
phone#
credit_limit
LastName
oracle$number
```

An identifier consists of a letter optionally followed by more letters, numerals, dollar signs, underscores, and number signs. Other characters such as hyphens, slashes, and spaces are not allowed, as the following examples show:

`mine&yours` is not allowed because of the ampersand
`debit-amount` is not allowed because of the hyphen
`on/off` is not allowed because of the slash
`user id` is not allowed because of the space

Adjoining and trailing dollar signs, underscores, and number signs are allowed:

```
money$$$tree
SN##
try_again_
```

You can use upper, lower, or mixed case to write identifiers. PL/SQL is not case sensitive except within string and character literals. If the only difference between identifiers is the case of corresponding letters, PL/SQL considers them the same:

```
lastname
LastName -- same as lastname
LASTNAME -- same as lastname and LastName
```

The size of an identifier cannot exceed 30 characters. Every character, including dollar signs, underscores, and number signs, is significant. For example, PL/SQL considers the following identifiers to be different:

```
lastname
last_name
```

Identifiers should be descriptive. Avoid obscure names such as `cpm`. Instead, use meaningful names such as `cost_per_thousand`.

Reserved Words

Some identifiers, called reserved words, have a special syntactic meaning to PL/SQL. For example, the words `BEGIN` and `END` are reserved. Often, reserved words are written in upper case for readability.

Trying to redefine a reserved word causes a compilation error. Instead, you can embed reserved words as part of a longer identifier. For example:

```
DECLARE
-- end BOOLEAN; the use of "end" is not allowed; causes compilation error
   end_of_game BOOLEAN;  -- allowed
```

In addition to reserved words, there are keywords that have special meaning in PL/SQL. PL/SQL keywords can be used for identifiers, but this is not recommended. For a list of PL/SQL reserved words and keywords, see Table D–1, " PL/SQL Reserved Words" on page D-1 and Table D–2, " PL/SQL Keywords" on page D-2.

Predefined Identifiers

Identifiers globally declared in package `STANDARD`, such as the exception `INVALID_NUMBER`, can be redeclared. However, redeclaring predefined identifiers is error prone because your local declaration overrides the global declaration.

Quoted Identifiers

For flexibility, PL/SQL lets you enclose identifiers within double quotes. Quoted identifiers are seldom needed, but occasionally they can be useful. They can contain any sequence of printable characters including spaces but excluding double quotes. Thus, the following identifiers are valid:

```
"X+Y"
"last name"
"on/off switch"
"employee(s)"
"*** header info ***"
```

The maximum size of a quoted identifier is 30 characters not counting the double quotes. Though allowed, using PL/SQL reserved words as quoted identifiers is a poor programming practice.

Literals

A literal is an explicit numeric, character, string, or `BOOLEAN` value not represented by an identifier. The numeric literal `147` and the `BOOLEAN` literal `FALSE` are examples. For information on the PL/SQL datatypes, see "Overview of Predefined PL/SQL Datatypes" on page 3-1.

Numeric Literals

Two kinds of numeric literals can be used in arithmetic expressions: integers and reals. An integer literal is an optionally signed whole number without a decimal point. Some examples follow:

```
030   6   -14   0   +32767
```

A real literal is an optionally signed whole or fractional number with a decimal point. Several examples follow:

```
6.6667   0.0   -12.0   3.14159   +8300.00   .5   25.
```

PL/SQL considers numbers such as `12.0` and `25.` to be reals even though they have integral values.

A numeric literal value that is composed only of digits and falls in the range -2147483648 to 2147483647 has a `PLS_INTEGER` datatype; otherwise this literal has the `NUMBER` datatype. You can add the `f` of `d` suffix to a literal value that is composed only of digits to specify the `BINARY_FLOAT` or `BINARY_TABLE` respectively. For the properties of the datatypes, see "PL/SQL Number Types" on page 3-2.

Numeric literals cannot contain dollar signs or commas, but can be written using scientific notation. Simply suffix the number with an `E` (or `e`) followed by an optionally signed integer. A few examples follow:

```
2E5   1.0E-7   3.14159e0   -1E38   -9.5e-3
```

`E` stands for times ten to the power of. As the next example shows, the number after `E` is the power of ten by which the number before `E` is multiplied (the double asterisk (`**`) is the exponentiation operator):

```
5E3 = 5 * 10**3 = 5 * 1000 = 5000
```

The number after `E` also corresponds to the number of places the decimal point shifts. In the last example, the implicit decimal point shifted three places to the right. In this example, it shifts three places to the left:

```
5E-3 = 5 * 10**-3 = 5 * 0.001 = 0.005
```

The absolute value of a `NUMBER` literal can be in the range `1.0E-130` up to (but not including) `1.0E126`. The literal can also be `0`. See Example 2–1. For information on results outside the valid range, see "NUMBER Datatype" on page 3-3.

Example 2–1 NUMBER Literals

```
DECLARE
  n NUMBER; -- declare n of NUMBER datatype
BEGIN
  n :=  -9.999999E-130;  -- valid
  n := 9.999E125; -- valid
--  n := 10.0E125; -- invalid, "numeric overflow or underflow"
END;
/
```

Real literals can also use the trailing letters `f` and `d` to specify the types `BINARY_FLOAT` and `BINARY_DOUBLE`, as shown in Example 2–2.

Example 2–2 Using BINARY_FLOAT and BINARY_DOUBLE

```
DECLARE
   x BINARY_FLOAT := sqrt(2.0f); -- single-precision floating-point number
   y BINARY_DOUBLE := sqrt(2.0d); -- double-precision floating-point number
BEGIN
```

```
   NULL;
END;
/
```

Character Literals

A character literal is an individual character enclosed by single quotes (apostrophes). Character literals include all the printable characters in the PL/SQL character set: letters, numerals, spaces, and special symbols. Some examples follow:

```
'Z'   '%'   '7'   ' '   'z'   '('
```

PL/SQL is case sensitive within character literals. For example, PL/SQL considers the literals `'Z'` and `'z'` to be different. Also, the character literals `'0'..'9'` are not equivalent to integer literals but can be used in arithmetic expressions because they are implicitly convertible to integers.

String Literals

A character value can be represented by an identifier or explicitly written as a string literal, which is a sequence of zero or more characters enclosed by single quotes. All string literals except the null string ('') have datatype `CHAR`.

The following are examples of string literals:

```
'Hello, world!'
'XYZ Corporation'
'10-NOV-91'
'He said "Life is like licking honey from a thorn."'
'$1,000,000'
```

PL/SQL is case sensitive within string literals. For example, PL/SQL considers the following literals to be different:

```
'baker'
'Baker'
```

To represent an apostrophe within a string, you can write two single quotes, which is not the same as writing a double quote:

```
'I''m a string, you''re a string.'
```

Doubling the quotation marks within a complicated literal, particularly one that represents a SQL statement, can be tricky. You can also use the following notation to define your own delimiter characters for the literal. You choose a character that is not present in the string, and then do not need to escape other single quotation marks inside the literal:

```
-- q'!...!' notation allows the of use single quotes
-- inside the literal
string_var := q'!I'm a string, you're a string.!';
```

You can use delimiters [, {, <, and (, pair them with], }, >, and), pass a string literal representing a SQL statement to a subprogram, without doubling the quotation marks around 'INVALID' as follows:

```
func_call(q'[select index_name from user_indexes where status =
           'INVALID']');
```

For `NCHAR` and `NVARCHAR2` literals, use the prefix `nq` instead of `q`:

```
where_clause := nq'#where col_value like '%é'#';
```

For more information about the NCHAR datatype and unicode strings, see *Oracle Database Globalization Support Guide*.

BOOLEAN Literals

BOOLEAN literals are the predefined values TRUE, FALSE, and NULL. NULL stands for a missing, unknown, or inapplicable value. Remember, BOOLEAN literals are values, not strings. For example, TRUE is no less a value than the number 25.

Datetime Literals

Datetime literals have various formats depending on the datatype. For example:

Example 2–3 Using DateTime Literals

```
DECLARE
   d1 DATE := DATE '1998-12-25';
   t1 TIMESTAMP := TIMESTAMP '1997-10-22 13:01:01';
   t2 TIMESTAMP WITH TIME ZONE := TIMESTAMP '1997-01-31 09:26:56.66 +02:00';
-- Three years and two months
-- For greater precision, we would use the day-to-second interval
   i1 INTERVAL YEAR TO MONTH := INTERVAL '3-2' YEAR TO MONTH;
-- Five days, four hours, three minutes, two and 1/100 seconds
   i2 INTERVAL DAY TO SECOND := INTERVAL '5 04:03:02.01' DAY TO SECOND;
```

You can also specify whether a given interval value is YEAR TO MONTH or DAY TO SECOND. For example, current_timestamp - current_timestamp produces a value of type INTERVAL DAY TO SECOND by default. You can specify the type of the interval using the formats:

- (*interval_expression*) DAY TO SECOND
- (*interval_expression*) YEAR TO MONTH

For details on the syntax for the date and time types, see the *Oracle Database SQL Reference*. For examples of performing date and time arithmetic, see *Oracle Database Application Developer's Guide - Fundamentals*.

Comments

The PL/SQL compiler ignores comments, but you should not. Adding comments to your program promotes readability and aids understanding. Generally, you use comments to describe the purpose and use of each code segment. PL/SQL supports two comment styles: single-line and multi-line.

Single-Line Comments

Single-line comments begin with a double hyphen (--) anywhere on a line and extend to the end of the line. A few examples follow:

Example 2–4 Using Single-Line Comments

```
DECLARE
   howmany    NUMBER;
   num_tables NUMBER;
BEGIN
-- begin processing
   SELECT COUNT(*) INTO howmany FROM USER_OBJECTS
```

```
      WHERE OBJECT_TYPE = 'TABLE'; -- Check number of tables
   num_tables := howmany;          -- Compute some other value
END;
/
```

Notice that comments can appear within a statement at the end of a line.

While testing or debugging a program, you might want to disable a line of code. The following example shows how you can disable a line by making it a comment:

```
-- DELETE FROM employees WHERE comm_pct IS NULL;
```

Multi-line Comments

Multi-line comments begin with a slash-asterisk (`/*`), end with an asterisk-slash (`*/`), and can span multiple lines, as shown in Example 2–5. You can use multi-line comment delimiters to comment-out whole sections of code.

Example 2–5 Using Multi-Line Comments

```
DECLARE
   some_condition BOOLEAN;
   pi NUMBER := 3.1415926;
   radius NUMBER := 15;
   area NUMBER;
BEGIN
  /* Perform some simple tests and assignments */
  IF 2 + 2 = 4 THEN
    some_condition := TRUE; /* We expect this THEN to always be performed */
  END IF;
  /* The following line computes the area of a circle using pi, which is the
     ratio between the circumference and diameter. After the area is computed,
     the result is displayed. */
  area := pi * radius**2;
  DBMS_OUTPUT.PUT_LINE('The area is: ' || TO_CHAR(area));
END;
/
```

Restrictions on Comments

You cannot nest comments. You cannot use single-line comments in a PL/SQL block that will be processed by an Oracle Precompiler program because end-of-line characters are ignored. As a result, single-line comments extend to the end of the block, not just to the end of a line. In this case, use the `/*  */` notation instead.

Declarations

Your program stores values in variables and constants. As the program executes, the values of variables can change, but the values of constants cannot.

You can declare variables and constants in the declarative part of any PL/SQL block, subprogram, or package. Declarations allocate storage space for a value, specify its datatype, and name the storage location so that you can reference it.

Some examples follow:

```
DECLARE
   birthday  DATE;
   emp_count SMALLINT := 0;
```

The first declaration names a variable of type DATE. The second declaration names a variable of type SMALLINT and uses the assignment operator to assign an initial value of zero to the variable.

The next examples show that the expression following the assignment operator can be arbitrarily complex and can refer to previously initialized variables:

```
DECLARE
   pi     REAL := 3.14159;
   radius REAL := 1;
   area   REAL := pi * radius**2;
```

By default, variables are initialized to NULL, so it is redundant to include ":= NULL" in a variable declaration.

Constants

To declare a constant, put the keyword CONSTANT before the type specifier. The following declaration names a constant of type REAL and assigns an unchangeable value of 5000 to the constant. A constant must be initialized in its declaration. Otherwise, a compilation error occurs.

```
DECLARE
   credit_limit CONSTANT REAL := 5000.00;
   max_days_in_year CONSTANT INTEGER := 366;
   urban_legend CONSTANT BOOLEAN := FALSE;
```

Using DEFAULT

You can use the keyword DEFAULT instead of the assignment operator to initialize variables. For example, the declaration

```
blood_type CHAR := 'O';
```

can be rewritten as follows:

```
blood_type CHAR DEFAULT 'O';
```

Use DEFAULT for variables that have a typical value. Use the assignment operator for variables (such as counters and accumulators) that have no typical value. For example:

```
hours_worked   INTEGER DEFAULT 40;
employee_count INTEGER := 0;
```

You can also use DEFAULT to initialize subprogram parameters, cursor parameters, and fields in a user-defined record.

Using NOT NULL

Besides assigning an initial value, declarations can impose the NOT NULL constraint:

```
DECLARE
  acct_id INTEGER(4) NOT NULL := 9999;
```

You cannot assign nulls to a variable defined as NOT NULL. If you try, PL/SQL raises the predefined exception VALUE_ERROR.

The NOT NULL constraint must be followed by an initialization clause.

PL/SQL provide subtypes NATURALN and POSITIVEN that are predefined as NOT NULL. You can omit the NOT NULL constraint when declaring variables of these types, and you must include an initialization clause.

Using the %TYPE Attribute

The %TYPE attribute provides the datatype of a variable or database column. As shown in Example 2–6, variables declared with %TYPE inherit the datatype of a variable, plus default values and constraints.

Example 2–6 Using %TYPE With the Datatype of a Variable

```
DECLARE
  credit PLS_INTEGER RANGE 1000..25000;
  debit  credit%TYPE;
  v_name VARCHAR2(20);
  name VARCHAR2(20) NOT NULL := 'JoHn SmItH';
-- If we increase the length of NAME, the other variables become longer also
  upper_name name%TYPE := UPPER(name);
  lower_name name%TYPE := LOWER(name);
  init_name name%TYPE := INITCAP(name);
BEGIN
-- display inherited default values
  DBMS_OUTPUT.PUT_LINE('name: ' || name || ' upper_name: ' || upper_name
          || ' lower_name: ' || lower_name || ' init_name: ' || init_name);
-- lower_name := 'jonathan henry smithson'; invalid, character string is too long
-- lower_name := NULL; invalid, NOT NULL CONSTRAINT
-- debit := 50000; invalid, value out of range
END;
/
```

Note that variables declared using %TYPE are treated like those declared using a datatype specifier. For example, given the previous declarations, PL/SQL treats debit like a PLS_INTEGER variable. A %TYPE declaration can also include an initialization clause.

The %TYPE attribute is particularly useful when declaring variables that refer to database columns. You can reference a table and column, or you can reference an owner, table, and column, as in:

```
DECLARE
-- If the length of the column ever changes, this code
-- will use the new length automatically.
   the_trigger user_triggers.trigger_name%TYPE;
```

When you use table_name.column_name.%TYPE to declare a variable, you do not need to know the actual datatype, and attributes such as precision, scale, and length. If the database definition of the column changes, the datatype of the variable changes accordingly at run time. However, %TYPE variables do not inherit column constraints, such as the NOT NULL or check constraint, or default values. For example, even though the database column empid is defined as NOT NULL in Example 2–7, you can assign a NULL to the variable v_empid.

Example 2–7 Using %TYPE With Table Columns

```
CREATE TABLE employees_temp (empid NUMBER(6) NOT NULL PRIMARY KEY,
 deptid NUMBER(6) CONSTRAINT check_deptid CHECK (deptid BETWEEN 100 AND 200),
 deptname VARCHAR2(30) DEFAULT 'Sales');
```

```
DECLARE
   v_empid    employees_temp.empid%TYPE;
   v_deptid   employees_temp.deptid%TYPE;
   v_deptname employees_temp.deptname%TYPE;
BEGIN
   v_empid := NULL;  -- this works, null constraint is not inherited
-- v_empid := 10000002; -- invalid, number precision too large
   v_deptid := 50; -- this works, check constraint is not inherited
-- the default value is not inherited in the following
   DBMS_OUTPUT.PUT_LINE('v_deptname: ' || v_deptname);
END;
/
```

See "Constraints and Default Values With Subtypes" on page 3-20 for information on column constraints that are inherited by subtypes declared using `%TYPE`.

Using the %ROWTYPE Attribute

The `%ROWTYPE` attribute provides a record type that represents a row in a table or view. Columns in a row and corresponding fields in a record have the same names and datatypes. However, fields in a `%ROWTYPE` record do not inherit constraints, such as the `NOT NULL` or check constraint, or default values, as shown in Example 2–8. See also Example 3–11 on page 3-20.

Example 2–8 Using %ROWTYPE With Table Rows

```
DECLARE
   emprec    employees_temp%ROWTYPE;
BEGIN
   emprec.empid := NULL;  -- this works, null constraint is not inherited
-- emprec.empid := 10000002; -- invalid, number precision too large
   emprec.deptid := 50; -- this works, check constraint is not inherited
-- the default value is not inherited in the following
   DBMS_OUTPUT.PUT_LINE('emprec.deptname: ' || emprec.deptname);
END;
/
```

The record can store an entire row of data selected from the table, or fetched from a cursor or strongly typed cursor variable as shown in Example 2–9.

Example 2–9 Using the %ROWTYPE Attribute

```
DECLARE
-- %ROWTYPE can include all the columns in a table...
   emp_rec employees%ROWTYPE;
-- ...or a subset of the columns, based on a cursor.
   CURSOR c1 IS
      SELECT department_id, department_name FROM departments;
   dept_rec c1%ROWTYPE;
-- Could even make a %ROWTYPE with columns from multiple tables.
   CURSOR c2 IS
      SELECT employee_id, email, employees.manager_id, location_id
      FROM employees, departments
      WHERE employees.department_id = departments.department_id;
   join_rec c2%ROWTYPE;
BEGIN
-- We know EMP_REC can hold a row from the EMPLOYEES table.
   SELECT * INTO emp_rec FROM employees WHERE ROWNUM < 2;
-- We can refer to the fields of EMP_REC using column names
-- from the EMPLOYEES table.
```

```
   IF emp_rec.department_id = 20 AND emp_rec.last_name = 'JOHNSON' THEN
      emp_rec.salary := emp_rec.salary * 1.15;
   END IF;
END;
/
```

Aggregate Assignment

Although a `%ROWTYPE` declaration cannot include an initialization clause, there are ways to assign values to all fields in a record at once. You can assign one record to another if their declarations refer to the same table or cursor. Example 2–10 shows record assignments that are allowed.

Example 2–10 Assigning Values to a Record With a %ROWTYPE Declaration

```
DECLARE
   dept_rec1 departments%ROWTYPE;
   dept_rec2 departments%ROWTYPE;
   CURSOR c1 IS SELECT department_id, location_id FROM departments;
   dept_rec3 c1%ROWTYPE;
BEGIN
   dept_rec1 := dept_rec2;  -- allowed
-- dept_rec2 refers to a table, dept_rec3 refers to a cursor
-- dept_rec2 := dept_rec3;  -- not allowed
END;
/
```

You can assign a list of column values to a record by using the `SELECT` or `FETCH` statement, as the following example shows. The column names must appear in the order in which they were defined by the `CREATE TABLE` or `CREATE VIEW` statement.

```
DECLARE
   dept_rec departments%ROWTYPE;
BEGIN
   SELECT * INTO dept_rec FROM departments
      WHERE department_id = 30 and ROWNUM < 2;
END;
/
```

However, there is no constructor for a record type, so you cannot assign a list of column values to a record by using an assignment statement.

Using Aliases

Select-list items fetched from a cursor associated with `%ROWTYPE` must have simple names or, if they are expressions, must have aliases. Example 2–11 uses an alias called `complete_name` to represent the concatenation of two columns:

Example 2–11 Using an Alias for Column Names

```
BEGIN
-- We assign an alias (complete_name) to the expression value, because
-- it has no column name.
   FOR item IN
   (  SELECT first_name || ' ' || last_name complete_name
      FROM employees WHERE ROWNUM < 11  )
   LOOP
-- Now we can refer to the field in the record using this alias.
     DBMS_OUTPUT.PUT_LINE('Employee name: ' || item.complete_name);
   END LOOP;
```

```
END;
/
```

Restrictions on Declarations

PL/SQL does not allow forward references. You must declare a variable or constant before referencing it in other statements, including other declarative statements.

PL/SQL does allow the forward declaration of subprograms. For more information, see "Declaring Nested PL/SQL Subprograms" on page 8-5.

Some languages allow you to declare a list of variables that have the same datatype. PL/SQL does not allow this. You must declare each variable separately:

```
DECLARE
-- Multiple declarations not allowed.
-- i, j, k, l SMALLINT;
-- Instead, declare each separately.
   i SMALLINT;
   j SMALLINT;
-- To save space, you can declare more than one on a line.
   k SMALLINT; l SMALLINT;
```

PL/SQL Naming Conventions

The same naming conventions apply to all PL/SQL program items and units including constants, variables, cursors, cursor variables, exceptions, procedures, functions, and packages. Names can be simple, qualified, remote, or both qualified and remote. For example, you might use the procedure name `raise_salary` in any of the following ways:

```
raise_salary(...);  -- simple
emp_actions.raise_salary(...);  -- qualified
raise_salary@newyork(...);  -- remote
emp_actions.raise_salary@newyork(...);  -- qualified and remote
```

In the first case, you simply use the procedure name. In the second case, you must qualify the name using dot notation because the procedure is stored in a package called `emp_actions`. In the third case, using the remote access indicator (`@`), you reference the database link `newyork` because the procedure is stored in a remote database. In the fourth case, you qualify the procedure name and reference a database link.

Synonyms

You can create synonyms to provide location transparency for remote schema objects such as tables, sequences, views, standalone subprograms, packages, and object types. However, you cannot create synonyms for items declared within subprograms or packages. That includes constants, variables, cursors, cursor variables, exceptions, and packaged subprograms.

Scoping

Within the same scope, all declared identifiers must be unique; even if their datatypes differ, variables and parameters cannot share the same name. In Example 2–12, the second declaration is not allowed.

Example 2–12 Errors With Duplicate Identifiers in Same Scope

```
DECLARE
   valid_id BOOLEAN;
   valid_id VARCHAR2(5);  -- not allowed, duplicate identifier
BEGIN
-- The error occurs when the identifier is referenced,
-- not in the declaration part.
   valid_id := FALSE; -- raises an error here
END;
/
```

For the scoping rules that apply to identifiers, see "Scope and Visibility of PL/SQL Identifiers" on page 2-15.

Case Sensitivity

Like all identifiers, the names of constants, variables, and parameters are not case sensitive. For instance, PL/SQL considers the following names to be the same:

Example 2–13 Case Sensitivity of Identifiers

```
DECLARE
   zip_code INTEGER;
   Zip_Code INTEGER;  -- duplicate identifier, despite Z/z case difference
BEGIN
   zip_code := 90120; -- raises error here because of duplicate identifiers
END;
/
```

Name Resolution

In potentially ambiguous SQL statements, the names of database columns take precedence over the names of local variables and formal parameters. For example, if a variable and a column with the same name are both used in a WHERE clause, SQL considers that both cases refer to the column.

To avoid ambiguity, add a prefix to the names of local variables and formal parameters, or use a block label to qualify references as shown in Example 2–14.

Example 2–14 Using a Block Label for Name Resolution

```
CREATE TABLE employees2 AS SELECT last_name FROM employees;
<<main>>
DECLARE
   last_name VARCHAR2(10) := 'King';
   v_last_name VARCHAR2(10) := 'King';
BEGIN
-- deletes everyone, because both LAST_NAMEs refer to the column
   DELETE FROM employees2 WHERE last_name = last_name;
   DBMS_OUTPUT.PUT_LINE('Deleted ' || SQL%ROWCOUNT || ' rows.');
   ROLLBACK;
-- OK, column and variable have different names
   DELETE FROM employees2 WHERE last_name = v_last_name;
   DBMS_OUTPUT.PUT_LINE('Deleted ' || SQL%ROWCOUNT || ' rows.');
   ROLLBACK;
-- OK, block name specifies that 2nd last_name is a variable
   DELETE FROM employees2 WHERE last_name = main.last_name;
   DBMS_OUTPUT.PUT_LINE('Deleted ' || SQL%ROWCOUNT || ' rows.');
   ROLLBACK;
END;
/
```

Example 2–15 shows that you can use a subprogram name to qualify references to local variables and formal parameters.

Example 2–15 Using a Subprogram Name for Name Resolution

```
DECLARE
   FUNCTION dept_name (department_id IN NUMBER)
      RETURN departments.department_name%TYPE
   IS
      department_name departments.department_name%TYPE;
   BEGIN
-- DEPT_NAME.department_name specifies the local variable
-- instead of the table column
      SELECT department_name INTO dept_name.department_name
         FROM departments
         WHERE department_id = dept_name.department_id;
      RETURN department_name;
   END;
BEGIN
   FOR item IN (SELECT department_id FROM departments)
   LOOP
      DBMS_OUTPUT.PUT_LINE('Department: ' || dept_name(item.department_id));
   END LOOP;
END;
/
```

For a full discussion of name resolution, see Appendix B, "How PL/SQL Resolves Identifier Names".

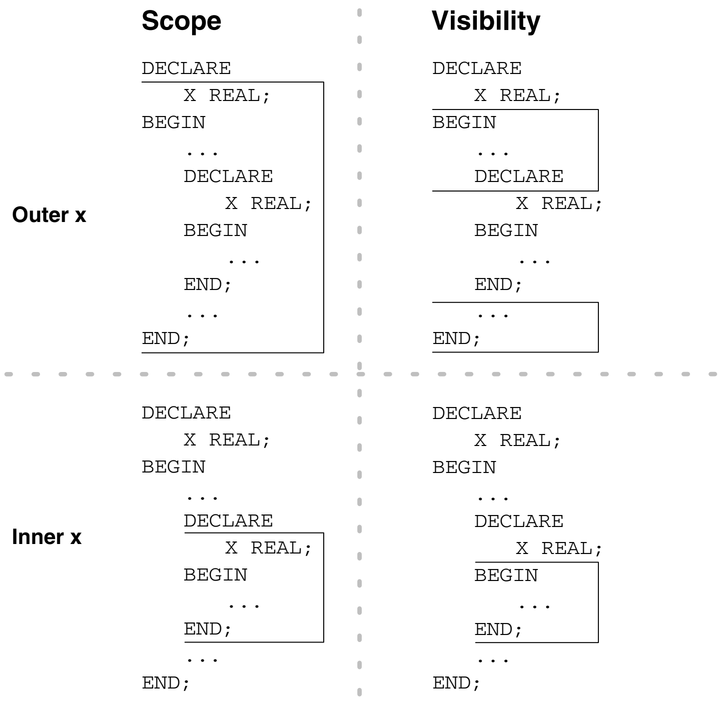
Scope and Visibility of PL/SQL Identifiers

References to an identifier are resolved according to its scope and visibility. The *scope* of an identifier is that region of a program unit (block, subprogram, or package) from which you can reference the identifier. An identifier is visible only in the regions from which you can reference the identifier using an unqualified name. Figure 2–1 shows the scope and visibility of a variable named `x`, which is declared in an enclosing block, then redeclared in a sub-block.

Identifiers declared in a PL/SQL block are considered local to that block and global to all its sub-blocks. If a global identifier is redeclared in a sub-block, both identifiers remain in scope. Within the sub-block, however, only the local identifier is visible because you must use a qualified name to reference the global identifier.

Although you cannot declare an identifier twice in the same block, you can declare the same identifier in two different blocks. The two items represented by the identifier are distinct, and any change in one does not affect the other. However, a block cannot reference identifiers declared in other blocks at the same level because those identifiers are neither local nor global to the block.

Figure 2–1 Scope and Visibility



```
DECLARE
   X REAL;
BEGIN
   ...
   DECLARE
      X REAL;
   BEGIN
      ...
   END;
   ...
END;
```

Example 2–16 illustrates the scope rules. Notice that the identifiers declared in one sub-block cannot be referenced in the other sub-block. That is because a block cannot reference identifiers declared in other blocks nested at the same level.

Example 2–16 Scope Rules

```
DECLARE
   a CHAR;
   b REAL;
BEGIN
   -- identifiers available here: a (CHAR), b
   DECLARE
      a INTEGER;
      c REAL;
   BEGIN
     NULL; -- identifiers available here: a (INTEGER), b, c
   END;
   DECLARE
      d REAL;
   BEGIN
     NULL; -- identifiers available here: a (CHAR), b, d
   END;
   -- identifiers available here: a (CHAR), b
END;
/
```

Recall that global identifiers can be redeclared in a sub-block, in which case the local declaration prevails and the sub-block cannot reference the global identifier unless you use a qualified name. The qualifier can be the label of an enclosing block as shown in Example 2–17.

Example 2–17 Using a Label Qualifier With Identifiers

```
<<outer>>
DECLARE
   birthdate DATE := '09-AUG-70';
BEGIN
   DECLARE
      birthdate DATE;
   BEGIN
      birthdate := '29-SEP-70';
      IF birthdate = outer.birthdate THEN
         DBMS_OUTPUT.PUT_LINE ('Same Birthday');
      ELSE
         DBMS_OUTPUT.PUT_LINE ('Different Birthday');
      END IF;
   END;
END;
/
```

As Example 2–18 shows, the qualifier can also be the name of an enclosing subprogram:

Example 2–18 Using Subprogram Qualifier With Identifiers

```
CREATE OR REPLACE PROCEDURE check_credit(limit NUMBER) AS
   rating NUMBER := 3;
   FUNCTION check_rating RETURN BOOLEAN IS
      rating       NUMBER := 1;
      over_limit   BOOLEAN;
   BEGIN
     IF check_credit.rating <= limit THEN
       over_limit := FALSE;
     ELSE
       rating := limit;
       over_limit := TRUE;
     END IF;
     RETURN over_limit;
   END check_rating;
BEGIN
   IF check_rating THEN
     DBMS_OUTPUT.PUT_LINE( 'Credit rating over limit (' || TO_CHAR(limit)
                           || ').' || ' Rating: ' || TO_CHAR(rating));
   ELSE
     DBMS_OUTPUT.PUT_LINE( 'Credit rating OK. ' || 'Rating: '
                           || TO_CHAR(rating) );
   END IF;
END;
/

CALL check_credit(1);
```

However, within the same scope, a label and a subprogram cannot have the same name. The use of duplicate labels, illustrated in Example 2–19, should be avoided.

Example 2–19 PL/SQL Block Using Multiple and Duplicate Labels

```
<<compute_ratio>>
<<another_label>>
DECLARE
   numerator   NUMBER := 22;
   denominator NUMBER := 7;
   the_ratio   NUMBER;
  BEGIN
     <<inner_label>>
     <<another_label>>
   DECLARE
      denominator NUMBER := 0;
    BEGIN
      -- first use the denominator value = 7 from global DECLARE
      -- to compute a rough value of pi
      the_ratio := numerator/compute_ratio.denominator;
      DBMS_OUTPUT.PUT_LINE('Ratio = ' || the_ratio);
      -- now use the local denominator value = 0 to raise an exception
      -- inner_label is not needed but used for clarification
      the_ratio := numerator/inner_label.denominator;
      DBMS_OUTPUT.PUT_LINE('Ratio = ' || the_ratio);
      -- if you use a duplicate label, you might get errors
      -- or unpredictable results
      the_ratio := numerator/another_label.denominator;
      DBMS_OUTPUT.PUT_LINE('Ratio = ' || the_ratio);
    EXCEPTION
      WHEN ZERO_DIVIDE THEN
        DBMS_OUTPUT.PUT_LINE('Divide-by-zero error: can''t divide '
         || numerator || ' by ' || denominator);
      WHEN OTHERS THEN
        DBMS_OUTPUT.PUT_LINE('Unexpected error.');
  END inner_label;
END compute_ratio;
/
```

Assigning Values to Variables

You can use assignment statements to assign values to variables. For example, the following statement assigns a new value to the variable `bonus`, overwriting its old value:

```
bonus := salary * 0.15;
```

Variables and constants are initialized every time a block or subprogram is entered. By default, variables are initialized to `NULL`. Unless you expressly initialize a variable, its value is undefined (`NULL`) as shown in Example 2–20.

Example 2–20 Initialization of Variables and Constants

```
DECLARE
   counter INTEGER;
BEGIN
-- COUNTER is initially NULL, so 'COUNTER + 1' is also null.
   counter := counter + 1;
   IF counter IS NULL THEN
      DBMS_OUTPUT.PUT_LINE('COUNTER is NULL not 1.');
   END IF;
END;
/
```

To avoid unexpected results, never reference a variable before you assign it a value. The expression following the assignment operator can be arbitrarily complex, but it must yield a datatype that is the same as or convertible to the datatype of the variable.

Assigning BOOLEAN Values

Only the values TRUE, FALSE, and NULL can be assigned to a BOOLEAN variable as shown in Example 2–21. You can assign these literal values, or expressions such as comparisons using relational operators.

Example 2–21 Assigning BOOLEAN Values

```
DECLARE
   done BOOLEAN; -- DONE is initially NULL
   counter NUMBER := 0;
BEGIN
   done := FALSE; -- Assign a literal value
   WHILE done != TRUE -- Compare to a literal value
   LOOP
      counter := counter + 1;
      done := (counter > 500); -- If counter > 500, DONE = TRUE
   END LOOP;
END;
/
```

Assigning a SQL Query Result to a PL/SQL Variable

You can use the SELECT statement to have Oracle assign values to a variable. For each item in the select list, there must be a corresponding, type-compatible variable in the INTO list as shown in Example 2–22.

Example 2–22 Assigning a Query Result to a Variable

```
DECLARE
   emp_id   employees.employee_id%TYPE := 100;
   emp_name employees.last_name%TYPE;
   wages    NUMBER(7,2);
BEGIN
   SELECT last_name, salary + (salary * nvl(commission_pct,0))
      INTO emp_name, wages FROM employees
      WHERE employee_id = emp_id;
   DBMS_OUTPUT.PUT_LINE('Employee ' || emp_name || ' might make ' || wages);
END;
/
```

Because SQL does not have a BOOLEAN type, you cannot select column values into a BOOLEAN variable. For additional information on assigning variables with the DML statements, including situations when the value of a variable is undefined, see "Data Manipulation" on page 6-1.

PL/SQL Expressions and Comparisons

Expressions are constructed using operands and operators. An operand is a variable, constant, literal, or function call that contributes a value to an expression. An example of a simple arithmetic expression follows:

```
-X / 2 + 3
```

Unary operators such as the negation operator (-) operate on one operand; binary operators such as the division operator (/) operate on two operands. PL/SQL has no ternary operators.

The simplest expressions consist of a single variable, which yields a value directly. PL/SQL evaluates an expression by combining the values of the operands in ways specified by the operators. An expression always returns a single value. PL/SQL determines the datatype of this value by examining the expression and the context in which it appears.

Operator Precedence

The operations within an expression are done in a particular order depending on their precedence (priority). Table 2–2 shows the default order of operations from first to last (top to bottom).

Table 2–2 Order of Operations

Operator	Operation
`**`	exponentiation
`+, -`	identity, negation
`*, /`	multiplication, division
`+, -, ||`	addition, subtraction, concatenation
`=, <, >, <=, >=, <>, !=, ~=, ^=, IS NULL, LIKE, BETWEEN, IN`	comparison
`NOT`	logical negation
`AND`	conjunction
`OR`	inclusion

Operators with higher precedence are applied first. In the following example, both expressions yield 8 because division has a higher precedence than addition. Operators with the same precedence are applied in no particular order.

```
5 + 12 / 4
12 / 4 + 5
```

You can use parentheses to control the order of evaluation. For example, the following expression yields 7, not 11, because parentheses override the default operator precedence:

```
(8 + 6) / 2
```

In the next example, the subtraction is done before the division because the most deeply nested subexpression is always evaluated first:

```
100 + (20 / 5 + (7 - 3))
```

The following example shows that you can always use parentheses to improve readability, even when they are not needed:

```
(salary * 0.05) + (commission * 0.25)
```

Logical Operators

The logical operators `AND`, `OR`, and `NOT` follow the tri-state logic shown in Table 2–3. `AND` and `OR` are binary operators; `NOT` is a unary operator.

Table 2–3 Logic Truth Table

x	y	x AND y	x OR y	NOT x
TRUE	TRUE	TRUE	TRUE	FALSE

Table 2–3 (Cont.) Logic Truth Table

x	y	x AND y	x OR y	NOT x
TRUE	FALSE	FALSE	TRUE	FALSE
TRUE	NULL	NULL	TRUE	FALSE
FALSE	TRUE	FALSE	TRUE	TRUE
FALSE	FALSE	FALSE	FALSE	TRUE
FALSE	NULL	FALSE	NULL	TRUE
NULL	TRUE	NULL	TRUE	NULL
NULL	FALSE	FALSE	NULL	NULL
NULL	NULL	NULL	NULL	NULL

As the truth table shows, AND returns TRUE only if both its operands are true. On the other hand, OR returns TRUE if either of its operands is true. NOT returns the opposite value (logical negation) of its operand. For example, NOT TRUE returns FALSE.

NOT NULL returns NULL, because nulls are indeterminate. Be careful to avoid unexpected results in expressions involving nulls; see "Handling Null Values in Comparisons and Conditional Statements" on page 2-27.

Order of Evaluation

When you do not use parentheses to specify the order of evaluation, operator precedence determines the order. Compare the following expressions:

```
NOT (valid AND done)   |   NOT valid AND done
```

If the BOOLEAN variables valid and done have the value FALSE, the first expression yields TRUE. However, the second expression yields FALSE because NOT has a higher precedence than AND. Therefore, the second expression is equivalent to:

```
(NOT valid) AND done
```

In the following example, notice that when valid has the value FALSE, the whole expression yields FALSE regardless of the value of done:

```
valid AND done
```

Likewise, in the next example, when valid has the value TRUE, the whole expression yields TRUE regardless of the value of done:

```
valid OR done
```

Short-Circuit Evaluation

When evaluating a logical expression, PL/SQL uses short-circuit evaluation. That is, PL/SQL stops evaluating the expression as soon as the result can be determined. This lets you write expressions that might otherwise cause an error. Consider the OR expression in Example 2–23.

Example 2–23 Short-Circuit Evaluation

```
DECLARE
   on_hand  INTEGER := 0;
   on_order INTEGER := 100;
BEGIN
-- Does not cause divide-by-zero error; evaluation stops after first expression
   IF (on_hand = 0) OR ((on_order / on_hand) < 5) THEN
```

```
      DBMS_OUTPUT.PUT_LINE('On hand quantity is zero.');
   END IF;
END;
/
```

When the value of `on_hand` is zero, the left operand yields `TRUE`, so PL/SQL does not evaluate the right operand. If PL/SQL evaluated both operands before applying the `OR` operator, the right operand would cause a division by zero error.

Short-circuit evaluation applies to `IF` statements, `CASE` statements, and `CASE` expressions in PL/SQL.

Comparison Operators

Comparison operators compare one expression to another. The result is always true, false, or null. Typically, you use comparison operators in conditional control statements and in the `WHERE` clause of SQL data manipulation statements. Example 2–24 provides some examples of comparisons for different types.

Example 2–24 Using Comparison Operators

```
DECLARE
   PROCEDURE assert(assertion VARCHAR2, truth BOOLEAN)
   IS
   BEGIN
      IF truth IS NULL THEN
         DBMS_OUTPUT.PUT_LINE('Assertion ' || assertion || ' is unknown (NULL)');
      ELSIF truth = TRUE THEN
         DBMS_OUTPUT.PUT_LINE('Assertion ' || assertion || ' is TRUE');
      ELSE
         DBMS_OUTPUT.PUT_LINE('Assertion ' || assertion || ' is FALSE');
      END IF;
   END;
BEGIN
   assert('2 + 2 = 4', 2 + 2 = 4);
   assert('10 > 1', 10 > 1);
   assert('10 <= 1', 10 <= 1);
   assert('5 BETWEEN 1 AND 10', 5 BETWEEN 1 AND 10);
   assert('NULL != 0', NULL != 0);
   assert('3 IN (1,3,5)', 3 IN (1,3,5));
   assert('''A'' < ''Z''', 'A' < 'Z');
   assert('''baseball'' LIKE ''%all%''', 'baseball' LIKE '%all%');
   assert('''suit'' || ''case'' = ''suitcase''', 'suit' || 'case' = 'suitcase');
END;
/
```

Relational Operators

The following table lists the relational operators with their meanings.

Operator	Meaning
=	equal to
<>, !=, ~=, ^=	not equal to
<	less than
>	greater than
<=	less than or equal to

Operator	Meaning
`>=`	greater than or equal to

IS NULL Operator

The `IS NULL` operator returns the `BOOLEAN` value `TRUE` if its operand is null or `FALSE` if it is not null. Comparisons involving nulls always yield `NULL`. Test whether a value is null as follows:

```
IF variable IS NULL THEN ...
```

LIKE Operator

You use the `LIKE` operator to compare a character, string, or `CLOB` value to a pattern. Case is significant. `LIKE` returns the `BOOLEAN` value `TRUE` if the patterns match or `FALSE` if they do not match.

The patterns matched by `LIKE` can include two special-purpose characters called wildcards. An underscore (_) matches exactly one character; a percent sign (`%`) matches zero or more characters. For example, if the value of `last_name` is `'JOHNSON'`, the following expression is true:

```
last_name LIKE 'J%S_N'
```

To search for the percent sign and underscore characters, you define an escape character and put that character before the percent sign or underscore. The following example uses the backslash as the escape character, so that the percent sign in the string does not act as a wildcard:

```
IF sale_sign LIKE '50\% off!' ESCAPE '\' THEN...
```

BETWEEN Operator

The `BETWEEN` operator tests whether a value lies in a specified range. It means "greater than or equal to *low value* and less than or equal to *high value*." For example, the following expression is false:

```
45 BETWEEN 38 AND 44
```

IN Operator

The `IN` operator tests set membership. It means "equal to any member of." The set can contain nulls, but they are ignored. For example, the following expression tests whether a value is part of a set of values:

```
letter IN ('a','b','c')
```

Be careful when inverting this condition. Expressions of the form:

```
value NOT IN set
```

yield `FALSE` if the set contains a null.

Concatenation Operator

Double vertical bars (||) serve as the concatenation operator, which appends one string (`CHAR`, `VARCHAR2`, `CLOB`, or the equivalent Unicode-enabled type) to another. For example, the expression

```
'suit' || 'case'
```

returns the following value:

```
'suitcase'
```

If both operands have datatype CHAR, the concatenation operator returns a CHAR value. If either operand is a CLOB value, the operator returns a temporary CLOB. Otherwise, it returns a VARCHAR2 value.

BOOLEAN Expressions

PL/SQL lets you compare variables and constants in both SQL and procedural statements. These comparisons, called BOOLEAN expressions, consist of simple or complex expressions separated by relational operators. Often, BOOLEAN expressions are connected by the logical operators AND, OR, and NOT. A BOOLEAN expression always yields TRUE, FALSE, or NULL.

In a SQL statement, BOOLEAN expressions let you specify the rows in a table that are affected by the statement. In a procedural statement, BOOLEAN expressions are the basis for conditional control. There are three kinds of BOOLEAN expressions: arithmetic, character, and date.

BOOLEAN Arithmetic Expressions

You can use the relational operators to compare numbers for equality or inequality. Comparisons are quantitative; that is, one number is greater than another if it represents a larger quantity. For example, given the assignments

```
number1 := 75;
number2 := 70;
```

the following expression is true:

```
number1 > number2
```

BOOLEAN Character Expressions

You can compare character values for equality or inequality. By default, comparisons are based on the binary values of each byte in the string. For example, given the assignments

```
string1 := 'Kathy';
string2 := 'Kathleen';
```

the following expression is true:

```
string1 > string2
```

By setting the initialization parameter NLS_COMP=ANSI, you can make comparisons use the collating sequence identified by the NLS_SORT initialization parameter. A collating sequence is an internal ordering of the character set in which a range of numeric codes represents the individual characters. One character value is greater than another if its internal numeric value is larger. Each language might have different rules about where such characters occur in the collating sequence. For example, an accented letter might be sorted differently depending on the database character set, even though the binary value is the same in each case.

Depending on the value of the NLS_SORT parameter, you can perform comparisons that are case-insensitive and even accent-insensitive. A case-insensitive comparison still returns true if the letters of the operands are different in terms of uppercase and lowercase. An accent-insensitive comparison is case-insensitive, and also returns true if the operands differ in accents or punctuation characters. For example, the character values 'True' and 'TRUE' are considered identical by a case-insensitive comparison;

the character values 'Cooperate', 'Co-Operate', and 'coöperate' are all considered the same. To make comparisons case-insensitive, add _CI to the end of your usual value for the NLS_SORT parameter. To make comparisons accent-insensitive, add _AI to the end of the NLS_SORT value.

There are semantic differences between the CHAR and VARCHAR2 base types that come into play when you compare character values. For more information, see "Differences between the CHAR and VARCHAR2 Datatypes" on page 3-23.

Many types can be converted to character types. For example, you can compare, assign, and do other character operations using CLOB variables. For details on the possible conversions, see "PL/SQL Character and String Types" on page 3-4.

BOOLEAN Date Expressions

You can also compare dates. Comparisons are chronological; that is, one date is greater than another if it is more recent. For example, given the assignments

```
date1 := '01-JAN-91';
date2 := '31-DEC-90';
```

the following expression is true:

```
date1 > date2
```

Guidelines for PL/SQL BOOLEAN Expressions

In general, do not compare real numbers for exact equality or inequality. Real numbers are stored as approximate values. For example, the following IF condition might not yield TRUE:

```
DECLARE
   fraction BINARY_FLOAT := 1/3;
BEGIN
   IF fraction = 11/33 THEN
      DBMS_OUTPUT.PUT_LINE('Fractions are equal (luckily!)');
   END IF;
END;
/
```

It is a good idea to use parentheses when doing comparisons. For example, the following expression is not allowed because 100 < tax yields a BOOLEAN value, which cannot be compared with the number 500:

```
100 < tax < 500 -- not allowed
```

The debugged version follows:

```
(100 < tax) AND (tax < 500)
```

A BOOLEAN variable is itself either true or false. You can just use the variable in a conditional test, rather than comparing it to the literal values TRUE and FALSE. In Example 2–25 the loops are all equivalent.

Example 2–25 Using BOOLEAN Variables in Conditional Tests

```
DECLARE
   done BOOLEAN ;
BEGIN
-- Each WHILE loop is equivalent
   done := FALSE;
   WHILE done = FALSE
   LOOP
      done := TRUE;
   END LOOP;
   done := FALSE;
   WHILE NOT (done = TRUE)
   LOOP
      done := TRUE;
   END LOOP;
   done := FALSE;
   WHILE NOT done
   LOOP
      done := TRUE;
   END LOOP;
END;
/
```

Using CLOB values with comparison operators, or functions such as LIKE and BETWEEN, can create temporary LOBs. You might need to make sure your temporary tablespace is large enough to handle these temporary LOBs.

CASE Expressions

There are two types of expressions used in CASE statements: simple and searched. These expressions correspond to the type of CASE statement in which they are used. See "Using CASE Statements" on page 4-4.

Simple CASE expression

A simple CASE expression selects a result from one or more alternatives, and returns the result. Although it contains a block that might stretch over several lines, it really is an expression that forms part of a larger statement, such as an assignment or a procedure call. The CASE expression uses a selector, an expression whose value determines which alternative to return.

A CASE expression has the form illustrated in Example 2–26. The selector (grade) is followed by one or more WHEN clauses, which are checked sequentially. The value of the selector determines which clause is evaluated. The first WHEN clause that matches the value of the selector determines the result value, and subsequent WHEN clauses are not evaluated. If there are no matches, then the optional ELSE clause is performed.

Example 2–26 Using the WHEN Clause With a CASE Statement

```
DECLARE
   grade CHAR(1) := 'B';
   appraisal VARCHAR2(20);
BEGIN
   appraisal :=
      CASE grade
         WHEN 'A' THEN 'Excellent'
         WHEN 'B' THEN 'Very Good'
         WHEN 'C' THEN 'Good'
         WHEN 'D' THEN 'Fair'
         WHEN 'F' THEN 'Poor'
         ELSE 'No such grade'
      END;
   DBMS_OUTPUT.PUT_LINE('Grade ' || grade || ' is ' || appraisal);
END;
/
```

The optional ELSE clause works similarly to the ELSE clause in an IF statement. If the value of the selector is not one of the choices covered by a WHEN clause, the ELSE clause is executed. If no ELSE clause is provided and none of the WHEN clauses are matched, the expression returns NULL.

Searched CASE Expression

A searched CASE expression lets you test different conditions instead of comparing a single expression to various values. It has the form shown in Example 2–27.

A searched CASE expression has no selector. Each WHEN clause contains a search condition that yields a BOOLEAN value, so you can test different variables or multiple conditions in a single WHEN clause.

Example 2–27 Using a Search Condition With a CASE Statement

```
DECLARE
   grade CHAR(1) := 'B';
   appraisal VARCHAR2(120);
   id NUMBER := 8429862;
   attendance NUMBER := 150;
   min_days CONSTANT NUMBER := 200;
FUNCTION attends_this_school(id NUMBER) RETURN BOOLEAN IS
   BEGIN RETURN TRUE; END;
BEGIN
   appraisal :=
      CASE
         WHEN attends_this_school(id) = FALSE THEN 'N/A - Student not enrolled'
-- Have to test this condition early to detect good students with bad attendance
         WHEN grade = 'F' OR attendance < min_days
            THEN 'Poor (poor performance or bad attendance)'
         WHEN grade = 'A' THEN 'Excellent'
         WHEN grade = 'B' THEN 'Very Good'
         WHEN grade = 'C' THEN 'Good'
         WHEN grade = 'D' THEN 'Fair'
         ELSE 'No such grade'
      END;
   DBMS_OUTPUT.PUT_LINE('Result for student ' || id || ' is ' || appraisal);
END;
/
```

The search conditions are evaluated sequentially. The BOOLEAN value of each search condition determines which WHEN clause is executed. If a search condition yields TRUE, its WHEN clause is executed. After any WHEN clause is executed, subsequent search conditions are not evaluated. If none of the search conditions yields TRUE, the optional ELSE clause is executed. If no WHEN clause is executed and no ELSE clause is supplied, the value of the expression is NULL.

Handling Null Values in Comparisons and Conditional Statements

When working with nulls, you can avoid some common mistakes by keeping in mind the following rules:

- Comparisons involving nulls always yield NULL
- Applying the logical operator NOT to a null yields NULL
- In conditional control statements, if the condition yields NULL, its associated sequence of statements is not executed

- If the expression in a simple CASE statement or CASE expression yields NULL, it cannot be matched by using WHEN NULL. In this case, you would need to use the searched case syntax and test WHEN *expression* IS NULL.

In Example 2–28, you might expect the sequence of statements to execute because x and y seem unequal. But, nulls are indeterminate. Whether or not x is equal to y is unknown. Therefore, the IF condition yields NULL and the sequence of statements is bypassed.

Example 2–28 Using NULLs in Comparisons

```
DECLARE
   x NUMBER := 5;
   y NUMBER := NULL;
BEGIN
   IF x != y THEN  -- yields NULL, not TRUE
      DBMS_OUTPUT.PUT_LINE('x != y');  -- not executed
   ELSIF x = y THEN -- also yields NULL
      DBMS_OUTPUT.PUT_LINE('x = y');
   ELSE
      DBMS_OUTPUT.PUT_LINE('Can''t tell if x and y are equal or not.');
   END IF;
END;
/
```

In the following example, you might expect the sequence of statements to execute because a and b seem equal. But, again, that is unknown, so the IF condition yields NULL and the sequence of statements is bypassed.

```
DECLARE
   a NUMBER := NULL;
   b NUMBER := NULL;
BEGIN
   IF a = b THEN  -- yields NULL, not TRUE
      DBMS_OUTPUT.PUT_LINE('a = b');  -- not executed
   ELSIF a != b THEN  -- yields NULL, not TRUE
      DBMS_OUTPUT.PUT_LINE('a != b');  -- not executed
   ELSE
      DBMS_OUTPUT.PUT_LINE('Can''t tell if two NULLs are equal');
   END IF;
END;
/
```

NULLs and the NOT Operator

Recall that applying the logical operator NOT to a null yields NULL. Thus, the following two IF statements are not always equivalent:

```
IF x > y THEN high := x; ELSE high := y; END IF;
IF NOT x > y THEN high := y; ELSE high := x; END IF;
```

The sequence of statements in the ELSE clause is executed when the IF condition yields FALSE or NULL. If neither x nor y is null, both IF statements assign the same value to high. However, if either x or y is null, the first IF statement assigns the value of y to high, but the second IF statement assigns the value of x to high.

NULLs and Zero-Length Strings

PL/SQL treats any zero-length string like a null. This includes values returned by character functions and `BOOLEAN` expressions. For example, the following statements assign nulls to the target variables:

```
DECLARE
   null_string VARCHAR2(80) := TO_CHAR('');
   address VARCHAR2(80);
   zip_code VARCHAR2(80) := SUBSTR(address, 25, 0);
   name VARCHAR2(80);
   valid BOOLEAN := (name != '');
```

Use the `IS NULL` operator to test for null strings, as follows:

```
IF v_string IS NULL THEN ...
```

NULLs and the Concatenation Operator

The concatenation operator ignores null operands. For example, the expression

```
'apple' || NULL || NULL || 'sauce'
```

returns the following value:

```
'applesauce'
```

NULLs as Arguments to Built-In Functions

If a null argument is passed to a built-in function, a null is returned except in the following cases.

The function `DECODE` compares its first argument to one or more search expressions, which are paired with result expressions. Any search or result expression can be null. If a search is successful, the corresponding result is returned. In Example 2–29, if the column `manager_id` is null, `DECODE` returns the value '`nobody`':

Example 2–29 Using the Function DECODE

```
DECLARE
   the_manager VARCHAR2(40);
   name employees.last_name%TYPE;
BEGIN
-- NULL is a valid argument to DECODE. In this case, manager_id is null
-- and the DECODE function returns 'nobody'.
   SELECT DECODE(manager_id, NULL, 'nobody', 'somebody'), last_name
      INTO the_manager, name FROM employees WHERE employee_id = 100;
   DBMS_OUTPUT.PUT_LINE(name || ' is managed by ' || the_manager);
END;
/
```

The function `NVL` returns the value of its second argument if its first argument is null. In Example 2–30, if the column specified in the query is null, the function returns the value -1 to signify a non-existent employee in the output:

Example 2–30 Using the Function NVL

```
DECLARE
   the_manager employees.manager_id%TYPE;
   name employees.last_name%TYPE;
BEGIN
-- NULL is a valid argument to NVL. In this case, manager_id is null
-- and the NVL function returns -1.
```

```
   SELECT NVL(manager_id, -1), last_name
      INTO the_manager, name FROM employees WHERE employee_id = 100;
   DBMS_OUTPUT.PUT_LINE(name || ' is managed by employee Id: ' || the_manager);
END;
/
```

The function REPLACE returns the value of its first argument if its second argument is null, whether the optional third argument is present or not. For example, the call to REPLACE in Example 2–31 does not make any change to the value of OLD_STRING:

Example 2–31 Using the Function REPLACE

```
DECLARE
   string_type VARCHAR2(60);
   old_string string_type%TYPE := 'Apples and oranges';
   v_string  string_type%TYPE := 'more apples';
-- NULL is a valid argument to REPLACE, but does not match
-- anything so no replacement is done.
   new_string string_type%TYPE := REPLACE(old_string, NULL, v_string);
BEGIN
   DBMS_OUTPUT.PUT_LINE('Old string = ' || old_string);
   DBMS_OUTPUT.PUT_LINE('New string = ' || new_string);
END;
/
```

If its third argument is null, REPLACE returns its first argument with every occurrence of its second argument removed. For example, the following call to REPLACE removes all the dashes from DASHED_STRING, instead of changing them to another character:

```
DECLARE
   string_type VARCHAR2(60);
   dashed string_type%TYPE := 'Gold-i-locks';
-- When the substitution text for REPLACE is NULL,
-- the text being replaced is deleted.
   name   string_type%TYPE := REPLACE(dashed, '-', NULL);
BEGIN
   DBMS_OUTPUT.PUT_LINE('Dashed name    = ' || dashed);
   DBMS_OUTPUT.PUT_LINE('Dashes removed = ' || name);
END;
/
```

If its second and third arguments are null, REPLACE just returns its first argument.

Conditional Compilation

Using conditional compilation, you can customize the functionality in a PL/SQL application without having to remove any source code. For example, using conditional compilation you can customize a PL/SQL application to:

- Utilize the latest functionality with the latest database release and disable the new features to run the application against an older release of the database
- Activate debugging or tracing functionality in the development environment and hide that functionality in the application while it runs at a production site

See the discussion of new features in "Conditional Compilation" on page xxv. For business use scenarios and best practices information, visit the Oracle Technology Web site at http://www.oracle.com/technology/tech/pl_sql/.

How Does Conditional Compilation Work?

Conditional compilation uses selection directives, inquiry directives, and error directives to specify source text for compilation. Inquiry directives access values set up through name-value pairs in the `PLSQL_CCFLAGS` initialization parameter. Selection directives can test inquiry directives or static package constants.

The `DBMS_DB_VERSION` package provides database version and release constants that can be used for conditional compilation. The `DBMS_PREPROCESSOR` package provides subprograms for accessing the post-processed source text that is selected by conditional compilation directives in a PL/SQL unit.

Note: The conditional compilation feature and related PL/SQL packages are available for Oracle release 10.1.0.4 and later releases.

Conditional Compilation Control Tokens

The conditional compilation trigger character is $ and is used to identify code that is processed before the application is compiled. A conditional compilation control token is of the form:

```
preprocessor_control_token ::= $plsql_identifier
```

The $ must be at the beginning of the identifier name and there cannot be a space between the $ and the name. The $ can also be embedded in the identifier name, but it has no special meaning. The reserved preprocessor control tokens are `$IF`, `$THEN`, `$ELSE`, `$ELSIF`, `$END`, and `$ERROR`. For an example of the use of the conditional compilation control tokens, see Example 2–34 on page 2-35.

Using Conditional Compilation Selection Directives

The conditional compilation selection directive evaluates static expressions to determine which text should be included in the compilation. The selection directive is of the form:

```
$IF boolean_static_expression $THEN text
  [ $ELSIF boolean_static_expression $THEN text ]
  [ $ELSE text ]
$END
```

`boolean_static_expression` must be a `BOOLEAN` static expression. For a description of `BOOLEAN` static expressions, see "Using Static Expressions with Conditional Compilation" on page 2-33. For information on PL/SQL `IF` .. `THEN` control structures, see "Testing Conditions: IF and CASE Statements" on page 4-2.

Using Conditional Compilation Error Directives

The error directive `$ERROR` raises a user-defined error and is of the form:

```
$ERROR varchar2_static_expression $END
```

`varchar2_static_expression` must be a `VARCHAR2` static expression. For a description of `VARCHAR2` static expressions, see "Using Static Expressions with Conditional Compilation" on page 2-33. See Example 2–33.

Using Conditional Compilation Inquiry Directives

The inquiry directive is used to check the compilation environment. The inquiry directive is of the form:

```
inquiry_directive ::= $$id
```

An inquiry directive can be predefined as described in "Using Predefined Inquiry Directives With Conditional Compilation" on page 2-32 or be user-defined. The following describes the order of the processing flow when conditional compilation attempts to resolve an inquiry directive:

1. The *id* is used as an inquiry directive in the form $$*id* for the search key.
2. The two-pass algorithm proceeds as follows:

   The string in the PLSQL_CCFLAGS initialization parameter is scanned from right to left, searching with *id* for a matching name (case insensitive); done if found.

   The predefined inquiry directives are searched; done if found.
3. If the $$*id* cannot be resolved to a value, then the PLW-6003 warning message is reported if the source text is not wrapped. The literal NULL is substituted as the value for undefined inquiry directives. Note that if the PL/SQL code is wrapped, then the warning message is disabled so that the undefined inquiry directive is not revealed.

For example, given the following session setting:

```
ALTER SESSION SET
   PLSQL_CCFLAGS = 'plsql_ccflags:true, debug:true, debug:0';
```

The value of $$debug is 0 and the value of $$plsql_ccflags is TRUE. Note that the value of $$plsql_ccflags resolves to the user-defined plsql_ccflags inside the value of the PLSQL_CCFLAGS compiler parameter. This occurs because a user-defined directive overrides the predefined one.

Given this session setting:

```
ALTER SESSION SET PLSQL_CCFLAGS = 'debug:true'
```

Now the value of $$debug is TRUE, the value of $$plsql_ccflags is 'debug:true', the value of $$my_id is the literal NULL, and the use of $$my_id raises PLW-6003 if the source text is not wrapped.

For an example of the use of an inquiry directive, see Example 2–34 on page 2-35.

Using Predefined Inquiry Directives With Conditional Compilation

This section describes the inquiry directive names that are predefined and can be used in conditional expressions. These include:

- The Oracle initialization parameters for PL/SQL compilation, such as PLSQL_CCFLAGS, PLSQL_DEBUG, PLSQL_OPTIMIZE_LEVEL, PLSQL_CODE_TYPE, PLSQL_WARNINGS, and NLS_LENGTH_SEMANTICS. See "Initialization Parameters for PL/SQL Compilation" on page 11-1. For an example, see Example 2–34.

  Note that recompiling a PL/SQL unit with the REUSE SETTINGS clause of the SQL ALTER statement can protect against changes made to initialization parameter values in the current PL/SQL compilation environment. See Example 2–35.
- PLSQL_LINE which is a PLS_INTEGER literal value indicating the line number reference to $$PLSQL_LINE in the current unit. For example:

  ```
  $IF $$PLSQL_LINE = 32 $THEN ...
  ```

Note that the value of PLSQL_LINE can be defined explicitly with PLSQL_CCFLAGS.

- PLSQL_UNIT which is a VARCHAR2 literal value indicating the current source unit. For a named compilation unit, $$PLSQL_UNIT contains, but might not be limited to, the unit name. For an anonymous block, $$PLSQL_UNIT contains the empty string. For example:

```
IF $$PLSQL_UNIT = 'AWARD_BONUS' THEN ...
```

Note that the value of PLSQL_UNIT can be defined explicitly with PLSQL_CCFLAGS. Also note that the previous example shows the use of PLSQL_UNIT in regular PL/SQL. Because $$PLSQL_UNIT = 'AWARD_BONUS' is a VARCHAR2 comparison, not a static expression, it is not supported with $IF. One valid use of $IF with PLSQL_UNIT is to determine an anonymous block:

```
$IF $$PLSQL_UNIT IS NULL $THEN ...
```

Using Static Expressions with Conditional Compilation

Only static expressions which can be fully evaluated by the compiler are allowed during conditional compilation processing. Any expression that contains references to variables or functions that require the execution of the PL/SQL are not available during compilation and cannot be evaluated. For information on PL/SQL datatypes, see "Overview of Predefined PL/SQL Datatypes" on page 3-1.

A static expression is either a BOOLEAN, PLS_INTEGER, or VARCHAR2 static expression. Static constants declared in packages are also static expressions.

Boolean Static Expressions BOOLEAN static expressions include:

- TRUE, FALSE, and the literal NULL
- x > y, x < y, x >= y, x <= y, x = y, and x <> y where x and y are PLS_INTEGER static expressions
- NOT x, x AND y, x OR y, x > y, x >= y, x = y, x <= y, x <> y where x and y are BOOLEAN static expressions
- x IS NULL and x IS NOT NULL where x is a static expression

PLS_INTEGER Static Expressions PLS_INTEGER static expressions include:

- -2147483648 to 2147483647, and the literal NULL

VARCHAR2 Static Expressions VARCHAR2 static expressions include:

- 'abcdef' and 'abc' || 'def'
- literal NULL
- TO_CHAR(x), where x is a PLS_INTEGER static expression
- TO_CHAR(*x f, n*) where *x* is a PLS_INTEGER static expression and *f* and *n* are VARCHAR2 static expressions
- x || y where x and y are VARCHAR2 or PLS_INTEGER static expressions

Static Constants Static constants are declared in a package specification as follows:

static_constant CONSTANT *datatype* := *static_expression*;

This is a valid declaration of a static constant if:

- The declared *datatype* and the type of *static_expression* are the same

- *static_expression* is a static expression
- *datatype* is either BOOLEAN or PLS_INTEGER

The static constant must be declared in the package specification and referred to as *package_name.constant_name*, even in the body of the *package_name* package.

If a static package constant is used as the BOOLEAN expression in a valid selection directive in a PL/SQL unit, then the conditional compilation mechanism automatically places a dependency on the package referred to. If the package is altered, then the dependent unit becomes invalid and needs to be recompiled to pick up any changes. Note that only valid static expressions can create dependencies.

If you choose to use a package with static constants for controlling conditional compilation in multiple PL/SQL units, then create only the package specification and dedicate it exclusively for controlling conditional compilation because of the multiple dependencies. Note that for control of conditional compilation in an individual unit, you can set a specific flag in PLSQL_CCFLAGS.

In Example 2–32 the my_debug package defines constants for controlling debugging and tracing in multiple PL/SQL units. In the example, the constants debug and trace are used in static expressions in procedures my_proc1 and my_proc2, which places a dependency from the procedures to my_debug.

Example 2–32 Using Static Constants

```
CREATE PACKAGE my_debug IS
  debug CONSTANT BOOLEAN := TRUE;
  trace CONSTANT BOOLEAN := TRUE;
END my_debug;
/
CREATE PROCEDURE my_proc1 IS
BEGIN
  $IF my_debug.debug $THEN DBMS_OUTPUT.put_line('Debugging ON');
  $ELSE DBMS_OUTPUT.put_line('Debugging OFF'); $END
END my_proc1;
/
CREATE PROCEDURE my_proc2 IS
BEGIN
  $IF my_debug.trace $THEN DBMS_OUTPUT.put_line('Tracing ON');
  $ELSE DBMS_OUTPUT.put_line('Tracing OFF'); $END
END my_proc2;
/
```

Changing the value of one of the constants forces all the dependent units of the package to recompile with the new value. For example, changing the value of debug to FALSE would cause my_proc1 to be recompiled without the debugging code. my_proc2 would also be recompiled, but my_proc2 would be unchanged because the value of trace did not change.

Setting the PLSQL_CCFLAGS Initialization Parameter

You can set the dynamic PLSQL_CCFLAGS initialization parameter to flag names with associated values to control conditional compilation on PL/SQL units. For example, the PLSQL_CCFLAGS initialization parameter could be set dynamically with ALTER SESSION to turn on debugging and tracing functionality in PL/SQL units as shown in Example 2–34.

You can also set the PLSQL_CCFLAGS initialization parameter to independently control conditional compilation on a specific PL/SQL unit with as shown in Example 2–35 with the SQL ALTER PROCEDURE statement.

The flag names can be set to any unquoted PL/SQL identifier, including reserved words and keywords. If a flag value is explicitly set, it must be set to a TRUE, FALSE, PLS_INTEGER, or NULL. The flag names and values are not case sensitive. For detailed information, including restrictions, on the PLSQL_CCFLAGS initialization parameter, see *Oracle Database Reference*.

Using DBMS_DB_VERSION Package Constants

The DBMS_DB_VERSION package provides constants that are useful when making simple selections for conditional compilation. The PLS_INTEGER constants VERSION and RELEASE identify the current Oracle version and release numbers. The BOOLEAN constants VER_LE_9, VER_LE_9_1, VER_LE_9_2, VER_LE_10, VER_LE_10_1, and VER_LE_10_2 evaluate to TRUE or FALSE on the basis of less than or equal to the version and the release. For example, the constants in Oracle 10*g* release 2 evaluate as follows:

- VER_LE_10 represents the condition that the database version is less than or equal to 10; it is TRUE
- VER_LE_10_2 represents the condition that database version is less than or equal to 10 and release is less than or equal to 2; it is TRUE
- All constants representing Oracle 10*g* release 1 or earlier are FALSE

Example 2–33 illustrates the use of a DBMS_DB_VERSION constant with conditional compilation. Both the Oracle database version and release are checked. This example also shows the use of $ERROR.

Example 2–33 Using DBMS_DB_VERSION Constants

```
BEGIN
$IF DBMS_DB_VERSION.VER_LE_10_1 $THEN
  $ERROR 'unsupported database release' $END
$ELSE
  DBMS_OUTPUT.PUT_LINE ('Release ' || DBMS_DB_VERSION.VERSION || '.' ||
                        DBMS_DB_VERSION.RELEASE || ' is supported.');
  -- Note that this COMMIT syntax is newly supported in 10.2
  COMMIT WRITE IMMEDIATE NOWAIT;
$END
END;
/
```

For information on the DBMS_DB_VERSION package, see *Oracle Database PL/SQL Packages and Types Reference*.

Conditional Compilation Examples

This section provides examples using conditional compilation.

Using Conditional Compilation to Specify Code for Database Versions

In Example 2–34, conditional compilation is used to determine whether the BINARY_DOUBLE datatype can be utilized in the calculations for PL/SQL units in the database. The BINARY_DOUBLE datatype can only be used in a database version that is 10*g* or later. This example also shows the use of the PLSQL_CCFLAGS parameter.

Example 2–34 Using Conditional Compilation With Database Versions

```
-- set flags for displaying debugging code and tracing info
ALTER SESSION SET PLSQL_CCFLAGS = 'my_debug:FALSE, my_tracing:FALSE';
```

```
CREATE PACKAGE my_pkg AS
  SUBTYPE my_real IS
    $IF DBMS_DB_VERSION.VERSION < 10 $THEN NUMBER; -- check database version
      $ELSE                                BINARY_DOUBLE;
    $END
  my_pi my_real; my_e my_real;
END my_pkg;
/

CREATE PACKAGE BODY my_pkg AS
BEGIN -- set up values for future calculations based on DB version
  $IF DBMS_DB_VERSION.VERSION < 10 $THEN
       my_pi := 3.14016408289008292431940027343666863227;
       my_e  := 2.71828182845904523536028747135266249775;
    $ELSE
       my_pi := 3.14016408289008292431940027343666863227d;
       my_e  := 2.71828182845904523536028747135266249775d;
  $END
END my_pkg;
/

CREATE PROCEDURE circle_area(radius my_pkg.my_real) IS
  my_area my_pkg.my_real;
  my_datatype VARCHAR2(30);
BEGIN
  my_area := my_pkg.my_pi * radius;
  DBMS_OUTPUT.PUT_LINE('Radius: ' || TO_CHAR(radius)
                       || ' Area: ' || TO_CHAR(my_area) );
  $IF $$my_debug $THEN -- if my_debug is TRUE, run some debugging code
    SELECT DATA_TYPE INTO my_datatype FROM USER_ARGUMENTS
       WHERE OBJECT_NAME = 'CIRCLE_AREA' AND ARGUMENT_NAME = 'RADIUS';
     DBMS_OUTPUT.PUT_LINE('Datatype of the RADIUS argument is: ' || my_datatype);
  $END
END;
/
```

If you want to set `my_debug` to `TRUE`, you can make this change only for procedure `circle_area` with the `REUSE SETTINGS` clause as shown in Example 2–35.

Example 2–35 Using ALTER PROCEDURE to Set PLSQL_CCFLAGS

```
ALTER PROCEDURE circle_area COMPILE PLSQL_CCFLAGS = 'my_debug:TRUE'
   REUSE SETTINGS;
```

Using DBMS_PREPROCESSOR Procedures to Print or Retrieve Source Text

`DBMS_PREPROCESSOR` subprograms print or retrieve the post-processed source text of a PL/SQL unit after processing the conditional compilation directives. This post-processed text is the actual source used to compile a valid PL/SQL unit. Example 2–36 shows how to print the post-processed form of `my_pkg` in Example 2–34 with the `PRINT_POST_PROCESSED_SOURCE` procedure.

Example 2–36 Using PRINT_POST_PROCESSED_SOURCE to Display Source Code

```
CALL DBMS_PREPROCESSOR.PRINT_POST_PROCESSED_SOURCE('PACKAGE', 'HR', 'MY_PKG');
```

When `my_pkg` in Example 2–34 is compiled on a 10*g* release or later database using the `HR` account, the output of Example 2–36 is similar to the following:

```
PACKAGE my_pkg AS
  SUBTYPE my_real IS

                                          BINARY_DOUBLE;

  my_pi my_real; my_e my_real;
END my_pkg;
```

`PRINT_POST_PROCESSED_SOURCE` replaces unselected text with whitespace. The lines of code in Example 2–34 that are not included in the post-processed text are represented as blank lines. For information on the `DBMS_PREPROCESSOR` package, see *Oracle Database PL/SQL Packages and Types Reference*.

Conditional Compilation Restrictions

A conditional compilation directive cannot be used in the specification of an object type or in the specification of a schema-level nested table or varray. The attribute structure of dependent types and the column structure of dependent tables is determined by the attribute structure specified in object type specifications. Any changes to the attribute structure of an object type must be done in a controlled manner to propagate the changes to dependent objects. The mechanism for propagating changes is the SQL `ALTER TYPE` ... `ATTRIBUTE` statement. Use of a preprocessor directive would allow changes to the attribute structure of the object type without the use of an `ALTER TYPE` ... `ATTRIBUTE` statement. As a consequence, dependent objects could go out of sync or dependent tables could become inaccessible.

The SQL parser imposes restrictions on the placement of directives when performing SQL operations such as the `CREATE [OR REPLACE]` statement or the execution of an anonymous block. When performing these SQL operations, the SQL parser imposes a restriction on the location of the first conditional compilation directive as follows:

- A conditional compilation directive cannot be used in the specification of an object type or in the specification of a schema-level nested table or varray.
- In a package specification, a package body, a type body, and in a schema-level function or procedure with no formal parameters, the first conditional compilation directive may occur immediately after the keyword `IS/AS`.
- In a schema-level function or procedure with at least one formal parameter, the first conditional compilation directive may occur immediately after the opening parenthesis that follows the unit's name. For example:

```
CREATE OR REPLACE PROCEDURE my_proc (
  $IF $$xxx $THEN i IN PLS_INTEGER $ELSE i IN INTEGER $END
) IS BEGIN NULL; END my_proc;
/
```

- In a trigger or an anonymous block, the first conditional compilation directive may occur immediately after the keyword `BEGIN` or immediately after the keyword `DECLARE` when the trigger block has a `DECLARE` section.
- If an anonymous block uses a placeholder, then this cannot occur within a conditional compilation directive. For example:

```
BEGIN
  :n := 1; -- valid use of placeholder
  $IF .... $THEN
    :n := 1; -- invalid use of placeholder
$END
```

Using PL/SQL to Create Web Applications and Server Pages

You can use PL/SQL to develop Web applications or server pages. These are briefly described in this section. For detailed information on using PL/SQL to create Web applications, see "Developing Applications with the PL/SQL Web Toolkit" in *Oracle Database Application Developer's Guide - Fundamentals*. For detailed information on using PL/SQL to create Web Server Pages (PSPs), see "Developing PL/SQL Server Pages" in *Oracle Database Application Developer's Guide - Fundamentals*.

PL/SQL Web Applications

With PL/SQL you can create applications that generate Web pages directly from an Oracle database, allowing you to make your database available on the Web and make back-office data accessible on the intranet.

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.

You can implement a Web browser-based application entirely in PL/SQL with PL/SQL Gateway and the PL/SQL Web Toolkit.

- PL/SQL gateway enables a Web browser to invoke a PL/SQL stored procedure through an HTTP listener. `mod_plsql`, one implementation of the PL/SQL gateway, is a plug-in of Oracle HTTP Server and enables Web browsers to invoke PL/SQL stored procedures.
- PL/SQL Web Toolkit is a set of PL/SQL packages that provides a generic interface to use stored procedures called by `mod_plsql` at runtime.

PL/SQL Server Pages

PL/SQL Server Pages (PSPs) enable you to develop Web pages with dynamic content. They are an alternative to coding a stored procedure that writes out the HTML code for a web page, one line at a time.

Using special tags, you can embed PL/SQL scripts into HTML source code. The scripts are executed when the pages are requested by Web clients such as browsers. A script can accept parameters, query or update the database, then display a customized page showing the results.

During development, PSPs can act like templates with a static part for page layout and a dynamic part for content. You can design the layouts using your favorite HTML authoring tools, leaving placeholders for the dynamic content. Then, you can write the PL/SQL scripts that generate the content. When finished, you simply load the resulting PSP files into the database as stored procedures.

Summary of PL/SQL Built-In Functions

PL/SQL provides many powerful functions to help you manipulate data. These built-in functions fall into the following categories:

Error reporting

Number
Character
Datatype conversion
Date
Object reference
Miscellaneous

Table 2–4 shows the functions in each category. For descriptions of the error-reporting functions, see "SQLCODE Function" on page 13-117 and "SQLERRM Function" on page 13-118. For descriptions of the other functions, see *Oracle Database SQL Reference*.

Except for the error-reporting functions `SQLCODE` and `SQLERRM`, you can use all the functions in SQL statements. Also, except for the object-reference functions `DEREF`, `REF`, and `VALUE` and the miscellaneous functions `DECODE`, `DUMP`, and `VSIZE`, you can use all the functions in procedural statements.

Although the SQL aggregate functions (such as `AVG` and `COUNT`) and the SQL analytic functions (such as `CORR` and `LAG`) are not built into PL/SQL, you can use them in SQL statements (but not in procedural statements).

Table 2–4 Built-In Functions

Error	Number	Character	Conversion	Date	Obj Ref	Misc
SQLCODE	ABS	ASCII	CHARTOROWID	ADD_MONTHS	DEREF	BFILENAME
SQLERRM	ACOS	ASCIISTR	CONVERT	CURRENT_DATE	REF	COALESCE
	ASIN	CHR	HEXTORAW	CURRENT_TIME	TREAT	DECODE
	ATAN	COMPOSE	RAWTOHEX	CURRENT_TIMESTAMP	VALUE	DUMP
	ATAN2	CONCAT	RAWTONHEX	DBTIMEZONE		EMPTY_BLOB
	BITAND	DECOMPOSE	ROWIDTOCHAR	EXTRACT		EMPTY_CLOB
	CEIL	INITCAP	TO_BINARY_DOUBLE	FROM_TZ		GREATEST
	COS	INSTR	TO_BLOB	LAST_DAY		LEAST
	COSH	INSTR2	TO_BINARY_FLOAT	LOCALTIMESTAMP		NANVL
	EXP	INSTR4	TO_CHAR	MONTHS_BETWEEN		NLS_CHARSET_DECL_LEN
	FLOOR	INSTRB	TO_CLOB	NEW_TIME		NLS_CHARSET_ID
	LN	INSTRC	TO_DATE	NEXT_DAY		NLS_CHARSET_NAME
	LOG	LENGTH	TO_MULTI_BYTE	NUMTODSINTERVAL		NULLIF
	MOD	LENGTH2	TO_NCHAR	NUMTOYMINTERVAL		NVL
	POWER	LENGTH4	TO_NCLOB	ROUND		SYS_CONTEXT
	REMAINDER	LENGTHB	TO_NUMBER	SCN_TO_TIMESTAMP		SYS_GUID
	ROUND	LENGTHC	TO_SINGLE_BYTE	SESSIONTIMEZONE		UID
	SIGN	LOWER		SYS_EXTRACT_UTC		USER
	SIN	LPAD		SYSDATE		USERENV
	SINH	LTRIM		SYSTIMESTAMP		VSIZE
	SQRT	NCHR		TIMESTAMP_TO_SCN		
	TAN	NLS_INITCAP		TO_DSINTERVAL		
	TANH	NLS_LOWER		TO_TIME		
	TRUNC	NLSSORT		TO_TIME_TZ		
		NLS_UPPER		TO_TIMESTAMP		
		REGEXP_INSTR		TO_TIMESTAMP_TZ		
		REGEXP_LIKE		TO_YMINTERVAL		
		REGEXP_REPLACE		TRUNC		
		REGEXP_SUBSTR		TZ_OFFSET		
		REPLACE				
		RPAD				
		RTRIM				
		SOUNDEX				
		SUBSTR				
		SUBSTR2				
		SUBSTR4				
		SUBSTRB				
		SUBSTRC				
		TRANSLATE				
		TRIM				
		UNISTR				
		UPPER				

3 PL/SQL Datatypes

Every constant, variable, and parameter has a datatype (or type), which specifies a storage format, constraints, and valid range of values. PL/SQL provides many predefined datatypes. For instance, you can choose from integer, floating point, character, `BOOLEAN`, date, collection, reference, and large object (LOB) types. PL/SQL also lets you define your own subtypes. This chapter covers the basic types used frequently in PL/SQL programs. Later chapters cover the more specialized types.

This chapter contains these topics:

Overview of Predefined PL/SQL Datatypes

Predefined PL/SQL datatypes are grouped into composite, `LOB`, reference, and scalar type categories.

- A composite type has internal components that can be manipulated individually, such as the elements of an array, record, or table. See Chapter 5, "Using PL/SQL Collections and Records".
- A `LOB` type holds values, called lob locators, that specify the location of large objects, such as text blocks or graphic images, that are stored separately from other database data. LOB types include `BFILE`, `BLOB`, `CLOB`, and `NCLOB`. See "PL/SQL LOB Types" on page 3-10.
- A reference type holds values, called pointers, that designate other program items. These types include `REF CURSORS` and `REF`s to object types. See "Using Cursor Variables (REF CURSORs)" on page 6-20.
- A scalar type has no internal components. It holds a single value, such as a number or character string. The scalar types fall into four families, which store number, character, Boolean, and date/time data. The scalar families with their datatypes are:
  - PL/SQL Number Types

    `BINARY_DOUBLE`, `BINARY_FLOAT`, `BINARY_INTEGER`, `DEC`, `DECIMAL`, `DOUBLE PRECISION`, `FLOAT`, `INT`, `INTEGER`, `NATURAL`, `NATURALN`, `NUMBER`, `NUMERIC`, `PLS_INTEGER`, `POSITIVE`, `POSITIVEN`, `REAL`, `SIGNTYPE`, `SMALLINT`

- PL/SQL Character and String Types and PL/SQL National Character Types

  CHAR, CHARACTER, LONG, LONG RAW, NCHAR, NVARCHAR2, RAW, ROWID, STRING, UROWID, VARCHAR, VARCHAR2

  Note that the LONG and LONG RAW datatypes are supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

- PL/SQL Boolean Types

  BOOLEAN

- PL/SQL Date, Time, and Interval Types

  DATE, TIMESTAMP, TIMESTAMP WITH TIMEZONE, TIMESTAMP WITH LOCAL TIMEZONE, INTERVAL YEAR TO MONTH, INTERVAL DAY TO SECOND

PL/SQL Number Types

Number types let you store numeric data (integers, real numbers, and floating-point numbers), represent quantities, and do calculations.

BINARY_INTEGER Datatype

The BINARY_INTEGER datatype is identical to PLS_INTEGER. BINARY_INTEGER subtypes can be considered as PLS_INTEGER subtypes. See "Change to the BINARY_INTEGER Datatype" on page xxvii. To simplify the documentation, PLS_INTEGER is primarily used throughout the book. See "PLS_INTEGER Datatype" on page 3-4.

BINARY_INTEGER Subtypes A base type is the datatype from which a subtype is derived. A subtype associates a base type with a constraint and so defines a subset of values. For your convenience, PL/SQL predefines the following BINARY_INTEGER subtypes:

```
NATURAL
NATURALN
POSITIVE
POSITIVEN
SIGNTYPE
```

The subtypes NATURAL and POSITIVE let you restrict an integer variable to non-negative or positive values, respectively. NATURALN and POSITIVEN prevent the assigning of nulls to an integer variable. SIGNTYPE lets you restrict an integer variable to the values -1, 0, and 1, which is useful in programming tri-state logic.

BINARY_FLOAT and BINARY_DOUBLE Datatypes

Single-precision and double-precision IEEE 754-format single-precision floating-point numbers. These types are used primarily for high-speed scientific computation. For usage information, see "Writing Computation-Intensive Programs in PL/SQL" on page 11-20. For information about writing math libraries that accept different numeric types, see "Guidelines for Overloading with Numeric Types" on page 8-10.

Literals of these types end with f (for BINARY_FLOAT) or d (for BINARY_DOUBLE). For example, 2.07f or 3.000094d.

Computations involving these types produce special values that you need to check for, rather than raising exceptions. To help deal with overflow, underflow, and other conditions that can occur with these numbers, you can use several special predefined constants: BINARY_FLOAT_NAN, BINARY_FLOAT_INFINITY, BINARY_FLOAT_MAX_NORMAL, BINARY_FLOAT_MIN_NORMAL, BINARY_FLOAT_MAX_SUBNORMAL, BINARY_FLOAT_MIN_SUBNORMAL, and corresponding names starting with BINARY_DOUBLE. The constants for NaN (not a number) and infinity are also defined by SQL; the others are PL/SQL-only.

NUMBER Datatype

The NUMBER datatype reliably stores fixed-point or floating-point numbers with absolute values in the range 1E-130 up to (but not including) 1.0E126. A NUMBER variable can also represent 0. See Example 2–1 on page 2-5.

Oracle recommends only using the value of a NUMBER literal or result of a NUMBER computation that falls within the specified range.

- If the value of the literal or a NUMBER computation is smaller than the range, the value is rounded to zero.
- If the value of the literal exceeds the upper limit, a compilation error is raised.
- If the value of a NUMBER computation exceeds the upper limit, the result is undefined and leads to unreliable results and errors.

The syntax of a NUMBER datatype is:

```
NUMBER[(precision,scale)]
```

Precision is the total number of digits and scale is the number of digits to the right of the decimal point. You cannot use constants or variables to specify precision and scale; you must use integer literals.

To declare fixed-point numbers, for which you must specify scale, use the following form that includes both precision and scale:

```
NUMBER(precision,scale)
```

To declare floating-point numbers, for which you cannot specify precision or scale because the decimal point can float to any position, use the following form without precision and scale:

```
NUMBER
```

To declare integers, which have no decimal point, use this form with precision only:

NUMBER(precision) -- same as NUMBER(precision,0)

The maximum precision that can be specified for a NUMBER value is 38 decimal digits. If you do not specify precision, it defaults to 39 or 40, or the maximum supported by your system, whichever is less.

Scale, which can range from -84 to 127, determines where rounding occurs. For instance, a scale of 2 rounds to the nearest hundredth (3.4562 becomes 3.46). A negative scale rounds to the left of the decimal point. For example, a scale of -3 rounds to the nearest thousand (34562 becomes 34000). A scale of 0 rounds to the nearest whole number (3.4562 becomes 3). If you do not specify scale, it defaults to 0, as shown in the following example.

```
DECLARE
  x NUMBER(3);
BEGIN
  x := 123.89;
  DBMS_OUTPUT.PUT_LINE('The value of x is ' || TO_CHAR(x));
END;
/
```

The output is: `The value of x is 124`

For more information on the `NUMBER` datatype, see *Oracle Database SQL Reference*.

NUMBER Subtypes You can use the following `NUMBER` subtypes for compatibility with ANSI/ISO and IBM types or when you want a more descriptive name:

```
DEC
DECIMAL
DOUBLE PRECISION
FLOAT
INT
INTEGER
NUMERIC
REAL
SMALLINT
```

Use the subtypes `DEC`, `DECIMAL`, and `NUMERIC` to declare fixed-point numbers with a maximum precision of 38 decimal digits.

Use the subtypes `DOUBLE PRECISION` and `FLOAT` to declare floating-point numbers with a maximum precision of 126 binary digits, which is roughly equivalent to 38 decimal digits. Or, use the subtype REAL to declare floating-point numbers with a maximum precision of 63 binary digits, which is roughly equivalent to 18 decimal digits.

Use the subtypes `INTEGER`, `INT`, and `SMALLINT` to declare integers with a maximum precision of 38 decimal digits.

PLS_INTEGER Datatype

You use the `PLS_INTEGER` datatype to store signed integers. Its magnitude range is -2147483648 to 2147483647, represented in 32 bits. `PLS_INTEGER` values require less storage than `NUMBER` values and `NUMBER` subtypes. Also, `PLS_INTEGER` operations use hardware arithmetic, so they are faster than `NUMBER` operations, which use library arithmetic. For efficiency, use `PLS_INTEGER` for all calculations that fall within its magnitude range. For calculations outside the range of `PLS_INTEGER`, you can use the `INTEGER` datatype.

Note:

- The `BINARY_INTEGER` and `PLS_INTEGER` datatypes are identical. See "Change to the BINARY_INTEGER Datatype" on page xxvii.
- When a calculation with two PLS_INTEGER datatypes overflows the magnitude range of `PLS_INTEGER`, an overflow exception is raised even if the result is assigned to a `NUMBER` datatype.

PL/SQL Character and String Types

Character types let you store alphanumeric data, represent words and text, and manipulate character strings.

CHAR Datatype

You use the `CHAR` datatype to store fixed-length character data. How the data is represented internally depends on the database character set. The `CHAR` datatype takes an optional parameter that lets you specify a maximum size up to 32767 bytes. You can specify the size in terms of bytes or characters, where each character contains one or more bytes, depending on the character set encoding. The syntax follows:

```
CHAR[(maximum_size [CHAR  |  BYTE] )]
```

You cannot use a symbolic constant or variable to specify the maximum size; you must use an integer literal in the range 1 .. 32767.

If you do not specify a maximum size, it defaults to 1. If you specify the maximum size in bytes rather than characters, a `CHAR(n)` variable might be too small to hold `n` multibyte characters. To avoid this possibility, use the notation `CHAR(n CHAR)` so that the variable can hold `n` characters in the database character set, even if some of those characters contain multiple bytes. When you specify the length in characters, the upper limit is still 32767 bytes. So for double-byte and multibyte character sets, you can only specify 1/2 or 1/3 as many characters as with a single-byte character set.

Although PL/SQL character variables can be relatively long, you cannot insert `CHAR` values longer than 2000 bytes into a `CHAR` database column.

You can insert any `CHAR(n)` value into a `LONG` database column because the maximum width of a `LONG` column is 2147483648 bytes or two gigabytes. However, you cannot retrieve a value longer than 32767 bytes from a `LONG` column into a `CHAR(n)` variable. Note that the `LONG` datatype is supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

When you do not use the `CHAR` or `BYTE` qualifiers, the default is determined by the setting of the `NLS_LENGTH_SEMANTICS` initialization parameter. When a PL/SQL procedure is compiled, the setting of this parameter is recorded, so that the same setting is used when the procedure is recompiled after being invalidated.

For information on semantic differences between the `CHAR` and `VARCHAR2` base types, see "Differences between the CHAR and VARCHAR2 Datatypes" on page 3-23.

CHAR Subtype The `CHAR` subtype `CHARACTER` has the same range of values as its base type. That is, `CHARACTER` is just another name for `CHAR`. You can use this subtype for compatibility with ANSI/ISO and IBM types or when you want an identifier more descriptive than `CHAR`.

LONG and LONG RAW Datatypes

Note: The `LONG` and `LONG RAW` datatypes are supported only for backward compatibility with existing applications. For new applications, use `CLOB` or `NCLOB` in place of `LONG`, and `BLOB` or `BFILE` in place of `LONG RAW`.

Oracle also recommends that you replace existing `LONG` and `LONG RAW` datatypes with `LOB` datatypes. `LOB` datatypes are subject to far fewer restrictions than `LONG` or `LONG RAW` datatypes. Further, `LOB` functionality is enhanced in every release, whereas `LONG` and `LONG RAW` functionality has been static for several releases. See "PL/SQL LOB Types" on page 3-10.

You use the `LONG` datatype to store variable-length character strings. The `LONG` datatype is like the `VARCHAR2` datatype, except that the maximum size of a `LONG` value is 32760 bytes.

You use the LONG RAW datatype to store binary data or byte strings. LONG RAW data is like LONG data, except that LONG RAW data is not interpreted by PL/SQL. The maximum size of a LONG RAW value is 32760 bytes.

You can insert any LONG value into a LONG database column because the maximum width of a LONG column is 2147483648 bytes or two gigabytes. However, you cannot retrieve a value longer than 32760 bytes from a LONG column into a LONG variable.

Likewise, you can insert any LONG RAW value into a LONG RAW database column because the maximum width of a LONG RAW column is 2147483648 bytes. However, you cannot retrieve a value longer than 32760 bytes from a LONG RAW column into a LONG RAW variable.

LONG columns can store text, arrays of characters, or even short documents. You can reference LONG columns in UPDATE, INSERT, and (most) SELECT statements, but *not* in expressions, SQL function calls, or certain SQL clauses such as WHERE, GROUP BY, and CONNECT BY. For more information, see *Oracle Database SQL Reference*.

In SQL statements, PL/SQL binds LONG values as VARCHAR2, not as LONG. However, if the length of the bound VARCHAR2 exceeds the maximum width of a VARCHAR2 column (4000 bytes), Oracle converts the bind type to LONG automatically, then issues an error message because you cannot pass LONG values to a SQL function.

RAW Datatype

You use the RAW datatype to store binary data or byte strings. For example, a RAW variable might store a sequence of graphics characters or a digitized picture. Raw data is like VARCHAR2 data, except that PL/SQL does not interpret raw data. Likewise, Oracle Net does no character set conversions when you transmit raw data from one system to another.

The RAW datatype takes a required parameter that lets you specify a maximum size up to 32767 bytes. The syntax follows:

```
RAW(maximum_size)
```

You cannot use a symbolic constant or variable to specify the maximum size; you must use an integer literal in the range 1 .. 32767.

You cannot insert RAW values longer than 2000 bytes into a RAW column. You can insert any RAW value into a LONG RAW database column because the maximum width of a LONG RAW column is 2147483648 bytes or two gigabytes. However, you cannot retrieve a value longer than 32767 bytes from a LONG RAW column into a RAW variable. Note that the LONG RAW datatype is supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

ROWID and UROWID Datatype

Internally, every database table has a ROWID pseudocolumn, which stores binary values called rowids. Each rowid represents the storage address of a row. A physical rowid identifies a row in an ordinary table. A logical rowid identifies a row in an index-organized table. The ROWID datatype can store only physical rowids. However, the UROWID (universal rowid) datatype can store physical, logical, or foreign (non-Oracle) rowids.

Note: Use the ROWID datatype only for backward compatibility with old applications. For new applications, use the UROWID datatype.

When you select or fetch a rowid into a ROWID variable, you can use the built-in function ROWIDTOCHAR, which converts the binary value into an 18-byte character string. Conversely, the function CHARTOROWID converts a ROWID character string into a rowid. If the conversion fails because the character string does not represent a valid rowid, PL/SQL raises the predefined exception SYS_INVALID_ROWID. This also applies to implicit conversions.

To convert between UROWID variables and character strings, use regular assignment statements without any function call. The values are implicitly converted between UROWID and character types.

Physical Rowids Physical rowids provide fast access to particular rows. As long as the row exists, its physical rowid does not change. Efficient and stable, physical rowids are useful for selecting a set of rows, operating on the whole set, and then updating a subset. For example, you can compare a UROWID variable with the ROWID pseudocolumn in the WHERE clause of an UPDATE or DELETE statement to identify the latest row fetched from a cursor. See "Fetching Across Commits" on page 6-35.

A physical rowid can have either of two formats. The 10-byte extended rowid format supports tablespace-relative block addresses and can identify rows in partitioned and non-partitioned tables. The 6-byte restricted rowid format is provided for backward compatibility.

Extended rowids use a base-64 encoding of the physical address for each row selected. For example, in SQL*Plus (which implicitly converts rowids into character strings), the query

```
SELECT rowid, last_name FROM employees WHERE employee_id = 120;
```

might return the following row:

```
ROWID              LAST_NAME
------------------ -------------------------
AAALktAAFAAAABSAAU Weiss
```

The format, OOOOOOFFFBBBBBBRRR, has four parts:

- OOOOOO: The data object number (AAALkt in the preceding example) identifies the database segment. Schema objects in the same segment, such as a cluster of tables, have the same data object number.
- FFF: The file number (AAF in the example) identifies the data file that contains the row. File numbers are unique within a database.
- BBBBBB: The block number (AAAABS in the example) identifies the data block that contains the row. Because block numbers are relative to their data file, not their tablespace, two rows in the same tablespace but in different data files can have the same block number.
- RRR: The row number (AAU in the example) identifies the row in the block.

Logical Rowids Logical rowids provide the fastest access to particular rows. Oracle uses them to construct secondary indexes on index-organized tables. Having no permanent physical address, a logical rowid can move across data blocks when new rows are inserted. However, if the physical location of a row changes, its logical rowid remains valid.

A logical rowid can include a guess, which identifies the block location of a row at the time the guess is made. Instead of doing a full key search, Oracle uses the guess to search the block directly. However, as new rows are inserted, guesses can become stale and slow down access to rows. To obtain fresh guesses, you can rebuild the secondary index.

You can use the ROWID pseudocolumn to select logical rowids (which are opaque values) from an index-organized table. Also, you can insert logical rowids into a column of type UROWID, which has a maximum size of 4000 bytes.

The ANALYZE statement helps you track the staleness of guesses. This is useful for applications that store rowids with guesses in a UROWID column, then use the rowids to fetch rows.

To manipulate rowids, you can use the supplied package DBMS_ROWID. For more information, see *Oracle Database PL/SQL Packages and Types Reference*.

VARCHAR2 Datatype

You use the VARCHAR2 datatype to store variable-length character data. How the data is represented internally depends on the database character set. The VARCHAR2 datatype takes a required parameter that specifies a maximum size up to 32767 bytes. The syntax follows:

```
VARCHAR2(maximum_size [CHAR  |  BYTE])
```

You cannot use a symbolic constant or variable to specify the maximum size; you must use an integer literal in the range 1 .. 32767.

Small VARCHAR2 variables are optimized for performance, and larger ones are optimized for efficient memory use. The cutoff point is 2000 bytes. For a VARCHAR2 that is 2000 bytes or longer, PL/SQL dynamically allocates only enough memory to hold the actual value. For a VARCHAR2 variable that is shorter than 2000 bytes, PL/SQL preallocates the full declared length of the variable. For example, if you assign the same 500-byte value to a VARCHAR2(2000 BYTE) variable and to a VARCHAR2(1999 BYTE) variable, the former takes up 500 bytes and the latter takes up 1999 bytes.

If you specify the maximum size in bytes rather than characters, a VARCHAR2(n) variable might be too small to hold n multibyte characters. To avoid this possibility, use the notation VARCHAR2(n CHAR) so that the variable can hold n characters in the database character set, even if some of those characters contain multiple bytes. When you specify the length in characters, the upper limit is still 32767 bytes. So for double-byte and multibyte character sets, you can only specify 1/2 or 1/3 as many characters as with a single-byte character set.

Although PL/SQL character variables can be relatively long, you cannot insert VARCHAR2 values longer than 4000 bytes into a VARCHAR2 database column.

You can insert any VARCHAR2(n) value into a LONG database column because the maximum width of a LONG column is 2147483648 bytes or two gigabytes. However, you cannot retrieve a value longer than 32767 bytes from a LONG column into a VARCHAR2(n) variable. Note that the LONG datatype is supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 more information.

When you do not use the CHAR or BYTE qualifiers, the default is determined by the setting of the NLS_LENGTH_SEMANTICS initialization parameter. When a PL/SQL procedure is compiled, the setting of this parameter is recorded, so that the same setting is used when the procedure is recompiled after being invalidated.

VARCHAR2 Subtypes The VARCHAR2 subtypes STRING and VARCHAR have the same range of values as their base type. For example, VARCHAR is just another name for VARCHAR2.

You can use the VARCHAR2 subtypes for compatibility with ANSI/ISO and IBM types.

Currently, VARCHAR is synonymous with VARCHAR2. However, in future releases of PL/SQL, to accommodate emerging SQL standards, VARCHAR might become a separate datatype with different comparison semantics. It is a good idea to use VARCHAR2 rather than VARCHAR.

PL/SQL National Character Types

The widely used one-byte ASCII and EBCDIC character sets are adequate to represent the Roman alphabet, but some Asian languages, such as Japanese, contain thousands of characters. These languages require two or three bytes to represent each character. To deal with such languages, Oracle provides globalization support, which lets you process single-byte and multi-byte character data and convert between character sets. It also lets your applications run in different language environments.

With globalization support, number and date formats adapt automatically to the language conventions specified for a user session. Thus, users around the world can interact with Oracle in their native languages.

PL/SQL supports two character sets called the *database character set*, which is used for identifiers and source code, and the *national character set*, which is used for national language data. The datatypes NCHAR and NVARCHAR2 store character strings formed from the national character set.

When converting CHAR or VARCHAR2 data between databases with different character sets, make sure the data consists of well-formed strings. For more information CHAR or VARCHAR2 data, see *Oracle Database Globalization Support Guide*.

Comparing UTF8 and AL16UTF16 Encodings

The national character set represents data as Unicode, using either the UTF8 or AL16UTF16 encoding.

Each character in the AL16UTF16 encoding takes up 2 bytes. This makes it simple to calculate string lengths to avoid truncation errors when mixing different programming languages, but requires extra storage overhead to store strings made up mostly of ASCII characters.

Each character in the UTF8 encoding takes up 1, 2, or 3 bytes. This lets you fit more characters into a variable or table column, but only if most characters can be represented in a single byte. It introduces the possibility of truncation errors when transferring the data to a buffer measured in bytes.

Oracle recommends that you use the default AL16UTF16 encoding wherever practical, for maximum runtime reliability. If you need to determine how many bytes are required to hold a Unicode string, use the LENGTHB function rather than LENGTH.

NCHAR Datatype

You use the NCHAR datatype to store fixed-length (blank-padded if necessary) national character data. How the data is represented internally depends on the national character set specified when the database was created, which might use a variable-width encoding (UTF8) or a fixed-width encoding (AL16UTF16). Because this type can always accommodate multibyte characters, you can use it to hold any Unicode character data.

The NCHAR datatype takes an optional parameter that lets you specify a maximum size in characters. The syntax follows:

```
NCHAR[(maximum_size)]
```

Because the physical limit is 32767 bytes, the maximum value you can specify for the length is 32767/2 in the `AL16UTF16` encoding, and 32767/3 in the `UTF8` encoding.

You cannot use a symbolic constant or variable to specify the maximum size; you must use an integer literal.

If you do not specify a maximum size, it defaults to 1. The value always represents the number of characters, unlike `CHAR` which can be specified in either characters or bytes.

`v_string NCHAR(100);` -- maximum size is 100 characters

You cannot insert `NCHAR` values longer than 2000 bytes into an `NCHAR` column.

If the `NCHAR` value is shorter than the defined width of the `NCHAR` column, Oracle blank-pads the value to the defined width.

You can interchange `CHAR` and `NCHAR` values in statements and expressions. It is always safe to turn a `CHAR` value into an `NCHAR` value, but turning an `NCHAR` value into a `CHAR` value might cause data loss if the character set for the `CHAR` value cannot represent all the characters in the `NCHAR` value. Such data loss can result in characters that usually look like question marks (?).

NVARCHAR2 Datatype

You use the `NVARCHAR2` datatype to store variable-length Unicode character data. How the data is represented internally depends on the national character set specified when the database was created, which might use a variable-width encoding (`UTF8`) or a fixed-width encoding (`AL16UTF16`). Because this type can always accommodate multibyte characters, you can use it to hold any Unicode character data.

The `NVARCHAR2` datatype takes a required parameter that specifies a maximum size in characters. The syntax follows:

```
NVARCHAR2(maximum_size)
```

Because the physical limit is 32767 bytes, the maximum value you can specify for the length is 32767/2 in the `AL16UTF16` encoding, and 32767/3 in the `UTF8` encoding.

You cannot use a symbolic constant or variable to specify the maximum size; you must use an integer literal.

The maximum size always represents the number of characters, unlike `VARCHAR2` which can be specified in either characters or bytes.

`v_string NVARCHAR2(200);` -- maximum size is 200 characters

The maximum width of a `NVARCHAR2` database column is 4000 bytes. Therefore, you cannot insert `NVARCHAR2` values longer than 4000 bytes into a `NVARCHAR2` column.

You can interchange `VARCHAR2` and `NVARCHAR2` values in statements and expressions. It is always safe to turn a `VARCHAR2` value into an `NVARCHAR2` value, but turning an `NVARCHAR2` value into a `VARCHAR2` value might cause data loss if the character set for the `VARCHAR2` value cannot represent all the characters in the `NVARCHAR2` value. Such data loss can result in characters that usually look like question marks (?).

PL/SQL LOB Types

The `LOB` (large object) datatypes `BFILE`, `BLOB`, `CLOB`, and `NCLOB` let you store blocks of unstructured data, such as text, graphic images, video clips, and sound waveforms. LOBs allow efficient, random, piece-wise access to the data. `BLOB`, `CLOB`, and `NCLOB` are from 8 to 128 terabytes in size. The size of a `BFILE` is system dependent, but cannot exceed four gigabytes (4GB - 1 bytes).

The LOB types differ from the LONG and LONG RAW types in several ways. For example, LOBs (except NCLOB) can be attributes of an object type, but LONGs cannot. The maximum size of a BLOB, CLOB, or NCLOB is 8 to 128 terabytes, but the maximum size of a LONG is two gigabytes. Also, LOBs support random access to data, but LONGs support only sequential access. Note that the LONG and LONG RAW datatypes are supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

LOB types store lob locators, which point to large objects stored in an external file, in-line (inside the row) or out-of-line (outside the row). Database columns of type BLOB, CLOB, NCLOB, or BFILE store the locators. BLOB, CLOB, and NCLOB data is stored in the database, in or outside the row. BFILE data is stored in operating system files outside the database.

PL/SQL operates on LOBs through the locators. For example, when you select a BLOB column value, only a locator is returned. If you got it during a transaction, the LOB locator includes a transaction ID, so you cannot use it to update that LOB in another transaction. Likewise, you cannot save a LOB locator during one session, then use it in another session.

You can also convert CLOBs to CHAR and VARCHAR2 types and vice versa, or BLOBs to RAW and vice versa, which lets you use LOB types in most SQL and PL/SQL statements and functions. To read, write, and do piecewise operations on LOBs, you can use the supplied package DBMS_LOB.

For more information on LOBs, see *Oracle Database Application Developer's Guide - Large Objects*.

BFILE Datatype

You use the BFILE datatype to store large binary objects in operating system files outside the database. Every BFILE variable stores a file locator, which points to a large binary file on the server. The locator includes a directory alias, which specifies a full path name. Logical path names are not supported.

BFILEs are read-only, so you cannot modify them. Your DBA makes sure that a given BFILE exists and that Oracle has read permissions on it. The underlying operating system maintains file integrity.

BFILEs do not participate in transactions, are not recoverable, and cannot be replicated. The maximum number of open BFILEs is set by the Oracle initialization parameter SESSION_MAX_OPEN_FILES, which is system dependent.

BLOB Datatype

You use the BLOB datatype to store large binary objects in the database, in-line or out-of-line. Every BLOB variable stores a locator, which points to a large binary object.

BLOBs participate fully in transactions, are recoverable, and can be replicated. Changes made by package DBMS_LOB can be committed or rolled back. BLOB locators can span transactions (for reads only), but they cannot span sessions.

CLOB Datatype

You use the CLOB datatype to store large blocks of character data in the database, in-line or out-of-line. Both fixed-width and variable-width character sets are supported. Every CLOB variable stores a locator, which points to a large block of character data.

CLOBs participate fully in transactions, are recoverable, and can be replicated. Changes made by package DBMS_LOB can be committed or rolled back. CLOB locators can span transactions (for reads only), but they cannot span sessions.

NCLOB Datatype

You use the NCLOB datatype to store large blocks of NCHAR data in the database, in-line or out-of-line. Both fixed-width and variable-width character sets are supported. Every NCLOB variable stores a locator, which points to a large block of NCHAR data.

NCLOBs participate fully in transactions, are recoverable, and can be replicated. Changes made by package DBMS_LOB can be committed or rolled back. NCLOB locators can span transactions (for reads only), but they cannot span sessions.

PL/SQL Boolean Types

PL/SQL has a type for representing Boolean values (true and false). Because SQL does not have an equivalent type, you can use BOOLEAN variables and parameters in PL/SQL contexts but not inside SQL statements or queries.

BOOLEAN Datatype

You use the BOOLEAN datatype to store the logical values TRUE, FALSE, and NULL (which stands for a missing, unknown, or inapplicable value). Only logic operations are allowed on BOOLEAN variables.

The BOOLEAN datatype takes no parameters. Only the values TRUE, FALSE, and NULL can be assigned to a BOOLEAN variable.

You cannot insert the values TRUE and FALSE into a database column. You cannot select or fetch column values into a BOOLEAN variable. Functions called from a SQL query cannot take any BOOLEAN parameters. Neither can built-in SQL functions such as TO_CHAR; to represent BOOLEAN values in output, you must use IF-THEN or CASE constructs to translate BOOLEAN values into some other type, such as 0 or 1, 'Y' or 'N', 'true' or 'false', and so on.

PL/SQL Date, Time, and Interval Types

The datatypes in this section let you store and manipulate dates, times, and intervals (periods of time). A variable that has a date and time datatype holds values called datetimes. A variable that has an interval datatype holds values called intervals. A datetime or interval consists of fields, which determine its value. The following list shows the valid values for each field:

Field Name	Valid Datetime Values	Valid Interval Values
YEAR	-4712 to 9999 (excluding year 0)	Any nonzero integer
MONTH	01 to 12	0 to 11
DAY	01 to 31 (limited by the values of MONTH and YEAR, according to the rules of the calendar for the locale)	Any nonzero integer
HOUR	00 to 23	0 to 23
MINUTE	00 to 59	0 to 59

Field Name	Valid Datetime Values	Valid Interval Values
SECOND	00 to 59.9(n), where 9(n) is the precision of time fractional seconds	0 to 59.9(n), where 9(n) is the precision of interval fractional seconds
TIMEZONE_HOUR	-12 to 14 (range accommodates daylight savings time changes)	Not applicable
TIMEZONE_MINUTE	00 to 59	Not applicable
TIMEZONE_REGION	Found in the view V$TIMEZONE_NAMES	Not applicable
TIMEZONE_ABBR	Found in the view V$TIMEZONE_NAMES	Not applicable

Except for TIMESTAMP WITH LOCAL TIMEZONE, these types are all part of the SQL92 standard. For information about datetime and interval format models, literals, time-zone names, and SQL functions, see *Oracle Database SQL Reference*.

DATE Datatype

You use the DATE datatype to store fixed-length datetimes, which include the time of day in seconds since midnight. The date portion defaults to the first day of the current month; the time portion defaults to midnight. The date function SYSDATE returns the current date and time.

- To compare dates for equality, regardless of the time portion of each date, use the function result TRUNC(*date_variable*) in comparisons, GROUP BY operations, and so on.
- To find just the time portion of a DATE variable, subtract the date portion: date_variable - TRUNC(*date_variable*).

Valid dates range from January 1, 4712 BC to December 31, 9999 AD. A Julian date is the number of days since January 1, 4712 BC. Julian dates allow continuous dating from a common reference. You can use the date format model 'J' with the date functions TO_DATE and TO_CHAR to convert between DATE values and their Julian equivalents.

In date expressions, PL/SQL automatically converts character values in the default date format to DATE values. The default date format is set by the Oracle initialization parameter NLS_DATE_FORMAT. For example, the default might be 'DD-MON-YY', which includes a two-digit number for the day of the month, an abbreviation of the month name, and the last two digits of the year.

You can add and subtract dates. In arithmetic expressions, PL/SQL interprets integer literals as days. For instance, SYSDATE + 1 signifies the same time tomorrow.

TIMESTAMP Datatype

The datatype TIMESTAMP, which extends the datatype DATE, stores the year, month, day, hour, minute, and second. The syntax is:

```
TIMESTAMP[(precision)]
```

where the optional parameter precision specifies the number of digits in the fractional part of the seconds field. You cannot use a symbolic constant or variable to specify the precision; you must use an integer literal in the range 0 .. 9. The default is 6.

The default timestamp format is set by the Oracle initialization parameter NLS_TIMESTAMP_FORMAT.

In Example 3–1, you declare a variable of type TIMESTAMP, then assign a literal value to it. In the example, the fractional part of the seconds field is 0.275.

Example 3–1 Assigning a Literal Value to a TIMESTAMP Variable

```
DECLARE
   checkout TIMESTAMP(3);
BEGIN
   checkout := '22-JUN-2004 07:48:53.275';
   DBMS_OUTPUT.PUT_LINE( TO_CHAR(checkout));
END;
/
```

In Example 3–2, the SCN_TO_TIMESTAMP and TIMESTAMP_TO_SCN functions are used to manipulate TIMESTAMPs.

Example 3–2 Using the SCN_TO_TIMESTAMP and TIMESTAMP_TO_SCN Functions

```
DECLARE
   right_now TIMESTAMP;
   yesterday TIMESTAMP;
   sometime TIMESTAMP;
   scn1 INTEGER;
   scn2 INTEGER;
   scn3 INTEGER;
BEGIN
   right_now := SYSTIMESTAMP; -- Get the current SCN
   scn1 := TIMESTAMP_TO_SCN(right_now);
   DBMS_OUTPUT.PUT_LINE('Current SCN is ' || scn1);
   yesterday := right_now - 1; -- Get the SCN from exactly 1 day ago
   scn2 := TIMESTAMP_TO_SCN(yesterday);
   DBMS_OUTPUT.PUT_LINE('SCN from yesterday is ' || scn2);
-- Find an arbitrary SCN somewhere between yesterday and today
-- In a real program we would have stored the SCN at some significant moment
   scn3 := (scn1 + scn2) / 2;
   sometime := SCN_TO_TIMESTAMP(scn3); -- What time was that SCN was in effect?
   DBMS_OUTPUT.PUT_LINE('SCN ' || scn3 || ' was in effect at ' ||
 TO_CHAR(sometime));
END;
/
```

TIMESTAMP WITH TIME ZONE Datatype

The datatype TIMESTAMP WITH TIME ZONE, which extends the datatype TIMESTAMP, includes a time-zone displacement. The time-zone displacement is the difference (in hours and minutes) between local time and Coordinated Universal Time (UTC)—formerly Greenwich Mean Time. The syntax is:

```
TIMESTAMP[(precision)] WITH TIME ZONE
```

where the optional parameter precision specifies the number of digits in the fractional part of the seconds field. You cannot use a symbolic constant or variable to specify the precision; you must use an integer literal in the range 0 .. 9. The default is 6.

The default timestamp with time zone format is set by the Oracle initialization parameter NLS_TIMESTAMP_TZ_FORMAT.

In Example 3–3, you declare a variable of type TIMESTAMP WITH TIME ZONE, then assign a literal value to it:

Example 3–3 Assigning a Literal to a TIMESTAMP WITH TIME ZONE Variable

```
DECLARE
   logoff TIMESTAMP(3) WITH TIME ZONE;
BEGIN
   logoff := '10-OCT-2004 09:42:37.114 AM +02:00';
   DBMS_OUTPUT.PUT_LINE( TO_CHAR(logoff));
END;
/
```

In this example, the time-zone displacement is `+02:00`.

You can also specify the time zone by using a symbolic name. The specification can include a long form such as `'US/Pacific'`, an abbreviation such as `'PDT'`, or a combination. For example, the following literals all represent the same time. The third form is most reliable because it specifies the rules to follow at the point when switching to daylight savings time.

```
TIMESTAMP '15-APR-2004 8:00:00 -8:00'
TIMESTAMP '15-APR-2004 8:00:00 US/Pacific'
TIMESTAMP '31-OCT-2004 01:30:00 US/Pacific PDT'
```

You can find the available names for time zones in the `TIMEZONE_REGION` and `TIMEZONE_ABBR` columns of the `V$TIMEZONE_NAMES` data dictionary view.

Two `TIMESTAMP WITH TIME ZONE` values are considered identical if they represent the same instant in UTC, regardless of their time-zone displacements. For example, the following two values are considered identical because, in UTC, 8:00 AM Pacific Standard Time is the same as 11:00 AM Eastern Standard Time:

```
'29-AUG-2004 08:00:00 -8:00'
'29-AUG-2004 11:00:00 -5:00'
```

TIMESTAMP WITH LOCAL TIME ZONE Datatype

The datatype `TIMESTAMP WITH LOCAL TIME ZONE`, which extends the datatype `TIMESTAMP`, includes a time-zone displacement. The time-zone displacement is the difference (in hours and minutes) between local time and Coordinated Universal Time (UTC)—formerly Greenwich Mean Time. You can also use named time zones, as with `TIMESTAMP WITH TIME ZONE`.

The syntax is

```
TIMESTAMP[(precision)] WITH LOCAL TIME ZONE
```

where the optional parameter `precision` specifies the number of digits in the fractional part of the seconds field. You cannot use a symbolic constant or variable to specify the precision; you must use an integer literal in the range 0 .. 9. The default is 6.

This datatype differs from `TIMESTAMP WITH TIME ZONE` in that when you insert a value into a database column, the value is normalized to the database time zone, and the time-zone displacement is not stored in the column. When you retrieve the value, Oracle returns it in your local session time zone.

In Example 3–4, you declare a variable of type `TIMESTAMP WITH LOCAL TIME ZONE`:

Example 3–4 Assigning a Literal Value to a TIMESTAMP WITH LOCAL TIME ZONE

```
DECLARE
   logoff TIMESTAMP(3) WITH LOCAL TIME ZONE;
BEGIN
--   logoff := '10-OCT-2004 09:42:37.114 AM +02:00'; raises an error
```

```
   logoff := '10-OCT-2004 09:42:37.114 AM '; -- okay without displacement
   DBMS_OUTPUT.PUT_LINE( TO_CHAR(logoff));
END;
/
```

INTERVAL YEAR TO MONTH Datatype

You use the datatype `INTERVAL YEAR TO MONTH` to store and manipulate intervals of years and months. The syntax is:

```
INTERVAL YEAR[(precision)] TO MONTH
```

where precision specifies the number of digits in the years field. You cannot use a symbolic constant or variable to specify the precision; you must use an integer literal in the range 0 .. 4. The default is 2.

In Example 3–5, you declare a variable of type `INTERVAL YEAR TO MONTH`, then assign a value of 101 years and 3 months to it:

Example 3–5 Assigning Literals to an INTERVAL YEAR TO MONTH Variable

```
DECLARE
   lifetime INTERVAL YEAR(3) TO MONTH;
BEGIN
   lifetime := INTERVAL '101-3' YEAR TO MONTH; -- interval literal
   lifetime := '101-3'; -- implicit conversion from character type
   lifetime := INTERVAL '101' YEAR; -- Can specify just the years
   lifetime := INTERVAL '3' MONTH; -- Can specify just the months
END;
/
```

INTERVAL DAY TO SECOND Datatype

You use the datatype `INTERVAL DAY TO SECOND` to store and manipulate intervals of days, hours, minutes, and seconds. The syntax is:

```
INTERVAL DAY[(leading_precision)]
  TO SECOND[(fractional_seconds_precision)]
```

where *leading_precision* and *fractional_seconds_precision* specify the number of digits in the days field and seconds field, respectively. In both cases, you cannot use a symbolic constant or variable to specify the precision; you must use an integer literal in the range 0 .. 9. The defaults are 2 and 6, respectively.

In Example 3–6, you declare a variable of type `INTERVAL DAY TO SECOND`:

Example 3–6 Assigning Literals to an INTERVAL DAY TO SECOND Variable

```
DECLARE
   lag_time INTERVAL DAY(3) TO SECOND(3);
BEGIN
   lag_time := '7 09:24:30';
   IF lag_time > INTERVAL '6' DAY THEN
     DBMS_OUTPUT.PUT_LINE ( 'Greater than 6 days');
   ELSE
     DBMS_OUTPUT.PUT_LINE ( 'Less than 6 days');
   END IF;
END;
/
```

Datetime and Interval Arithmetic

PL/SQL lets you construct datetime and interval expressions. The following list shows the operators that you can use in such expressions:

Operand 1	Operator	Operand 2	Result Type
datetime	+	interval	datetime
datetime	–	interval	datetime
interval	+	datetime	datetime
datetime	–	datetime	interval
interval	+	interval	interval
interval	–	interval	interval
interval	*	numeric	interval
numeric	*	interval	interval
interval	/	numeric	interval

You can also manipulate datetime values using various functions, such as `EXTRACT`. For a list of such functions, see Table 2–4, " Built-In Functions" on page 2-40.

For further information and examples of datetime arithmetic, see *Oracle Database SQL Reference* and *Oracle Database Application Developer's Guide - Fundamentals*.

Avoiding Truncation Problems Using Date and Time Subtypes

The default precisions for some of the date and time types are less than the maximum precision. For example, the default for `DAY TO SECOND` is `DAY(2) TO SECOND(6)`, while the highest precision is `DAY(9) TO SECOND(9)`. To avoid truncation when assigning variables and passing procedure parameters of these types, you can declare variables and procedure parameters of the following subtypes, which use the maximum values for precision:

```
TIMESTAMP_UNCONSTRAINED
TIMESTAMP_TZ_UNCONSTRAINED
TIMESTAMP_LTZ_UNCONSTRAINED
YMINTERVAL_UNCONSTRAINED
DSINTERVAL_UNCONSTRAINED
```

Overview of PL/SQL Subtypes

Each PL/SQL base type specifies a set of values and a set of operations applicable to items of that type. Subtypes specify the same set of operations as their base type, but only a subset of its values. A subtype does not introduce a new type; rather, it places an optional constraint on its base type.

Subtypes can increase reliability, provide compatibility with ANSI/ISO types, and improve readability by indicating the intended use of constants and variables. PL/SQL predefines several subtypes in package `STANDARD`. For example, PL/SQL predefines the subtypes `CHARACTER` and `INTEGER` as follows:

```
SUBTYPE CHARACTER IS CHAR;
SUBTYPE INTEGER IS NUMBER(38,0);  -- allows only whole numbers
```

The subtype CHARACTER specifies the same set of values as its base type CHAR, so CHARACTER is an unconstrained subtype. But, the subtype INTEGER specifies only a subset of the values of its base type NUMBER, so INTEGER is a constrained subtype.

Defining Subtypes

You can define your own subtypes in the declarative part of any PL/SQL block, subprogram, or package using the syntax

```
SUBTYPE subtype_name IS base_type[(constraint)] [NOT NULL];
```

where subtype_name is a type specifier used in subsequent declarations, base_type is any scalar or user-defined PL/SQL datatype, and constraint applies only to base types that can specify precision and scale or a maximum size. Note that a default value is not permitted; see Example 3–10 on page 3-20.

Some examples follow:

```
DECLARE
   SUBTYPE BirthDate IS DATE NOT NULL;  -- based on DATE type
   SUBTYPE Counter IS NATURAL;          -- based on NATURAL subtype
   TYPE NameList IS TABLE OF VARCHAR2(10);
   SUBTYPE DutyRoster IS NameList;      -- based on TABLE type
   TYPE TimeRec IS RECORD (minutes INTEGER, hours INTEGER);
   SUBTYPE FinishTime IS TimeRec;       -- based on RECORD type
   SUBTYPE ID_Num IS employees.employee_id%TYPE; -- based on column type
```

You can use %TYPE or %ROWTYPE to specify the base type. When %TYPE provides the datatype of a database column, the subtype inherits the size constraint (if any) of the column. The subtype does not inherit other kinds of column constraints, such as NOT NULL or check constraint, or the default value, as shown in Example 3–11 on page 3-20. For more information, see "Using the %TYPE Attribute" on page 2-10 and "Using the %ROWTYPE Attribute" on page 2-11.

Using Subtypes

After you define a subtype, you can declare items of that type. In the following example, you declare a variable of type Counter. Notice how the subtype name indicates the intended use of the variable.

```
DECLARE
   SUBTYPE Counter IS NATURAL;
   rows Counter;
```

You can constrain a user-defined subtype when declaring variables of that type:

```
DECLARE
   SUBTYPE Accumulator IS NUMBER;
   total Accumulator(7,2);
```

Subtypes can increase reliability by detecting out-of-range values. InExample 3–7, you restrict the subtype pinteger to storing integers in the range -9 .. 9. If your program tries to store a number outside that range in a pinteger variable, PL/SQL raises an exception.

Example 3–7   Using Ranges With Subtypes

```
DECLARE
  v_sqlerrm VARCHAR2(64);
  SUBTYPE pinteger IS PLS_INTEGER RANGE -9 .. 9;
  y_axis pinteger;
  PROCEDURE p (x IN pinteger) IS
    BEGIN  DBMS_OUTPUT.PUT_LINE (x);  END p;
BEGIN
   y_axis := 9; -- valid, in range
   p(10); -- invalid for procedure p
   EXCEPTION
     WHEN OTHERS THEN
       v_sqlerrm := SUBSTR(SQLERRM, 1, 64);
       DBMS_OUTPUT.PUT_LINE('Error: ' || v_sqlerrm);
END;
/
```

Type Compatibility With Subtypes

An unconstrained subtype is interchangeable with its base type. For example, given the following declarations, the value of `amount` can be assigned to `total` without conversion:

Example 3–8   Type Compatibility With the NUMBER Datatype

```
DECLARE
   SUBTYPE Accumulator IS NUMBER;
   amount NUMBER(7,2);
   total  Accumulator;
BEGIN
   amount := 10000.50;
   total := amount;
END;
/
```

Different subtypes are interchangeable if they have the same base type:

```
DECLARE
   SUBTYPE b1 IS BOOLEAN;
   SUBTYPE b2 IS BOOLEAN;
   finished  b1; -- Different subtypes,
   debugging b2; -- both based on BOOLEAN.
BEGIN
   finished :=FALSE;
   debugging := finished; -- They can be assigned to each other.
END;
/
```

Different subtypes are also interchangeable if their base types are in the same datatype family. For example, given the following declarations, the value of `verb` can be assigned to `sentence`:

```
DECLARE
   SUBTYPE Word IS CHAR(15);
   SUBTYPE Text IS VARCHAR2(1500);
   verb     Word;       -- Different subtypes
   sentence Text(150);  -- of types from the same family
BEGIN
  verb := 'program';
  sentence := verb;    -- can be assigned, if not too long.
END;
/
```

Constraints and Default Values With Subtypes

The examples in this section illustrate the use of constraints and default values with subtypes. In Example 3–9, the procedure enforces the `NOT NULL` constraint, but does not enforce the size.

Example 3–9 Constraints Inherited by Subprograms

```
DECLARE
  SUBTYPE v_word IS VARCHAR2(10) NOT NULL;
  verb     v_word := 'run';
  noun     VARCHAR2(10) := NULL;
  PROCEDURE word_to_upper (w IN v_word) IS
  BEGIN
    DBMS_OUTPUT.PUT_LINE (UPPER(w));
  END word_to_upper;
BEGIN
   word_to_upper('run_over_ten_characters'); -- size constraint is not enforced
-- word_to_upper(noun); invalid, NOT NULL constraint is enforced
END;
/
```

Example 3–10 shows to assign a default value to a subtype variable.

Example 3–10 Default Value With Subtypes

```
DECLARE
  SUBTYPE v_word IS VARCHAR2(10) NOT NULL; -- invalid to put default here
  verb  v_word  := 'verb';
  noun  v_word  := 'noun';
BEGIN
   DBMS_OUTPUT.PUT_LINE (UPPER(verb));
   DBMS_OUTPUT.PUT_LINE (UPPER(noun));
END;
/
```

Example 3–11 shows how column constraints are inherited by subtypes.

Example 3–11 Using SUBTYPE With %TYPE and %ROWTYPE

```
CREATE TABLE employees_temp (empid NUMBER(6) NOT NULL PRIMARY KEY,
 deptid NUMBER(6) CONSTRAINT check_deptid CHECK (deptid BETWEEN 100 AND 200),
 deptname VARCHAR2(30) DEFAULT 'Sales');

DECLARE
   SUBTYPE v_empid_subtype IS employees_temp.empid%TYPE;
   SUBTYPE v_deptid_subtype IS  employees_temp.deptid%TYPE;
   SUBTYPE v_deptname_subtype IS employees_temp.deptname%TYPE;
   SUBTYPE v_emprec_subtype IS employees_temp%ROWTYPE;
   v_empid    v_empid_subtype;
   v_deptid   v_deptid_subtype;
   v_deptname v_deptname_subtype;
   v_emprec   v_emprec_subtype;
BEGIN
   v_empid := NULL;  -- this works, null constraint is not inherited
-- v_empid := 10000002; -- invalid, number precision too large
   v_deptid := 50; -- this works, check constraint is not inherited
-- the default value is not inherited in the following
   DBMS_OUTPUT.PUT_LINE('v_deptname: ' || v_deptname);
   v_emprec.empid := NULL;  -- this works, null constraint is not inherited
-- v_emprec.empid := 10000002; -- invalid, number precision too large
```

```
   v_emprec.deptid := 50; -- this works, check constraint is not inherited
-- the default value is not inherited in the following
   DBMS_OUTPUT.PUT_LINE('v_emprec.deptname: ' || v_emprec.deptname);
END;
/
```

Converting PL/SQL Datatypes

Sometimes it is necessary to convert a value from one datatype to another. For example, to use a DATE value in a report, you must convert it to a character string. PL/SQL supports both explicit and implicit (automatic) datatype conversion. To ensure your program does exactly what you expect, use explicit conversions wherever possible.

Explicit Conversion

To convert values from one datatype to another, you use built-in functions. For example, to convert a CHAR value to a DATE or NUMBER value, you use the function TO_DATE or TO_NUMBER, respectively. Conversely, to convert a DATE or NUMBER value to a CHAR value, you use the function TO_CHAR. For more information about these functions, see *Oracle Database SQL Reference*.

Using explicit conversions, particularly when passing parameters to subprograms, can avoid unexpected errors or wrong results. For example, the TO_CHAR function lets you specify the format for a DATE value, rather than relying on language settings in the database. Including an arithmetic expression among strings being concatenated with the || operator can produce an error unless you put parentheses or a call to TO_CHAR around the entire arithmetic expression.

Implicit Conversion

When it makes sense, PL/SQL can convert the datatype of a value implicitly. This lets you use literals, variables, and parameters of one type where another type is expected. For example, you can pass a numeric literal to a subprogram that expects a string value, and the subprogram receives the string representation of the number.

In Example 3–12, the CHAR variables start_time and finish_time hold string values representing the number of seconds past midnight. The difference between those values must be assigned to the NUMBER variable elapsed_time. PL/SQL converts the CHAR values to NUMBER values automatically.

Example 3–12   Implicit Conversion

```
DECLARE
   start_time   CHAR(5);
   finish_time  CHAR(5);
   elapsed_time NUMBER(5);
BEGIN
   /* Get system time as seconds past midnight. */
   SELECT TO_CHAR(SYSDATE,'SSSSS') INTO start_time FROM sys.dual;
   -- processing done here...
   /* Get system time again. */
   SELECT TO_CHAR(SYSDATE,'SSSSS') INTO finish_time FROM sys.dual;
   /* Compute elapsed time in seconds. */
   elapsed_time := finish_time - start_time;
   DBMS_OUTPUT.PUT_LINE( 'Elapsed time: ' || TO_CHAR(elapsed_time) );
END;
```

```
/
```

Before assigning a selected column value to a variable, PL/SQL will, if necessary, convert the value from the datatype of the source column to the datatype of the variable. This happens, for example, when you select a `DATE` column value into a `VARCHAR2` variable.

Likewise, before assigning the value of a variable to a database column, PL/SQL will, if necessary, convert the value from the datatype of the variable to the datatype of the target column. If PL/SQL cannot determine which implicit conversion is needed, you get a compilation error. In such cases, you must use a datatype conversion function. Table 3–1 shows which implicit conversions PL/SQL can do.

Notes:

- The labels `PLS_INT` and `BIN_INT` represent the types `PLS_INTEGER` and `BINARY_INTEGER` in the table. You cannot use them as abbreviations in code.
- The `PLS_INTEGER` and `BINARY_INTEGER` datatypes are identical so no conversion takes place.
- The table lists only types that have different representations. Types that have the same representation, such as `CLOB` and `NCLOB`, `CHAR` and `NCHAR`, and `VARCHAR` and `NVARCHAR2`, can be substituted for each other.
- You can implicitly convert between `CLOB` and `NCLOB`, but be careful because this can be an expensive operation. To make clear that this conversion is intended, you can use the conversion functions `TO_CLOB` and `TO_NCLOB`.
- `TIMESTAMP`, `TIMESTAMP WITH TIME ZONE`, `TIMESTAMP WITH LOCAL TIME ZONE`, `INTERVAL DAY TO SECOND`, and `INTERVAL YEAR TO MONTH` can all be converted using the same rules as the `DATE` type. However, because of their different internal representations, these types cannot always be converted to each other. See *Oracle Database SQL Reference* for details on implicit conversions between different date and time types.

Table 3–1 Implicit Conversions

	BIN_INT	BLOB	CHAR	CLOB	DATE	LONG	NUMBER	PLS_INT	RAW	UROWID	VARCHAR2
BIN_INT			X			X	X				X
BLOB									X		
CHAR	X			X	X	X	X	X	X	X	X
CLOB			X								X
DATE			X			X					X
LONG			X						X		X
NUMBER	X		X			X		X			X
PLS_INT			X			X	X				X
RAW		X	X			X					X
UROWID			X								X
VARCHAR2	X		X	X	X	X	X	X	X	X	

It is your responsibility to ensure that values are convertible. For instance, PL/SQL can convert the `CHAR` value `'02-JUN-92'` to a `DATE` value but cannot convert the `CHAR` value `'YESTERDAY'` to a `DATE` value. Similarly, PL/SQL cannot convert a `VARCHAR2` value containing alphabetic characters to a `NUMBER` value.

Choosing Between Implicit and Explicit Conversion

Relying on implicit datatype conversions is a poor programming practice because they can be slower and the conversion rules might change in later software releases. Implicit conversions are context-sensitive and not always predictable. For best reliability and maintainability, use datatype conversion functions.

DATE Values

When you select a `DATE` column value into a `CHAR` or `VARCHAR2` variable, PL/SQL must convert the internal binary value to a character value. PL/SQL calls the function `TO_CHAR`, which returns a character string in the default date format. To get other information, such as the time or Julian date, call `TO_CHAR` with a format mask.

A conversion is also necessary when you insert a `CHAR` or `VARCHAR2` value into a `DATE` column. PL/SQL calls the function `TO_DATE`, which expects the default date format. To insert dates in other formats, call `TO_DATE` with a format mask.

RAW and LONG RAW Values

When you select a `RAW` or `LONG RAW` column value into a `CHAR` or `VARCHAR2` variable, PL/SQL must convert the internal binary value to a character value. In this case, PL/SQL returns each binary byte of `RAW` or `LONG RAW` data as a pair of characters. Each character represents the hexadecimal equivalent of a nibble (half a byte). For example, PL/SQL returns the binary byte 11111111 as the pair of characters `'FF'`. The function `RAWTOHEX` does the same conversion.

A conversion is also necessary when you insert a `CHAR` or `VARCHAR`2 value into a `RAW` or `LONG RAW` column. Each pair of characters in the variable must represent the hexadecimal equivalent of a binary byte. Otherwise, PL/SQL raises an exception. Note that the `LONG RAW` datatype is supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

Differences between the CHAR and VARCHAR2 Datatypes

This section explains the semantic differences between the `CHAR` and `VARCHAR2` base types. These subtle but important differences come into play when you assign, compare, insert, update, select, or fetch character values.

Assigning Character Values

When you assign a character value to a `CHAR` variable, if the value is shorter than the declared length of the variable, PL/SQL blank-pads the value to the declared length. Information about trailing blanks in the original value is lost. In the following example, the value assigned to `last_name` includes six trailing blanks, not just one:

```
last_name CHAR(10) := 'CHEN ';  -- note trailing blank
```

If the character value is longer than the declared length of the `CHAR` variable, PL/SQL aborts the assignment and raises the predefined exception `VALUE_ERROR`. PL/SQL neither truncates the value nor tries to trim trailing blanks. For example, given the declaration

```
acronym CHAR(4);
```

the following assignment raises `VALUE_ERROR`:

```
acronym := 'SPCA ';  -- note trailing blank
```

When you assign a character value to a VARCHAR2 variable, if the value is shorter than the declared length of the variable, PL/SQL neither blank-pads the value nor strips trailing blanks. Character values are assigned intact, so no information is lost. If the character value is longer than the declared length of the VARCHAR2 variable, PL/SQL aborts the assignment and raises VALUE_ERROR. PL/SQL neither truncates the value nor tries to trim trailing blanks.

Comparing Character Values

You can use the relational operators to compare character values for equality or inequality. Comparisons are based on the collating sequence used for the database character set. One character value is greater than another if it follows it in the collating sequence. For example, given the following declarations in Example 3–13, the IF condition is TRUE.

Example 3–13 Comparing Character Values

```
DECLARE
  last_name1 VARCHAR2(10) := 'COLES';
  last_name2 VARCHAR2(10) := 'COLEMAN';
BEGIN
  IF last_name1 > last_name2 THEN
    DBMS_OUTPUT.PUT_LINE ( last_name1 || ' is greater than ' || last_name2 );
  ELSE
    DBMS_OUTPUT.PUT_LINE ( last_name2 || ' is greater than ' || last_name1 );
  END IF;
END;
/
```

The SQL standard requires that two character values being compared have equal lengths. If both values in a comparison have datatype CHAR, blank-padding semantics are used. Before comparing character values of unequal length, PL/SQL blank-pads the shorter value to the length of the longer value. For example, given the following declarations, the IF condition is TRUE.

```
DECLARE
  last_name1 CHAR(5) := 'BELLO';
  last_name2 CHAR(10) := 'BELLO   ';  -- note trailing blanks
BEGIN
  IF last_name1 = last_name2 THEN
    DBMS_OUTPUT.PUT_LINE ( last_name1 || ' is equal to ' || last_name2 );
  ELSE
    DBMS_OUTPUT.PUT_LINE ( last_name2 || ' is not equal to ' || last_name1 );
  END IF;
END;
/
```

If either value in a comparison has datatype VARCHAR2, non-blank-padding semantics are used: when comparing character values of unequal length, PL/SQL makes no adjustments and uses the exact lengths. For example, given the following declarations, the IF condition is FALSE.

```
DECLARE
  last_name1 VARCHAR2(10) := 'DOW';
  last_name2 VARCHAR2(10) := 'DOW   ';  -- note trailing blanks
BEGIN
  IF last_name1 = last_name2 THEN
    DBMS_OUTPUT.PUT_LINE ( last_name1 || ' is equal to ' || last_name2 );
  ELSE
```

```
    DBMS_OUTPUT.PUT_LINE ( last_name2 || ' is not equal to ' || last_name1 );
  END IF;
END;
/
```

If a VARCHAR2 value is compared to a CHAR value, non-blank-padding semantics are used. But, remember, when you assign a character value to a CHAR variable, if the value is shorter than the declared length of the variable, PL/SQL blank-pads the value to the declared length. Given the following declarations, the IF condition is FALSE because the value of last_name2 includes five trailing blanks.

```
DECLARE
  last_name1 VARCHAR2(10) := 'STAUB';
  last_name2 CHAR(10)     := 'STAUB';  -- PL/SQL blank-pads value
BEGIN
  IF last_name1 = last_name2 THEN
    DBMS_OUTPUT.PUT_LINE ( last_name1 || ' is equal to ' || last_name2 );
  ELSE
    DBMS_OUTPUT.PUT_LINE ( last_name2 || ' is not equal to ' || last_name1 );
  END IF;
END;
/
```

All string literals have datatype CHAR. If both values in a comparison are literals, blank-padding semantics are used. If one value is a literal, blank-padding semantics are used only if the other value has datatype CHAR.

Inserting Character Values

When you insert the value of a PL/SQL character variable into an Oracle database column, whether the value is blank-padded or not depends on the column type, not on the variable type.

When you insert a character value into a CHAR database column, Oracle does not strip trailing blanks. If the value is shorter than the defined width of the column, Oracle blank-pads the value to the defined width. As a result, information about trailing blanks is lost. If the character value is longer than the defined width of the column, Oracle aborts the insert and generates an error.

When you insert a character value into a VARCHAR2 database column, Oracle does not strip trailing blanks. If the value is shorter than the defined width of the column, Oracle does not blank-pad the value. Character values are stored intact, so no information is lost. If the character value is longer than the defined width of the column, Oracle aborts the insert and generates an error.

The rules discussed in this section also apply when updating.

When inserting character values, to ensure that no trailing blanks are stored, use the function RTRIM, which trims trailing blanks, as shown in Example 3–14.

Example 3–14 Using the Function RTRIM

```
DECLARE
   v_empid NUMBER(6);
   v_last_name VARCHAR2(25);
   v_first_name VARCHAR2(20);
BEGIN
   v_empid := 300;
   v_last_name := 'Lee   ';  -- note trailing blanks
   v_first_name := 'Brenda';
   DBMS_OUTPUT.PUT_LINE ( 'Employee Id: ' || v_empid || ' Name: '
                          || RTRIM(v_last_name) || ', ' || v_first_name );
END;
/
```

Selecting Character Values

When you select a value from an Oracle database column into a PL/SQL character variable, whether the value is blank-padded or not depends on the variable type, not on the column type.

When you select a column value into a `CHAR` variable, if the value is shorter than the declared length of the variable, PL/SQL blank-pads the value to the declared length. As a result, information about trailing blanks is lost. If the character value is longer than the declared length of the variable, PL/SQL aborts the assignment and raises `VALUE_ERROR`.

When you select a column value into a `VARCHAR2` variable, if the value is shorter than the declared length of the variable, PL/SQL neither blank-pads the value nor strips trailing blanks. Character values are stored intact, so no information is lost.

For example, when you select a blank-padded `CHAR` column value into a `VARCHAR2` variable, the trailing blanks are not stripped. If the character value is longer than the declared length of the `VARCHAR2` variable, PL/SQL aborts the assignment and raises `VALUE_ERROR`.

The rules discussed in this section also apply when fetching.

4

Using PL/SQL Control Structures

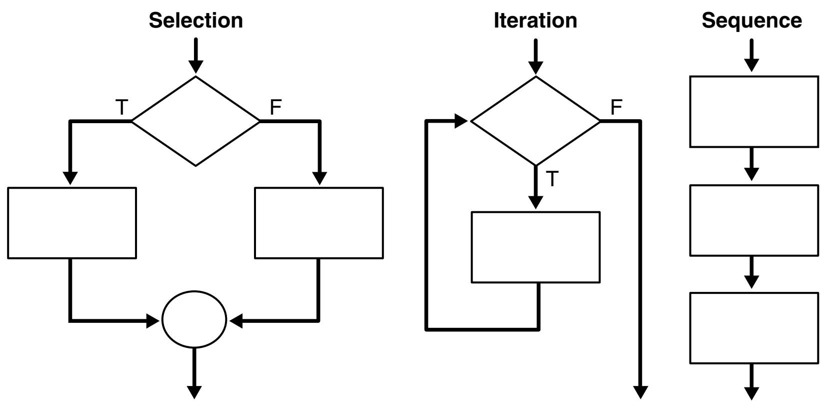
This chapter shows you how to structure the flow of control through a PL/SQL program. PL/SQL provides conditional tests, loops, and branches that let you produce well-structured programs.

This chapter contains these topics:

Overview of PL/SQL Control Structures

Procedural computer programs use the basic control structures shown in Figure 4–1.

Figure 4–1 Control Structures



The selection structure tests a condition, then executes one sequence of statements instead of another, depending on whether the condition is true or false. A condition is any variable or expression that returns a `BOOLEAN` value (`TRUE` or `FALSE`). The iteration structure executes a sequence of statements repeatedly as long as a condition holds true. The sequence structure simply executes a sequence of statements in the order in which they occur.

Testing Conditions: IF and CASE Statements

The IF statement executes a sequence of statements depending on the value of a condition. There are three forms of IF statements: IF-THEN, IF-THEN-ELSE, and IF-THEN-ELSIF. For a description of the syntax of the IF statement, see "IF Statement" on page 13-64.

The CASE statement is a compact way to evaluate a single condition and choose between many alternative actions. It makes sense to use CASE when there are three or more alternatives to choose from. For a description of the syntax of the CASE statement, see "CASE Statement" on page 13-14.

Using the IF-THEN Statement

The simplest form of IF statement associates a condition with a sequence of statements enclosed by the keywords THEN and END IF (not ENDIF) as illustrated in Example 4–1.

The sequence of statements is executed only if the condition is TRUE. If the condition is FALSE or NULL, the IF statement does nothing. In either case, control passes to the next statement.

Example 4–1 Using a Simple IF-THEN Statement

```
DECLARE
  sales  NUMBER(8,2) := 10100;
  quota  NUMBER(8,2) := 10000;
  bonus  NUMBER(6,2);
  emp_id NUMBER(6) := 120;
BEGIN
  IF sales > (quota + 200) THEN
     bonus := (sales - quota)/4;
     UPDATE employees SET salary = salary + bonus WHERE employee_id = emp_id;
  END IF;
END;
/
```

Using the IF-THEN-ELSE Statement

The second form of IF statement adds the keyword ELSE followed by an alternative sequence of statements, as shown in Example 4–2.

The statements in the ELSE clause are executed only if the condition is FALSE or NULL. The IF-THEN-ELSE statement ensures that one or the other sequence of statements is executed. In the Example 4–2, the first UPDATE statement is executed when the condition is TRUE, and the second UPDATE statement is executed when the condition is FALSE or NULL.

Example 4–2 Using a Simple IF-THEN-ELSE Statement

```
DECLARE
  sales  NUMBER(8,2) := 12100;
  quota  NUMBER(8,2) := 10000;
  bonus  NUMBER(6,2);
  emp_id NUMBER(6) := 120;
BEGIN
  IF sales > (quota + 200) THEN
     bonus := (sales - quota)/4;
  ELSE
```

```
     bonus := 50;
  END IF;
  UPDATE employees SET salary = salary + bonus WHERE employee_id = emp_id;
END;
/
```

`IF` statements can be nested as shown in Example 4–3.

Example 4–3 Nested IF Statements

```
DECLARE
  sales  NUMBER(8,2) := 12100;
  quota  NUMBER(8,2) := 10000;
  bonus  NUMBER(6,2);
  emp_id NUMBER(6) := 120;
BEGIN
  IF sales > (quota + 200) THEN
     bonus := (sales - quota)/4;
  ELSE
     IF sales > quota THEN
        bonus := 50;
     ELSE
        bonus := 0;
     END IF;
  END IF;
  UPDATE employees SET salary = salary + bonus WHERE employee_id = emp_id;
END;
/
```

Using the IF-THEN-ELSIF Statement

Sometimes you want to choose between several alternatives. You can use the keyword `ELSIF` (not `ELSEIF` or `ELSE IF`) to introduce additional conditions, as shown in Example 4–4.

If the first condition is `FALSE` or `NULL`, the `ELSIF` clause tests another condition. An `IF` statement can have any number of `ELSIF` clauses; the final `ELSE` clause is optional. Conditions are evaluated one by one from top to bottom. If any condition is `TRUE`, its associated sequence of statements is executed and control passes to the next statement. If all conditions are false or `NULL`, the sequence in the `ELSE` clause is executed, as shown in Example 4–4.

Example 4–4 Using the IF-THEN-ELSEIF Statement

```
DECLARE
  sales  NUMBER(8,2) := 20000;
  bonus  NUMBER(6,2);
  emp_id NUMBER(6) := 120;
BEGIN
   IF sales > 50000 THEN
      bonus := 1500;
   ELSIF sales > 35000 THEN
      bonus := 500;
   ELSE
      bonus := 100;
   END IF;
   UPDATE employees SET salary = salary + bonus WHERE employee_id = emp_id;
END;
/
```

If the value of `sales` is larger than 50000, the first and second conditions are `TRUE`. Nevertheless, `bonus` is assigned the proper value of 1500 because the second condition is never tested. When the first condition is `TRUE`, its associated statement is executed and control passes to the `INSERT` statement.

Another example of an `IF-THEN-ELSE` statement is Example 4–5.

Example 4–5 Extended IF-THEN Statement

```
DECLARE
  grade CHAR(1);
BEGIN
  grade := 'B';
  IF grade = 'A' THEN
    DBMS_OUTPUT.PUT_LINE('Excellent');
  ELSIF grade = 'B' THEN
    DBMS_OUTPUT.PUT_LINE('Very Good');
  ELSIF grade = 'C' THEN
    DBMS_OUTPUT.PUT_LINE('Good');
  ELSIF grade = 'D' THEN
    DBMS_OUTPUT. PUT_LINE('Fair');
  ELSIF grade = 'F' THEN
    DBMS_OUTPUT.PUT_LINE('Poor');
  ELSE
    DBMS_OUTPUT.PUT_LINE('No such grade');
  END IF;
ENd;
/
```

Using CASE Statements

Like the `IF` statement, the `CASE` statement selects one sequence of statements to execute. However, to select the sequence, the `CASE` statement uses a selector rather than multiple Boolean expressions. A selector is an expression whose value is used to select one of several alternatives.

To compare the `IF` and `CASE` statements, consider the code in Example 4–5 that outputs descriptions of school grades. Note the five Boolean expressions. In each instance, we test whether the same variable, `grade`, is equal to one of five values: `'A'`, `'B'`, `'C'`, `'D'`, or `'F'`. You can rewrite the code inExample 4–5 using the `CASE` statement, as shown in Example 4–6.

Example 4–6 Using the CASE-WHEN Statement

```
DECLARE
  grade CHAR(1);
BEGIN
  grade := 'B';
  CASE grade
    WHEN 'A' THEN DBMS_OUTPUT.PUT_LINE('Excellent');
    WHEN 'B' THEN DBMS_OUTPUT.PUT_LINE('Very Good');
    WHEN 'C' THEN DBMS_OUTPUT.PUT_LINE('Good');
    WHEN 'D' THEN DBMS_OUTPUT.PUT_LINE('Fair');
    WHEN 'F' THEN DBMS_OUTPUT.PUT_LINE('Poor');
    ELSE DBMS_OUTPUT.PUT_LINE('No such grade');
  END CASE;
END;
/
```

The CASE statement is more readable and more efficient. When possible, rewrite lengthy IF-THEN-ELSIF statements as CASE statements.

The CASE statement begins with the keyword CASE. The keyword is followed by a selector, which is the variable grade in the last example. The selector expression can be arbitrarily complex. For example, it can contain function calls. Usually, however, it consists of a single variable. The selector expression is evaluated only once. The value it yields can have any PL/SQL datatype other than BLOB, BFILE, an object type, a PL/SQL record, an index-by-table, a varray, or a nested table.

The selector is followed by one or more WHEN clauses, which are checked sequentially. The value of the selector determines which clause is executed. If the value of the selector equals the value of a WHEN-clause expression, that WHEN clause is executed. For instance, in the last example, if grade equals 'C', the program outputs 'Good'. Execution never falls through; if any WHEN clause is executed, control passes to the next statement.

The ELSE clause works similarly to the ELSE clause in an IF statement. In the last example, if the grade is not one of the choices covered by a WHEN clause, the ELSE clause is selected, and the phrase 'No such grade' is output. The ELSE clause is optional. However, if you omit the ELSE clause, PL/SQL adds the following implicit ELSE clause:

```
ELSE RAISE CASE_NOT_FOUND;
```

There is always a default action, even when you omit the ELSE clause. If the CASE statement does not match any of the WHEN clauses and you omit the ELSE clause, PL/SQL raises the predefined exception CASE_NOT_FOUND.

The keywords END CASE terminate the CASE statement. These two keywords must be separated by a space. The CASE statement has the following form:

Like PL/SQL blocks, CASE statements can be labeled. The label, an undeclared identifier enclosed by double angle brackets, must appear at the beginning of the CASE statement. Optionally, the label name can also appear at the end of the CASE statement.

Exceptions raised during the execution of a CASE statement are handled in the usual way. That is, normal execution stops and control transfers to the exception-handling part of your PL/SQL block or subprogram.

An alternative to the CASE statement is the CASE expression, where each WHEN clause is an expression. For details, see "CASE Expressions" on page 2-26.

Searched CASE Statement

PL/SQL also provides a searched CASE statement, similar to the simple CASE statement, which has the form shown in Example 4–7.

The searched CASE statement has no selector. Also, its WHEN clauses contain search conditions that yield a Boolean value, not expressions that can yield a value of any type. as shown in Example 4–7.

Example 4–7 Using the Searched CASE Statement

```
DECLARE
  grade CHAR(1);
BEGIN
  grade := 'B';
  CASE
    WHEN grade = 'A' THEN DBMS_OUTPUT.PUT_LINE('Excellent');
    WHEN grade = 'B' THEN DBMS_OUTPUT.PUT_LINE('Very Good');
    WHEN grade = 'C' THEN DBMS_OUTPUT.PUT_LINE('Good');
    WHEN grade = 'D' THEN DBMS_OUTPUT.PUT_LINE('Fair');
    WHEN grade = 'F' THEN DBMS_OUTPUT.PUT_LINE('Poor');
    ELSE DBMS_OUTPUT.PUT_LINE('No such grade');
  END CASE;
END;
-- rather than using the ELSE in the CASE, could use the following
--  EXCEPTION
--    WHEN CASE_NOT_FOUND THEN
--      DBMS_OUTPUT.PUT_LINE('No such grade');
/
```

The search conditions are evaluated sequentially. The Boolean value of each search condition determines which `WHEN` clause is executed. If a search condition yields `TRUE`, its `WHEN` clause is executed. If any `WHEN` clause is executed, control passes to the next statement, so subsequent search conditions are not evaluated.

If none of the search conditions yields `TRUE`, the `ELSE` clause is executed. The `ELSE` clause is optional. However, if you omit the `ELSE` clause, PL/SQL adds the following implicit `ELSE` clause:

```
ELSE RAISE CASE_NOT_FOUND;
```

Exceptions raised during the execution of a searched `CASE` statement are handled in the usual way. That is, normal execution stops and control transfers to the exception-handling part of your PL/SQL block or subprogram.

Guidelines for PL/SQL Conditional Statements

Avoid clumsy `IF` statements like those in the following example:

```
IF new_balance < minimum_balance THEN
  overdrawn := TRUE;
ELSE
  overdrawn := FALSE;
END IF;
  ...
IF overdrawn = TRUE THEN
  RAISE insufficient_funds;
END IF;
```

The value of a Boolean expression can be assigned directly to a Boolean variable. You can replace the first `IF` statement with a simple assignment:

```
overdrawn := new_balance < minimum_balance;
```

A Boolean variable is itself either true or false. You can simplify the condition in the second `IF` statement:

```
IF overdrawn THEN ...
```

When possible, use the `ELSIF` clause instead of nested `IF` statements. Your code will be easier to read and understand. Compare the following `IF` statements:

```
IF condition1 THEN statement1;
  ELSE IF condition2 THEN statement2;
    ELSE IF condition3 THEN statement3; END IF;
  END IF;
END IF;

IF condition1 THEN statement1;
  ELSEIF condition2 THEN statement2;
```

```
   ELSEIF condition3 THEN statement3;
END IF;
```

These statements are logically equivalent, but the second statement makes the logic clearer.

To compare a single expression to multiple values, you can simplify the logic by using a single `CASE` statement instead of an `IF` with several `ELSIF` clauses.

Controlling Loop Iterations: LOOP and EXIT Statements

`LOOP` statements execute a sequence of statements multiple times. There are three forms of `LOOP` statements: `LOOP`, `WHILE-LOOP`, and `FOR-LOOP`. For a description of the syntax of the `LOOP` statement, see "LOOP Statements" on page 13-72.

Using the LOOP Statement

The simplest form of `LOOP` statement is the basic loop, which encloses a sequence of statements between the keywords `LOOP` and `END LOOP`, as follows:

```
LOOP
  sequence_of_statements
END LOOP;
```

With each iteration of the loop, the sequence of statements is executed, then control resumes at the top of the loop. You use an `EXIT` statement to stop looping and prevent an infinite loop. You can place one or more `EXIT` statements anywhere inside a loop, but not outside a loop. There are two forms of `EXIT` statements: `EXIT` and `EXIT-WHEN`.

Using the EXIT Statement

The `EXIT` statement forces a loop to complete unconditionally. When an `EXIT` statement is encountered, the loop completes immediately and control passes to the next statement as shown in Example 4–8.

Example 4–8 Using an EXIT Statement

```
DECLARE
  credit_rating NUMBER := 0;
BEGIN
  LOOP
    credit_rating := credit_rating + 1;
    IF credit_rating > 3 THEN
       EXIT;  -- exit loop immediately
    END IF;
 END LOOP;
 -- control resumes here
 DBMS_OUTPUT.PUT_LINE ('Credit rating: ' || TO_CHAR(credit_rating));
 IF credit_rating > 3 THEN
       RETURN;  -- use RETURN not EXIT when outside a LOOP
 END IF;
 DBMS_OUTPUT.PUT_LINE ('Credit rating: ' || TO_CHAR(credit_rating));
END;
/
```

Remember, the `EXIT` statement must be placed inside a loop. To complete a PL/SQL block before its normal end is reached, you can use the `RETURN` statement. For more information, see "Using the RETURN Statement" on page 8-5.

Using the EXIT-WHEN Statement

The `EXIT-WHEN` statement lets a loop complete conditionally. When the `EXIT` statement is encountered, the condition in the `WHEN` clause is evaluated. If the condition is true, the loop completes and control passes to the next statement after the loop. See Example 1–10 on page 1-12 for an example that uses the `EXIT-WHEN` statement.

Until the condition is true, the loop cannot complete. A statement inside the loop must change the value of the condition. In the previous example, if the `FETCH` statement returns a row, the condition is false. When the `FETCH` statement fails to return a row, the condition is true, the loop completes, and control passes to the `CLOSE` statement.

The `EXIT-WHEN` statement replaces a simple `IF` statement. For example, compare the following statements:

```
IF count > 100 THEN EXIT; ENDIF;
EXIT WHEN count > 100;
```

These statements are logically equivalent, but the `EXIT-WHEN` statement is easier to read and understand.

Labeling a PL/SQL Loop

Like PL/SQL blocks, loops can be labeled. The optional label, an undeclared identifier enclosed by double angle brackets, must appear at the beginning of the `LOOP` statement. The label name can also appear at the end of the `LOOP` statement. When you nest labeled loops, use ending label names to improve readability.

With either form of `EXIT` statement, you can complete not only the current loop, but any enclosing loop. Simply label the enclosing loop that you want to complete. Then, use the label in an `EXIT` statement, as shown in Example 4–9. Every enclosing loop up to and including the labeled loop is exited.

Example 4–9 Using EXIT With Labeled Loops

```
DECLARE
  s      PLS_INTEGER := 0;
  i      PLS_INTEGER := 0;
  j      PLS_INTEGER;
BEGIN
  <<outer_loop>>
  LOOP
    i := i + 1;
    j := 0;
    <<inner_loop>>
    LOOP
      j := j + 1;
      s := s + i * j; -- sum a bunch of products
      EXIT inner_loop WHEN (j > 5);
      EXIT outer_loop WHEN ((i * j) > 15);
    END LOOP inner_loop;
  END LOOP outer_loop;
  DBMS_OUTPUT.PUT_LINE('The sum of products equals: ' || TO_CHAR(s));
END;
```

```
/
```

Using the WHILE-LOOP Statement

The WHILE-LOOP statement executes the statements in the loop body as long as a condition is true:

```
WHILE condition LOOP
   sequence_of_statements
END LOOP;
```

Before each iteration of the loop, the condition is evaluated. If it is TRUE, the sequence of statements is executed, then control resumes at the top of the loop. If it is FALSE or NULL, the loop is skipped and control passes to the next statement. See Example 1–9 on page 1-11 for an example using the WHILE-LOOP statement.

The number of iterations depends on the condition and is unknown until the loop completes. The condition is tested at the top of the loop, so the sequence might execute zero times.

Some languages have a LOOP UNTIL or REPEAT UNTIL structure, which tests the condition at the bottom of the loop instead of at the top, so that the sequence of statements is executed at least once. The equivalent in PL/SQL would be:

```
LOOP
   sequence_of_statements
   EXIT WHEN boolean_expression;
END LOOP;
```

To ensure that a WHILE loop executes at least once, use an initialized Boolean variable in the condition, as follows:

```
done := FALSE;
WHILE NOT done LOOP
   sequence_of_statements
   done := boolean_expression;
END LOOP;
```

A statement inside the loop must assign a new value to the Boolean variable to avoid an infinite loop.

Using the FOR-LOOP Statement

Simple FOR loops iterate over a specified range of integers. The number of iterations is known before the loop is entered. A double dot (..) serves as the range operator. The range is evaluated when the FOR loop is first entered and is never re-evaluated. If the lower bound equals the higher bound, the loop body is executed once.

As Example 4–10 shows, the sequence of statements is executed once for each integer in the range 1 to 500. After each iteration, the loop counter is incremented.

Example 4–10 Using a Simple FOR..LOOP Statement

```
DECLARE
  p     NUMBER := 0;
BEGIN
  FOR k IN 1..500 LOOP -- calculate pi with 500 terms
    p := p +  (  ( (-1) ** (k + 1) ) / ((2 * k) - 1) );
  END LOOP;
  p := 4 * p;
  DBMS_OUTPUT.PUT_LINE( 'pi is approximately : ' || p ); -- print result
END;
/
```

By default, iteration proceeds upward from the lower bound to the higher bound. If you use the keyword REVERSE, iteration proceeds downward from the higher bound to the lower bound. After each iteration, the loop counter is decremented. You still write the range bounds in ascending (not descending) order.

Example 4–11 Using a Reverse FOR..LOOP Statement

```
BEGIN
  FOR i IN REVERSE 1..3 LOOP  -- assign the values 1,2,3 to i
    DBMS_OUTPUT.PUT_LINE (TO_CHAR(i));
  END LOOP;
END;
/
```

Inside a FOR loop, the counter can be read but cannot be changed.

```
BEGIN
  FOR i IN 1..3 LOOP  -- assign the values 1,2,3 to i
    IF i < 3 THEN
       DBMS_OUTPUT.PUT_LINE (TO_CHAR(i));
    ELSE
       i := 2; -- not allowed, raises an error
    END IF;
  END LOOP;
END;
/
```

A useful variation of the FOR loop uses a SQL query instead of a range of integers. This technique lets you run a query and process all the rows of the result set with straightforward syntax. For details, see "Querying Data with PL/SQL: Implicit Cursor FOR Loop" on page 6-16.

How PL/SQL Loops Iterate

The bounds of a loop range can be literals, variables, or expressions but must evaluate to numbers. Otherwise, PL/SQL raises the predefined exception VALUE_ERROR. The lower bound need not be 1, but the loop counter increment or decrement must be 1.

```
j IN -5..5
k IN REVERSE first..last
step IN 0..TRUNC(high/low) * 2
```

Internally, PL/SQL assigns the values of the bounds to temporary PLS_INTEGER variables, and, if necessary, rounds the values to the nearest integer. The magnitude range of a PLS_INTEGER is -2147483648 to 2147483647, represented in 32 bits. If a bound evaluates to a number outside that range, you get a *numeric overflow* error when PL/SQL attempts the assignment. See "PLS_INTEGER Datatype" on page 3-4.

Some languages provide a STEP clause, which lets you specify a different increment (5 instead of 1 for example). PL/SQL has no such structure, but you can easily build one. Inside the FOR loop, simply multiply each reference to the loop counter by the new increment. In Example 4–12, you assign today's date to elements 5, 10, and 15 of an index-by table:

Example 4–12 Changing the Increment of the Counter in a FOR..LOOP Statement

```
DECLARE
   TYPE DateList IS TABLE OF DATE INDEX BY PLS_INTEGER;
   dates DateList;
   k CONSTANT INTEGER := 5;  -- set new increment
BEGIN
   FOR j IN 1..3 LOOP
      dates(j*k) := SYSDATE;  -- multiply loop counter by increment
   END LOOP;
END;
/
```

Dynamic Ranges for Loop Bounds

PL/SQL lets you specify the loop range at run time by using variables for bounds as shown in Example 4–13.

Example 4–13 Specifying a LOOP Range at Run Time

```
CREATE TABLE temp (emp_no NUMBER, email_addr VARCHAR2(50));
DECLARE
  emp_count NUMBER;
BEGIN
  SELECT COUNT(employee_id) INTO emp_count FROM employees;
  FOR i IN 1..emp_count LOOP
   INSERT INTO temp VALUES(i, 'to be added later');
  END LOOP;
  COMMIT;
END;
/
```

If the lower bound of a loop range evaluates to a larger integer than the upper bound, the loop body is not executed and control passes to the next statement:

```
-- limit becomes 1
FOR i IN 2..limit LOOP
   sequence_of_statements  -- executes zero times
END LOOP;
-- control passes here
```

Scope of the Loop Counter Variable

The loop counter is defined only within the loop. You cannot reference that variable name outside the loop. After the loop exits, the loop counter is undefined:

Example 4–14 Scope of the LOOP Counter Variable

```
BEGIN
  FOR i IN 1..3 LOOP  -- assign the values 1,2,3 to i
    DBMS_OUTPUT.PUT_LINE (TO_CHAR(i));
  END LOOP;
  DBMS_OUTPUT.PUT_LINE (TO_CHAR(i)); -- raises an error
END;
/
```

You do not need to declare the loop counter because it is implicitly declared as a local variable of type `INTEGER`. It is safest not to use the name of an existing variable, because the local declaration hides any global declaration.

```
DECLARE
```

```
  i NUMBER := 5;
BEGIN
  FOR i IN 1..3 LOOP  -- assign the values 1,2,3 to i
    DBMS_OUTPUT.PUT_LINE (TO_CHAR(i));
  END LOOP;
  DBMS_OUTPUT.PUT_LINE (TO_CHAR(i)); -- refers to original variable value (5)
END;
/
```

To reference the global variable in this example, you must use a label and dot notation, as shown in Example 4–15.

Example 4–15 Using a Label for Referencing Variables Outside a Loop

```
<<main>>
DECLARE
  i NUMBER := 5;
BEGIN
  FOR i IN 1..3 LOOP  -- assign the values 1,2,3 to i
    DBMS_OUTPUT.PUT_LINE( 'local: ' || TO_CHAR(i)
                       || ' global: ' || TO_CHAR(main.i));
  END LOOP;
END main;
/
```

The same scope rules apply to nested `FOR` loops. In Example 4–16 both loop counters have the same name. To reference the outer loop counter from the inner loop, you use a label and dot notation.

Example 4–16 Using Labels on Loops for Referencing

```
BEGIN
<<outer_loop>>
  FOR i IN 1..3 LOOP  -- assign the values 1,2,3 to i
    <<inner_loop>>
    FOR i IN 1..3 LOOP
      IF outer_loop.i = 2 THEN
        DBMS_OUTPUT.PUT_LINE( 'outer: ' || TO_CHAR(outer_loop.i) || ' inner: '
                              || TO_CHAR(inner_loop.i));
      END IF;
    END LOOP inner_loop;
  END LOOP outer_loop;
END;
/
```

Using the EXIT Statement in a FOR Loop

The `EXIT` statement lets a `FOR` loop complete early. In Example 4–17, the loop normally executes ten times, but as soon as the `FETCH` statement fails to return a row, the loop completes no matter how many times it has executed.

Example 4–17 Using EXIT in a LOOP

```
DECLARE
   v_employees employees%ROWTYPE;  -- declare record variable
   CURSOR c1 is SELECT * FROM employees;
BEGIN
  OPEN c1; -- open the cursor before fetching
-- An entire row is fetched into the v_employees record
```

```
  FOR i IN 1..10 LOOP
    FETCH c1 INTO v_employees;
    EXIT WHEN c1%NOTFOUND;
    -- process data here
  END LOOP;
  CLOSE c1;
END;
/
```

Suppose you must exit early from a nested `FOR` loop. To complete not only the current loop, but also any enclosing loop, label the enclosing loop and use the label in an `EXIT` statement as shown in Example 4–18.

Example 4–18   Using EXIT With a Label in a LOOP

```
DECLARE
   v_employees employees%ROWTYPE;  -- declare record variable
   CURSOR c1 is SELECT * FROM employees;
BEGIN
  OPEN c1; -- open the cursor before fetching
-- An entire row is fetched into the v_employees record
<<outer_loop>>
  FOR i IN 1..10 LOOP
    -- process data here
    FOR j IN 1..10 LOOP
      FETCH c1 INTO v_employees;
      EXIT WHEN c1%NOTFOUND;
      -- process data here
    END LOOP;
  END LOOP outer_loop;
  CLOSE c1;
END;
/
```

See also Example 6–10 on page 6-10.

Sequential Control: GOTO and NULL Statements

Unlike the `IF` and `LOOP` statements, the `GOTO` and `NULL` statements are not crucial to PL/SQL programming. The `GOTO` statement is seldom needed. Occasionally, it can simplify logic enough to warrant its use. The `NULL` statement can improve readability by making the meaning and action of conditional statements clear.

Overuse of `GOTO` statements can result in code that is hard to understand and maintain. Use `GOTO` statements sparingly. For example, to branch from a deeply nested structure to an error-handling routine, raise an exception rather than use a `GOTO` statement. PL/SQL's exception-handling mechanism is discussed in Chapter 10, "Handling PL/SQL Errors".

Using the GOTO Statement

The `GOTO` statement branches to a label unconditionally. The label must be unique within its scope and must precede an executable statement or a PL/SQL block. When executed, the `GOTO` statement transfers control to the labeled statement or block. The labeled statement or block can be down or up in the sequence of statements. In Example 4–19 you go to a PL/SQL block up in the sequence of statements.

Example 4–19 Using a Simple GOTO Statement

```
DECLARE
  p        VARCHAR2(30);
  n        PLS_INTEGER := 37; -- test any integer > 2 for prime
BEGIN
  FOR j in 2..ROUND(SQRT(n)) LOOP
    IF n MOD j = 0 THEN -- test for prime
      p := ' is not a prime number'; -- not a prime number
      GOTO print_now;
    END IF;
  END LOOP;
  p := ' is a prime number';
<<print_now>>
  DBMS_OUTPUT.PUT_LINE(TO_CHAR(n) || p);
END;
/
```

The label `end_loop` in the Example 4–20 is not allowed unless it is preceded by an executable statement. To make the label legal, a `NULL` statement is added.

Example 4–20 Using a NULL Statement to Allow a GOTO to a Label

```
DECLARE
   done  BOOLEAN;
BEGIN
   FOR i IN 1..50 LOOP
      IF done THEN
         GOTO end_loop;
      END IF;
   <<end_loop>>  -- not allowed unless an executable statement follows
   NULL; -- add NULL statement to avoid error
   END LOOP;  -- raises an error without the previous NULL
END;
/
```

Example 4–21 shows a `GOTO` statement can branch to an enclosing block from the current block.

Example 4–21 Using a GOTO Statement to Branch an Enclosing Block

```
-- example with GOTO statement
DECLARE
   v_last_name  VARCHAR2(25);
   v_emp_id     NUMBER(6) := 120;
BEGIN
   <<get_name>>
   SELECT last_name INTO v_last_name FROM employees
          WHERE employee_id = v_emp_id;
   BEGIN
      DBMS_OUTPUT.PUT_LINE (v_last_name);
      v_emp_id := v_emp_id + 5;
      IF v_emp_id < 120 THEN
        GOTO get_name;  -- branch to enclosing block
      END IF;
   END;
END;
/
```

The `GOTO` statement branches to the first enclosing block in which the referenced label appears.

Restrictions on the GOTO Statement

Some possible destinations of a GOTO statement are not allowed. Specifically, a GOTO statement cannot branch into an IF statement, CASE statement, LOOP statement, or sub-block. For example, the following GOTO statement is not allowed:

```
BEGIN
  GOTO update_row; -- cannot branch into IF statement
  IF valid THEN
    <<update_row>>
    UPDATE emp SET ...
  END IF;
END;
```

A GOTO statement cannot branch from one IF statement clause to another, or from one CASE statement WHEN clause to another.

A GOTO statement cannot branch from an outer block into a sub-block (that is, an inner BEGIN-END block).

A GOTO statement cannot branch out of a subprogram. To end a subprogram early, you can use the RETURN statement or use GOTO to branch to a place right before the end of the subprogram.

A GOTO statement cannot branch from an exception handler back into the current BEGIN-END block. However, a GOTO statement can branch from an exception handler into an enclosing block.

Using the NULL Statement

The NULL statement does nothing, and passes control to the next statement. Some languages refer to such an instruction as a no-op (no operation). See "NULL Statement" on page 13-77.

In Example 4–22, the NULL statement emphasizes that only salespeople receive commissions.

Example 4–22 Using the NULL Statement to Show No Action

```
DECLARE
  v_job_id  VARCHAR2(10);
  v_emp_id  NUMBER(6) := 110;
BEGIN
  SELECT job_id INTO v_job_id FROM employees WHERE employee_id = v_emp_id;
  IF v_job_id = 'SA_REP' THEN
    UPDATE employees SET commission_pct = commission_pct * 1.2;
  ELSE
    NULL; -- do nothing if not a sales representative
  END IF;
END;
/
```

The NULL statement is a handy way to create placeholders and stub procedures. In Example 4–23, the NULL statement lets you compile this procedure, then fill in the real body later. Note that the use of the NULL statement might raise an unreachable code warning if warnings are enabled. See "Overview of PL/SQL Compile-Time Warnings" on page 10-17.

Example 4–23 Using NULL as a Placeholder When Creating a Subprogram

```
CREATE OR REPLACE PROCEDURE award_bonus (emp_id NUMBER, bonus NUMBER) AS
BEGIN  -- executable part starts here
  NULL; -- use NULL as placeholder, raises "unreachable code" if warnings enabled
END award_bonus;
/
```

You can use the NULL statement to indicate that you are aware of a possibility, but no action is necessary. In the following exception block, the NULL statement shows that you have chosen not to take any action for unnamed exceptions:

```
EXCEPTION
  WHEN ZERO_DIVIDE THEN
    ROLLBACK;
  WHEN OTHERS THEN
    NULL;
END;
```

See Example 1–12, "Creating a Stored Subprogram" on page 1-13.

5

Using PL/SQL Collections and Records

Many programming techniques use collection types such as arrays, bags, lists, nested tables, sets, and trees. You can model these types in database applications using the PL/SQL datatypes `TABLE` and `VARRAY`, which allow you to declare nested tables, associative arrays, and variable-size arrays. This chapter shows how to reference and manipulate collections of data as local variables. You also learn how the `RECORD` datatype lets you manipulate related values of different types as a logical unit.

This chapter contains these topics:

What are PL/SQL Collections and Records?

Collections and records are composite types that have internal components that can be manipulated individually, such as the elements of an array, record, or table.

A collection is an ordered group of elements, all of the same type. It is a general concept that encompasses lists, arrays, and other datatypes used in classic programming algorithms. Each element is addressed by a unique subscript.

A record is a group of related data items stored in fields, each with its own name and datatype. You can think of a record as a variable that can hold a table row, or some columns from a table row. The fields correspond to table columns.

The following sections discuss PL/SQL collections and records:

- Understanding PL/SQL Collections
- Understanding PL/SQL Records

Understanding PL/SQL Collections

PL/SQL offers these collection types:

- Associative arrays, also known as index-by tables, let you look up elements using arbitrary numbers and strings for subscript values. These are similar to hash tables in other programming languages.
- Nested tables hold an arbitrary number of elements. They use sequential numbers as subscripts. You can define equivalent SQL types, allowing nested tables to be stored in database tables and manipulated through SQL.
- Varrays (short for variable-size arrays) hold a fixed number of elements (although you can change the number of elements at runtime). They use sequential numbers as subscripts. You can define equivalent SQL types, allowing varrays to be stored in database tables. They can be stored and retrieved through SQL, but with less flexibility than nested tables.

Although collections have only one dimension, you can model multi-dimensional arrays by creating collections whose elements are also collections.

To use collections in an application, you define one or more PL/SQL types, then define variables of those types. You can define collection types in a procedure, function, or package. You can pass collection variables as parameters to stored subprograms.

To look up data that is more complex than single values, you can store PL/SQL records or SQL object types in collections. Nested tables and varrays can also be attributes of object types.

Understanding Nested Tables

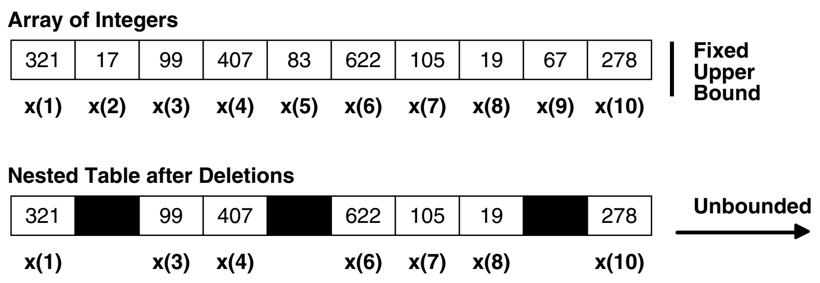
PL/SQL nested tables represent sets of values. You can think of them as one-dimensional arrays with no declared number of elements. You can model multi-dimensional arrays by creating nested tables whose elements are also nested tables.

Within the database, nested tables are column types that hold sets of values. Oracle stores the rows of a nested table in no particular order. When you retrieve a nested table from the database into a PL/SQL variable, the rows are given consecutive subscripts starting at 1. That gives you array-like access to individual rows.

Nested tables differ from arrays in two important ways:

1. Nested tables do not have a declared number of elements, while arrays have a predefined number as illustrated in Figure 5–1. The size of a nested table can increase dynamically; however, a maximum limit is imposed. See "Referencing Collection Elements" on page 5-11.
2. Nested tables might not have consecutive subscripts, while arrays are always dense (have consecutive subscripts). Initially, nested tables are dense, but they can become sparse (have nonconsecutive subscripts). You can delete elements from a nested table using the built-in procedure `DELETE`. The built-in function `NEXT` lets you iterate over all the subscripts of a nested table, even if the sequence has gaps.

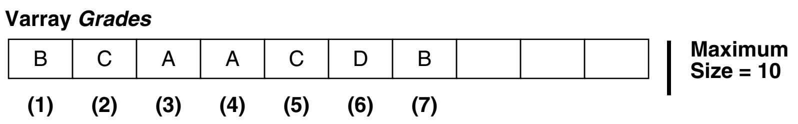
Figure 5–1 Array versus Nested Table



Understanding Varrays

Items of type `VARRAY` are called varrays. They let you reference individual elements for array operations, or manipulate the collection as a whole. To reference an element, you use standard subscripting syntax (see Figure 5–2). For example, `Grade(3)` references the third element in varray `Grades`.

Figure 5–2 Varray of Size 10



A varray has a maximum size, which you specify in its type definition. Its index has a fixed lower bound of 1 and an extensible upper bound. For example, the current upper bound for varray `Grades` is 7, but you can increase its upper bound to maximum of 10. A varray can contain a varying number of elements, from zero (when empty) to the maximum specified in its type definition.

Understanding Associative Arrays (Index-By Tables)

Associative arrays are sets of key-value pairs, where each key is unique and is used to locate a corresponding value in the array. The key can be an integer or a string.

Assigning a value using a key for the first time adds that key to the associative array. Subsequent assignments using the same key update the same entry. It is important to choose a key that is unique. For example, key values might come from the primary key of a database table, from a numeric hash function, or from concatenating strings to form a unique string value.

For example, here is the declaration of an associative array type, and two arrays of that type, using keys that are strings:

Example 5–1 Declaring Collection Types

```
DECLARE
  TYPE population_type IS TABLE OF NUMBER INDEX BY VARCHAR2(64);
  country_population population_type;
  continent_population population_type;
  howmany NUMBER;
  which VARCHAR2(64);
BEGIN
  country_population('Greenland') := 100000; -- Creates new entry
  country_population('Iceland') := 750000;   -- Creates new entry
-- Looks up value associated with a string
  howmany := country_population('Greenland');
  continent_population('Australia') := 30000000;
  continent_population('Antarctica') := 1000; -- Creates new entry
  continent_population('Antarctica') := 1001; -- Replaces previous value
-- Returns 'Antarctica' as that comes first alphabetically.
  which := continent_population.FIRST;
-- Returns 'Australia' as that comes last alphabetically.
  which := continent_population.LAST;
-- Returns the value corresponding to the last key, in this
-- case the population of Australia.
  howmany := continent_population(continent_population.LAST);
END;
/
```

Associative arrays help you represent data sets of arbitrary size, with fast lookup for an individual element without knowing its position within the array and without having to loop through all the array elements. It is like a simple version of a SQL table where you can retrieve values based on the primary key. For simple temporary storage of lookup data, associative arrays let you avoid using the disk space and network operations required for SQL tables.

Because associative arrays are intended for temporary data rather than storing persistent data, you cannot use them with SQL statements such as `INSERT` and `SELECT INTO`. You can make them persistent for the life of a database session by declaring the type in a package and assigning the values in a package body.

How Globalization Settings Affect VARCHAR2 Keys for Associative Arrays

If settings for national language or globalization change during a session that uses associative arrays with `VARCHAR2` key values, the program might encounter a runtime error. For example, changing the `NLS_COMP` or `NLS_SORT` initialization parameters within a session might cause methods such as `NEXT` and `PRIOR` to raise exceptions. If you need to change these settings during the session, make sure to set them back to their original values before performing further operations with these kinds of associative arrays.

When you declare an associative array using a string as the key, the declaration must use a `VARCHAR2`, `STRING`, or `LONG` type. You can use a different type, such as `NCHAR` or `NVARCHAR2`, as the key value to reference an associative array. You can even use a type such as `DATE`, as long as it can be converted to `VARCHAR2` by the `TO_CHAR` function. Note that the `LONG` datatype is supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

However, you must be careful when using other types that the values used as keys are consistent and unique. For example, the string value of `SYSDATE` might change if the `NLS_DATE_FORMAT` initialization parameter changes, so that `array_element(SYSDATE)` does not produce the same result as before. Two different `NVARCHAR2` values might turn into the same `VARCHAR2` value (containing question marks instead of certain national characters). In that case, `array_element(national_string1)` and `array_element(national_string2)` might refer to the same element. Two different `CHAR` or `VARCHAR2` values that differ in terms of case, accented characters, or punctuation characters might also be considered the same if the value of the `NLS_SORT` initialization parameter ends in `_CI` (case-insensitive comparisons) or `_AI` (accent- and case-insensitive comparisons).

When you pass an associative array as a parameter to a remote database using a database link, the two databases can have different globalization settings. When the remote database performs operations such as `FIRST` and `NEXT`, it uses its own character order even if that is different from the order where the collection originated. If character set differences mean that two keys that were unique are not unique on the remote database, the program receives a `VALUE_ERROR` exception.

Understanding PL/SQL Records

Records are composed of a group of fields, similar to the columns in a row. The `%ROWTYPE` attribute lets you declare a PL/SQL record that represents a row in a database table, without listing all the columns. Your code keeps working even after columns are added to the table. If you want to represent a subset of columns in a table, or columns from different tables, you can define a view or declare a cursor to select the right columns and do any necessary joins, and then apply `%ROWTYPE` to the view or cursor.

For information on using records in PL/SQL, see the following sections in this chapter:

- Defining and Declaring Records
- Assigning Values to Records

Choosing Which PL/SQL Collection Types to Use

If you already have code or business logic that uses some other language, you can usually translate that language's array and set types directly to PL/SQL collection types.

- Arrays in other languages become varrays in PL/SQL.
- Sets and bags in other languages become nested tables in PL/SQL.
- Hash tables and other kinds of unordered lookup tables in other languages become associative arrays in PL/SQL.

When you are writing original code or designing the business logic from the start, you should consider the strengths of each collection type to decide which is appropriate for each situation.

Choosing Between Nested Tables and Associative Arrays

Both nested tables and associative arrays (formerly known as index-by tables) use similar subscript notation, but they have different characteristics when it comes to persistence and ease of parameter passing.

Nested tables can be stored in a database column, but associative arrays cannot. Nested tables can simplify SQL operations where you would normally join a single-column table with a larger table.

Associative arrays are appropriate for relatively small lookup tables where the collection can be constructed in memory each time a procedure is called or a package is initialized. They are good for collecting information whose volume is unknown beforehand, because there is no fixed limit on their size. Their index values are more flexible, because associative array subscripts can be negative, can be nonsequential, and can use string values instead of numbers.

PL/SQL automatically converts between host arrays and associative arrays that use numeric key values. The most efficient way to pass collections to and from the database server is to set up data values in associative arrays, then use those associative arrays with bulk constructs (the `FORALL` statement or `BULK COLLECT` clause).

Choosing Between Nested Tables and Varrays

Varrays are a good choice when:

- The number of elements is known in advance.

- The elements are usually all accessed in sequence.

When stored in the database, varrays keep their ordering and subscripts.

Each varray is stored as a single object, either inside the table of which it is a column (if the varray is less than 4KB) or outside the table but still in the same tablespace (if the varray is greater than 4KB). You must update or retrieve all elements of the varray at the same time, which is most appropriate when performing some operation on all the elements at once. But you might find it impractical to store and retrieve large numbers of elements this way.

Nested tables are a good choice when:

- The index values are not consecutive.
- There is no set number of index values. However, a maximum limit is imposed. See "Referencing Collection Elements" on page 5-11.
- You need to delete or update some elements, but not all the elements at once.
- You would usually create a separate lookup table, with multiple entries for each row of the main table, and access it through join queries.

Nested tables can be sparse: you can delete arbitrary elements, rather than just removing an item from the end.

Nested table data is stored in a separate store table, a system-generated database table associated with the nested table. The database joins the tables for you when you access the nested table. This makes nested tables suitable for queries and updates that only affect some elements of the collection.

You cannot rely on the order and subscripts of a nested table remaining stable as the nested table is stored in and retrieved from the database, because the order and subscripts are not preserved in the database.

Defining Collection Types and Declaring Collection Variables

To create collections, you define a collection type, then declare variables of that type. Collections follow the same scoping and instantiation rules as other types and variables. Collections are instantiated when you enter a block or subprogram, and cease to exist when you exit. In a package, collections are instantiated when you first reference the package and cease to exist when you end the database session.

Note: For information on using PL/SQL with SQL object types, see Chapter 12, "Using PL/SQL With Object Types". For information on the `CREATE TYPE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE TYPE BODY` SQL statement, see *Oracle Database SQL Reference*.

You can define `TABLE` and `VARRAY` types in the declarative part of any PL/SQL block, subprogram, or package using a `TYPE` definition. For the syntax information, see "Collection Definition" on page 13-17.

For nested tables and varrays declared within PL/SQL, the element type of the table or varray can be any PL/SQL datatype except `REF CURSOR`.

When defining a `VARRAY` type, you must specify its maximum size with a positive integer. In the following example, you define a type that stores up to 366 dates:

```
DECLARE
```

```
   TYPE Calendar IS VARRAY(366) OF DATE;
```

Associative arrays (also known as index-by tables) let you insert elements using arbitrary key values. The keys do not have to be consecutive.

The key datatype can be PLS_INTEGER, BINARY_INTEGER, or VARCHAR2, or one of VARCHAR2 subtypes VARCHAR, STRING, or LONG. Note that PLS_INTEGER and BINARY_INTEGER are identical dataypes.

You must specify the length of a VARCHAR2-based key, except for LONG which is equivalent to declaring a key type of VARCHAR2(32760). The types RAW, LONG RAW, ROWID, CHAR, and CHARACTER are not allowed as keys for an associative array. Note that the LONG and LONG RAW datatypes are supported only for backward compatibility; see "LONG and LONG RAW Datatypes" on page 3-5 for more information.

An initialization clause is not allowed. There is no constructor notation for associative arrays. When you reference an element of an associative array that uses a VARCHAR2-based key, you can use other types, such as DATE or TIMESTAMP, as long as they can be converted to VARCHAR2 with the TO_CHAR function.

Associative arrays can store data using a primary key value as the index, where the key values are not sequential. Example 5–2 creates a single element in an associative array, with a subscript of 100 rather than 1.

Example 5–2 Declaring an Associative Array

```
DECLARE
   TYPE EmpTabTyp IS TABLE OF employees%ROWTYPE
      INDEX BY PLS_INTEGER;
   emp_tab EmpTabTyp;
BEGIN
   /* Retrieve employee record. */
   SELECT * INTO emp_tab(100) FROM employees WHERE employee_id = 100;
END;
/
```

Declaring PL/SQL Collection Variables

After defining a collection type, you declare variables of that type. You use the new type name in the declaration, the same as with predefined types such as NUMBER.

Example 5–3 Declaring Nested Tables, Varrays, and Associative Arrays

```
DECLARE
   TYPE nested_type IS TABLE OF VARCHAR2(30);
   TYPE varray_type IS VARRAY(5) OF INTEGER;
   TYPE assoc_array_num_type IS TABLE OF NUMBER INDEX BY PLS_INTEGER;
   TYPE assoc_array_str_type IS TABLE OF VARCHAR2(32) INDEX BY PLS_INTEGER;
   TYPE assoc_array_str_type2 IS TABLE OF VARCHAR2(32) INDEX BY VARCHAR2(64);
   v1 nested_type;
   v2 varray_type;
   v3 assoc_array_num_type;
   v4 assoc_array_str_type;
   v5 assoc_array_str_type2;
BEGIN
-- an arbitrary number of strings can be inserted v1
   v1 := nested_type('Shipping','Sales','Finance','Payroll');
   v2 := varray_type(1, 2, 3, 4, 5); -- Up to 5 integers
   v3(99) := 10; -- Just start assigning to elements
   v3(7) := 100; -- Subscripts can be any integer values
   v4(42) := 'Smith'; -- Just start assigning to elements
   v4(54) := 'Jones'; -- Subscripts can be any integer values
   v5('Canada') := 'North America'; -- Just start assigning to elements
   v5('Greece') := 'Europe';        -- Subscripts can be string values
END;
/
```

As shown in Example 5–4, you can use `%TYPE` to specify the datatype of a previously declared collection, so that changing the definition of the collection automatically updates other variables that depend on the number of elements or the element type.

Example 5–4   Declaring Collections with %TYPE

```
DECLARE
   TYPE few_depts IS VARRAY(10) OF VARCHAR2(30);
   TYPE many_depts IS VARRAY(100) OF VARCHAR2(64);
   some_depts few_depts;
-- If we change the type of some_depts from few_depts to many_depts,
-- local_depts and global_depts will use the same type
-- when this block is recompiled
   local_depts some_depts%TYPE;
   global_depts some_depts%TYPE;
BEGIN
   NULL;
END;
/
```

You can declare collections as the formal parameters of functions and procedures. That way, you can pass collections to stored subprograms and from one subprogram to another. Example 5–5 declares a nested table as a parameter of a packaged procedure.

Example 5–5   Declaring a Procedure Parameter as a Nested Table

```
CREATE PACKAGE personnel AS
   TYPE staff_list IS TABLE OF employees.employee_id%TYPE;
   PROCEDURE award_bonuses (empleos_buenos IN staff_list);
END personnel;
/

CREATE PACKAGE BODY personnel AS
 PROCEDURE award_bonuses (empleos_buenos staff_list) IS
  BEGIN
    FOR i IN empleos_buenos.FIRST..empleos_buenos.LAST
    LOOP
     UPDATE employees SET salary = salary + 100
         WHERE employees.employee_id = empleos_buenos(i);
   END LOOP;
  END;
 END;
/
```

To call `personnel.award_bonuses` from outside the package, you declare a variable of type `personnel.staff_list` and pass that variable as the parameter.

Example 5–6   Calling a Procedure With a Nested Table Parameter

```
DECLARE
  good_employees personnel.staff_list;
BEGIN
```

```
  good_employees :=  personnel.staff_list(100, 103, 107);
  personnel.award_bonuses (good_employees);
END;
/
```

You can also specify a collection type in the RETURN clause of a function specification.

To specify the element type, you can use %TYPE, which provides the datatype of a variable or database column. Also, you can use %ROWTYPE, which provides the rowtype of a cursor or database table. See Example 5–7 and Example 5–8.

Example 5–7   Specifying Collection Element Types with %TYPE and %ROWTYPE

```
DECLARE
-- Nested table type that can hold an arbitrary number of employee IDs.
-- The element type is based on a column from the EMPLOYEES table.
-- We do not need to know whether the ID is a number or a string.
   TYPE EmpList IS TABLE OF employees.employee_id%TYPE;
-- Declare a cursor to select a subset of columns.
   CURSOR c1 IS SELECT employee_id FROM employees;
-- Declare an Array type that can hold information about 10 employees.
-- The element type is a record that contains all the same
-- fields as the EMPLOYEES table.
   TYPE Senior_Salespeople IS VARRAY(10) OF employees%ROWTYPE;
-- Declare a cursor to select a subset of columns.
   CURSOR c2 IS SELECT first_name, last_name FROM employees;
-- Array type that can hold a list of names. The element type
-- is a record that contains the same fields as the cursor
-- (that is, first_name and last_name).
   TYPE NameList IS VARRAY(20) OF c2%ROWTYPE;
BEGIN
   NULL;
END;
/
```

Example 5–8 uses a RECORD type to specify the element type. See "Defining and Declaring Records" on page 5-29.

Example 5–8   VARRAY of Records

```
DECLARE
   TYPE name_rec IS RECORD ( first_name VARCHAR2(20), last_name VARCHAR2(25) );
   TYPE names IS VARRAY(250) OF name_rec;
BEGIN
   NULL;
END;
/
```

You can also impose a NOT NULL constraint on the element type, as shown in Example 5–9.

Example 5–9   NOT NULL Constraint on Collection Elements

```
DECLARE
   TYPE EmpList IS TABLE OF employees.employee_id%TYPE NOT NULL;
   v_employees EmpList := EmpList(100, 150, 160, 200);
BEGIN
   v_employees(3) := NULL; -- assigning NULL raises an error
END;
/
```

Initializing and Referencing Collections

Until you initialize it, a nested table or varray is atomically null; the collection itself is null, not its elements. To initialize a nested table or varray, you use a constructor, a system-defined function with the same name as the collection type. This function constructs collections from the elements passed to it.

You must explicitly call a constructor for each varray and nested table variable. Associative arrays, the third kind of collection, do not use constructors. Constructor calls are allowed wherever function calls are allowed.

Example 5–10 initializes a nested table using a constructor, which looks like a function with the same name as the collection type:

Example 5–10 Constructor for a Nested Table

```
DECLARE
   TYPE dnames_tab IS TABLE OF VARCHAR2(30);
   dept_names dnames_tab;
BEGIN
   dept_names := dnames_tab('Shipping','Sales','Finance','Payroll');
END;
/
```

Because a nested table does not have a declared size, you can put as many elements in the constructor as necessary.

Example 5–11 initializes a varray using a constructor, which looks like a function with the same name as the collection type:

Example 5–11 Constructor for a Varray

```
DECLARE
-- In the varray, we put an upper limit on the number of elements
   TYPE dnames_var IS VARRAY(20) OF VARCHAR2(30);
   dept_names dnames_var;
BEGIN
-- Because dnames is declared as VARRAY(20), we can put up to 10
-- elements in the constructor
   dept_names := dnames_var('Shipping','Sales','Finance','Payroll');
END;
/
```

Unless you impose the `NOT NULL` constraint in the type declaration, you can pass null elements to a constructor as in Example 5–12.

Example 5–12 Collection Constructor Including Null Elements

```
DECLARE
   TYPE dnames_tab IS TABLE OF VARCHAR2(30);
   dept_names dnames_tab;
   TYPE dnamesNoNulls_type IS TABLE OF VARCHAR2(30) NOT NULL;
BEGIN
   dept_names := dnames_tab('Shipping', NULL,'Finance', NULL);
-- If dept_names was of type dnamesNoNulls_type, we could not include
-- null values in the constructor
END;
/
```

You can initialize a collection in its declaration, which is a good programming practice, as shown in Example 5–13. In this case, you can call the collection's `EXTEND` method to add elements later.

Example 5–13 Combining Collection Declaration and Constructor

```
DECLARE
   TYPE dnames_tab IS TABLE OF VARCHAR2(30);
   dept_names dnames_tab := dnames_tab('Shipping','Sales','Finance','Payroll');
BEGIN
   NULL;
END;
/
```

If you call a constructor without arguments, you get an empty but non-null collection as shown in Example 5–14.

Example 5–14 Empty Varray Constructor

```
DECLARE
   TYPE dnames_var IS VARRAY(20) OF VARCHAR2(30);
   dept_names dnames_var;
BEGIN
   IF dept_names IS NULL THEN
      DBMS_OUTPUT.PUT_LINE('Before initialization, the varray is null.');
-- While the varray is null, we cannot check its COUNT attribute.
--   DBMS_OUTPUT.PUT_LINE('It has ' || dept_names.COUNT || ' elements.');
   ELSE
      DBMS_OUTPUT.PUT_LINE('Before initialization, the varray is not null.');
   END IF;
   dept_names := dnames_var(); -- initialize empty varray
   IF dept_names IS NULL THEN
      DBMS_OUTPUT.PUT_LINE('After initialization, the varray is null.');
   ELSE
      DBMS_OUTPUT.PUT_LINE('After initialization, the varray is not null.');
      DBMS_OUTPUT.PUT_LINE('It has ' || dept_names.COUNT || ' elements.');
   END IF;
END;
/
```

Referencing Collection Elements

Every reference to an element includes a collection name and a subscript enclosed in parentheses. The subscript determines which element is processed. To reference an element, you specify its subscript using the syntax

`collection_name`(*`subscript`*)

where *`subscript`* is an expression that yields an integer in most cases, or a `VARCHAR2` for associative arrays declared with strings as keys.

The allowed subscript ranges are:

- For nested tables, 1 .. 2147483647 (the upper limit of `PLS_INTEGER`).
- For varrays, 1 .. *`size_limit`*, where you specify the limit in the declaration (not to exceed 2147483647).
- For associative arrays with a numeric key, -2147483648 to 2147483647.

- For associative arrays with a string key, the length of the key and number of possible values depends on the `VARCHAR2` length limit in the type declaration, and the database character set.

Example 5–15 shows how to reference an element in a nested table.

Example 5–15 Referencing a Nested Table Element

```
DECLARE
  TYPE Roster IS TABLE OF VARCHAR2(15);
  names Roster := Roster('D Caruso', 'J Hamil', 'D Piro', 'R Singh');
  PROCEDURE verify_name(the_name VARCHAR2) IS
  BEGIN
    DBMS_OUTPUT.PUT_LINE(the_name);
  END;
BEGIN
  FOR i IN names.FIRST .. names.LAST
  LOOP
      IF names(i) = 'J Hamil' THEN
        DBMS_OUTPUT.PUT_LINE(names(i)); -- reference to nested table element
      END IF;
  END LOOP;
  verify_name(names(3));  -- procedure call with reference to element
END;
/
```

Example 5–16 shows how you can reference the elements of an associative array in a function call.

Example 5–16 Referencing an Element of an Associative Array

```
DECLARE
  TYPE sum_multiples IS TABLE OF PLS_INTEGER INDEX BY PLS_INTEGER;
  n  PLS_INTEGER := 5;   -- number of multiples to sum for display
  sn PLS_INTEGER := 10;  -- number of multiples to sum
  m  PLS_INTEGER := 3;   -- multiple
FUNCTION get_sum_multiples(multiple IN PLS_INTEGER, num IN PLS_INTEGER)
  RETURN sum_multiples IS
  s sum_multiples;
  BEGIN
      FOR i IN 1..num LOOP
        s(i) := multiple * ((i * (i + 1)) / 2) ; -- sum of multiples
      END LOOP;
    RETURN s;
  END get_sum_multiples;
BEGIN
-- call function to retrieve the element identified by subscript (key)
  DBMS_OUTPUT.PUT_LINE('Sum of the first ' || TO_CHAR(n) || ' multiples of ' ||
                TO_CHAR(m) || ' is ' || TO_CHAR(get_sum_multiples (m, sn)(n)));
END;
/
```

Assigning Collections

One collection can be assigned to another by an `INSERT`, `UPDATE`, `FETCH`, or `SELECT` statement, an assignment statement, or a subprogram call. You can assign the value of an expression to a specific element in a collection using the syntax:

`collection_name`(*`subscript`*) := *`expression`*;

where *expression* yields a value of the type specified for elements in the collection type definition.

You can use operators such as `SET`, `MULTISET UNION`, `MULTISET INTERSECT`, and `MULTISET EXCEPT` to transform nested tables as part of an assignment statement.

Assigning a value to a collection element can cause exceptions, such as:

- If the subscript is `NULL` or is not convertible to the right datatype, PL/SQL raises the predefined exception `VALUE_ERROR`. Usually, the subscript must be an integer. Associative arrays can also be declared to have `VARCHAR2` subscripts.
- If the subscript refers to an uninitialized element, PL/SQL raises `SUBSCRIPT_BEYOND_COUNT`.
- If the collection is atomically null, PL/SQL raises `COLLECTION_IS_NULL`.

For more information on collection exceptions, see "Avoiding Collection Exceptions" on page 5-27, Example 5–38 on page 5-27, and "Summary of Predefined PL/SQL Exceptions" on page 10-4.

Example 5–17 shows that collections must have the same datatype for an assignment to work. Having the same element type is not enough.

Example 5–17 Datatype Compatibility for Collection Assignment

```
DECLARE
   TYPE last_name_typ IS VARRAY(3) OF VARCHAR2(64);
   TYPE surname_typ IS VARRAY(3) OF VARCHAR2(64);
-- These first two variables have the same datatype.
   group1 last_name_typ := last_name_typ('Jones','Wong','Marceau');
   group2 last_name_typ := last_name_typ('Klein','Patsos','Singh');
-- This third variable has a similar declaration, but is not the same type.
   group3 surname_typ := surname_typ('Trevisi','Macleod','Marquez');
BEGIN
-- Allowed because they have the same datatype
   group1 := group2;
-- Not allowed because they have different datatypes
--   group3 := group2; -- raises an error
END;
/
```

If you assign an atomically null nested table or varray to a second nested table or varray, the second collection must be reinitialized, as shown in Example 5–18. In the same way, assigning the value `NULL` to a collection makes it atomically null.

Example 5–18 Assigning a Null Value to a Nested Table

```
DECLARE
   TYPE dnames_tab IS TABLE OF VARCHAR2(30);
-- This nested table has some values
   dept_names dnames_tab := dnames_tab('Shipping','Sales','Finance','Payroll');
-- This nested table is not initialized ("atomically null").
   empty_set dnames_tab;
BEGIN
-- At first, the initialized variable is not null.
   if dept_names IS NOT NULL THEN
      DBMS_OUTPUT.PUT_LINE('OK, at first dept_names is not null.');
   END IF;
-- Then we assign a null nested table to it.
   dept_names := empty_set;
-- Now it is null.
```

```
   if dept_names IS NULL THEN
      DBMS_OUTPUT.PUT_LINE('OK, now dept_names has become null.');
   END IF;
-- We must use another constructor to give it some values.
   dept_names := dnames_tab('Shipping','Sales','Finance','Payroll');
END;
/
```

Example 5–19 shows some of the ANSI-standard operators that you can apply to nested tables.

Example 5–19 Assigning Nested Tables with Set Operators

```
DECLARE
  TYPE nested_typ IS TABLE OF NUMBER;
  nt1 nested_typ := nested_typ(1,2,3);
  nt2 nested_typ := nested_typ(3,2,1);
  nt3 nested_typ := nested_typ(2,3,1,3);
  nt4 nested_typ := nested_typ(1,2,4);
  answer nested_typ;
-- The results might be in a different order than you expect.
-- Remember, you should not rely on the order of elements in nested tables.
  PROCEDURE print_nested_table(the_nt nested_typ) IS
     output VARCHAR2(128);
  BEGIN
     IF the_nt IS NULL THEN
        DBMS_OUTPUT.PUT_LINE('Results: <NULL>');
        RETURN;
     END IF;
     IF the_nt.COUNT = 0 THEN
        DBMS_OUTPUT.PUT_LINE('Results: empty set');
        RETURN;
     END IF;
     FOR i IN the_nt.FIRST .. the_nt.LAST
     LOOP
        output := output || the_nt(i) || ' ';
     END LOOP;
     DBMS_OUTPUT.PUT_LINE('Results: ' || output);
  END;
BEGIN
  answer := nt1 MULTISET UNION nt4; -- (1,2,3,1,2,4)
  print_nested_table(answer);
  answer := nt1 MULTISET UNION nt3; -- (1,2,3,2,3,1,3)
  print_nested_table(answer);
  answer := nt1 MULTISET UNION DISTINCT nt3; -- (1,2,3)
  print_nested_table(answer);
  answer := nt2 MULTISET INTERSECT nt3; -- (3,2,1)
  print_nested_table(answer);
  answer := nt2 MULTISET INTERSECT DISTINCT nt3; -- (3,2,1)
  print_nested_table(answer);
  answer := SET(nt3); -- (2,3,1)
  print_nested_table(answer);
  answer := nt3 MULTISET EXCEPT nt2; -- (3)
  print_nested_table(answer);
  answer := nt3 MULTISET EXCEPT DISTINCT nt2; -- ()
  print_nested_table(answer);
END;
/
```

Example 5–20 shows an assignment to a VARRAY of records with an assignment statement.

Example 5–20   Assigning Values to VARRAYs with Complex Datatypes

```
DECLARE
  TYPE emp_name_rec is RECORD (
    firstname    employees.first_name%TYPE,
    lastname     employees.last_name%TYPE,
    hiredate     employees.hire_date%TYPE
    );

-- Array type that can hold information 10 employees
   TYPE EmpList_arr IS VARRAY(10) OF emp_name_rec;
   SeniorSalespeople EmpList_arr;

-- Declare a cursor to select a subset of columns.
   CURSOR c1 IS SELECT first_name, last_name, hire_date FROM employees;
   Type NameSet IS TABLE OF c1%ROWTYPE;
   SeniorTen NameSet;
   EndCounter NUMBER := 10;

BEGIN
  SeniorSalespeople := EmpList_arr();
  SELECT first_name, last_name, hire_date BULK COLLECT INTO SeniorTen FROM
     employees WHERE job_id = 'SA_REP' ORDER BY hire_date;
  IF SeniorTen.LAST > 0 THEN
    IF SeniorTen.LAST < 10 THEN EndCounter := SeniorTen.LAST;
    END IF;
    FOR i in 1..EndCounter LOOP
      SeniorSalespeople.EXTEND(1);
      SeniorSalespeople(i) := SeniorTen(i);
      DBMS_OUTPUT.PUT_LINE(SeniorSalespeople(i).lastname || ', '
       || SeniorSalespeople(i).firstname || ', ' ||
       SeniorSalespeople(i).hiredate);
    END LOOP;
  END IF;
END;
/
```

Example 5–21 shows an assignment to a nested table of records with a `FETCH` statement.

Example 5–21   Assigning Values to Tables with Complex Datatypes

```
DECLARE
  TYPE emp_name_rec is RECORD (
    firstname    employees.first_name%TYPE,
    lastname     employees.last_name%TYPE,
    hiredate     employees.hire_date%TYPE
    );

-- Table type that can hold information about employees
   TYPE EmpList_tab IS TABLE OF emp_name_rec;
   SeniorSalespeople EmpList_tab;

-- Declare a cursor to select a subset of columns.
   CURSOR c1 IS SELECT first_name, last_name, hire_date FROM employees;
   EndCounter NUMBER := 10;
   TYPE EmpCurTyp IS REF CURSOR;
   emp_cv EmpCurTyp;

BEGIN
  OPEN emp_cv FOR SELECT first_name, last_name, hire_date FROM employees
```

```
     WHERE job_id = 'SA_REP' ORDER BY hire_date;

  FETCH emp_cv BULK COLLECT INTO SeniorSalespeople;
  CLOSE emp_cv;

-- for this example, display a maximum of ten employees
  IF SeniorSalespeople.LAST > 0 THEN
    IF SeniorSalespeople.LAST < 10 THEN EndCounter := SeniorSalespeople.LAST;
    END IF;
    FOR i in 1..EndCounter LOOP
      DBMS_OUTPUT.PUT_LINE(SeniorSalespeople(i).lastname || ', '
      || SeniorSalespeople(i).firstname || ', ' || SeniorSalespeople(i).hiredate);
    END LOOP;
  END IF;
END;
/
```

Comparing Collections

You can check whether a collection is null. Comparisons such as greater than, less than, and so on are not allowed. This restriction also applies to implicit comparisons. For example, collections cannot appear in a `DISTINCT`, `GROUP BY`, or `ORDER BY` list.

If you want to do such comparison operations, you must define your own notion of what it means for collections to be greater than, less than, and so on, and write one or more functions to examine the collections and their elements and return a true or false value.

For nested tables, you can check whether two nested table of the same declared type are equal or not equal, as shown in Example 5–23. You can also apply set operators (`CARDINALITY`, `MEMBER OF`, `IS A SET`, `IS EMPTY`) to check certain conditions within a nested table or between two nested tables, as shown in Example 5–24.

Because nested tables and varrays can be atomically null, they can be tested for nullity, as shown in Example 5–22.

Example 5–22   Checking if a Collection Is Null

```
DECLARE
  TYPE emp_name_rec is RECORD (
    firstname    employees.first_name%TYPE,
    lastname     employees.last_name%TYPE,
    hiredate     employees.hire_date%TYPE
    );
   TYPE staff IS TABLE OF emp_name_rec;
   members staff;
BEGIN
  -- Condition yields TRUE because we have not used a constructor.
   IF members IS NULL THEN
     DBMS_OUTPUT.PUT_LINE('NULL');
   ELSE
     DBMS_OUTPUT.PUT_LINE('Not NULL');
   END IF;
END;
/
```

Example 5–23 shows that nested tables can be compared for equality or inequality. They cannot be ordered, because there is no greater than or less than comparison.

Example 5–23 Comparing Two Nested Tables

```
DECLARE
   TYPE dnames_tab IS TABLE OF VARCHAR2(30);
   dept_names1 dnames_tab := dnames_tab('Shipping','Sales','Finance','Payroll');
   dept_names2 dnames_tab := dnames_tab('Sales','Finance','Shipping','Payroll');
   dept_names3 dnames_tab := dnames_tab('Sales','Finance','Payroll');
BEGIN
-- We can use = or !=, but not < or >.
-- Notice that these 2 are equal even though the members are in different order.
   IF dept_names1 = dept_names2 THEN
      DBMS_OUTPUT.PUT_LINE('dept_names1 and dept_names2 have the same members.');
   END IF;
   IF dept_names2 != dept_names3 THEN
      DBMS_OUTPUT.PUT_LINE('dept_names2 and dept_names3 have different members.');
   END IF;
END;
/
```

You can test certain properties of a nested table, or compare two nested tables, using ANSI-standard set operations, as shown in Example 5–24.

Example 5–24 Comparing Nested Tables with Set Operators

```
DECLARE
  TYPE nested_typ IS TABLE OF NUMBER;
  nt1 nested_typ := nested_typ(1,2,3);
  nt2 nested_typ := nested_typ(3,2,1);
  nt3 nested_typ := nested_typ(2,3,1,3);
  nt4 nested_typ := nested_typ(1,2,4);
  answer BOOLEAN;
  howmany NUMBER;
  PROCEDURE testify(truth BOOLEAN DEFAULT NULL, quantity NUMBER DEFAULT NULL) IS
  BEGIN
    IF truth IS NOT NULL THEN
      DBMS_OUTPUT.PUT_LINE(CASE truth WHEN TRUE THEN 'True' WHEN FALSE THEN
'False' END);
    END IF;
    IF quantity IS NOT NULL THEN
        DBMS_OUTPUT.PUT_LINE(quantity);
    END IF;
  END;
BEGIN
  answer := nt1 IN (nt2,nt3,nt4); -- true, nt1 matches nt2
  testify(truth => answer);
  answer := nt1 SUBMULTISET OF nt3; -- true, all elements match
  testify(truth => answer);
  answer := nt1 NOT SUBMULTISET OF nt4; -- also true
  testify(truth => answer);
  howmany := CARDINALITY(nt3); -- number of elements in nt3
  testify(quantity => howmany);
  howmany := CARDINALITY(SET(nt3)); -- number of distinct elements
  testify(quantity => howmany);
  answer := 4 MEMBER OF nt1; -- false, no element matches
  testify(truth => answer);
  answer := nt3 IS A SET; -- false, nt3 has duplicates
  testify(truth => answer);
  answer := nt3 IS NOT A SET; -- true, nt3 has duplicates
  testify(truth => answer);
  answer := nt1 IS EMPTY; -- false, nt1 has some members
  testify(truth => answer);
```

```
END;
/
```

Using Multilevel Collections

In addition to collections of scalar or object types, you can also create collections whose elements are collections. For example, you can create a nested table of varrays, a varray of varrays, a varray of nested tables, and so on.

When creating a nested table of nested tables as a column in SQL, check the syntax of the `CREATE TABLE` statement to see how to define the storage table.

Example 5–25, Example 5–26, and Example 5–27 are some examples showing the syntax and possibilities for multilevel collections. See also Example 12–17, "Using BULK COLLECT with Nested Tables" on page 12-11.

Example 5–25 Multilevel VARRAY

```
DECLARE
 TYPE t1 IS VARRAY(10) OF INTEGER;
 TYPE nt1 IS VARRAY(10) OF t1; -- multilevel varray type
 va t1 := t1(2,3,5);
-- initialize multilevel varray
 nva nt1 := nt1(va, t1(55,6,73), t1(2,4), va);
 i INTEGER;
 va1 t1;
BEGIN
 -- multilevel access
 i := nva(2)(3); -- i will get value 73
 DBMS_OUTPUT.PUT_LINE('I = ' || i);
 -- add a new varray element to nva
 nva.EXTEND;
-- replace inner varray elements
 nva(5) := t1(56, 32);
 nva(4) := t1(45,43,67,43345);
-- replace an inner integer element
 nva(4)(4) := 1; -- replaces 43345 with 1
-- add a new element to the 4th varray element
-- and store integer 89 into it.
 nva(4).EXTEND;
 nva(4)(5) := 89;
END;
/
```

Example 5–26 Multilevel Nested Table

```
DECLARE
 TYPE tb1 IS TABLE OF VARCHAR2(20);
 TYPE Ntb1 IS TABLE OF tb1; -- table of table elements
 TYPE Tv1 IS VARRAY(10) OF INTEGER;
 TYPE ntb2 IS TABLE OF tv1; -- table of varray elements
 vtb1 tb1 := tb1('one', 'three');
 vntb1 ntb1 := ntb1(vtb1);
 vntb2 ntb2 := ntb2(tv1(3,5), tv1(5,7,3));  -- table of varray elements
BEGIN
 vntb1.EXTEND;
 vntb1(2) := vntb1(1);
-- delete the first element in vntb1
 vntb1.DELETE(1);
```

```
-- delete the first string from the second table in the nested table
 vntb1(2).DELETE(1);
END;
/
```

Example 5–27 Multilevel Associative Array

```
DECLARE
 TYPE tb1 IS TABLE OF INTEGER INDEX BY PLS_INTEGER;
-- the following is index-by table of index-by tables
 TYPE ntb1 IS TABLE OF tb1 INDEX BY PLS_INTEGER;
 TYPE va1 IS VARRAY(10) OF VARCHAR2(20);
-- the following is index-by table of varray elements
 TYPE ntb2 IS TABLE OF va1 INDEX BY PLS_INTEGER;
 v1 va1 := va1('hello', 'world');
 v2 ntb1;
 v3 ntb2;
 v4 tb1;
 v5 tb1; -- empty table
BEGIN
 v4(1) := 34;
 v4(2) := 46456;
 v4(456) := 343;
 v2(23) := v4;
 v3(34) := va1(33, 456, 656, 343);
-- assign an empty table to v2(35) and try again
   v2(35) := v5;
   v2(35)(2) := 78; -- it works now
END;
/
```

Using Collection Methods

Collection methods make collections easier to use, and make your applications easier to maintain. These methods include `COUNT`, `DELETE`, `EXISTS`, `EXTEND`, `FIRST`, `LAST`, `LIMIT`, `NEXT`, `PRIOR`, and `TRIM`.

A collection method is a built-in function or procedure that operates on collections and is called using dot notation. The following apply to collection methods:

- Collection methods cannot be called from SQL statements.
- `EXTEND` and `TRIM` cannot be used with associative arrays.
- `EXISTS`, `COUNT`, `LIMIT`, `FIRST`, `LAST`, `PRIOR`, and `NEXT` are functions; `EXTEND`, `TRIM`, and `DELETE` are procedures.
- `EXISTS`, `PRIOR`, `NEXT`, `TRIM`, `EXTEND`, and `DELETE` take parameters corresponding to collection subscripts, which are usually integers but can also be strings for associative arrays.
- Only `EXISTS` can be applied to atomically null collections. If you apply another method to such collections, PL/SQL raises `COLLECTION_IS_NULL`.

For more information, see "Collection Methods" on page 13-20.

Checking If a Collection Element Exists (EXISTS Method)

`EXISTS(n)` returns `TRUE` if the *n*th element in a collection exists. Otherwise, `EXISTS(n)` returns `FALSE`. By combining `EXISTS` with `DELETE`, you can work with sparse nested tables. You can also use EXISTS to avoid referencing a nonexistent element, which raises an exception. When passed an out-of-range subscript, EXISTS returns FALSE instead of raising SUBSCRIPT_OUTSIDE_LIMIT.

Example 5–28 Checking Whether a Collection Element EXISTS

```
DECLARE
   TYPE NumList IS TABLE OF INTEGER;
   n NumList := NumList(1,3,5,7);
BEGIN
   n.DELETE(2); -- Delete the second element
   IF n.EXISTS(1) THEN
      DBMS_OUTPUT.PUT_LINE('OK, element #1 exists.');
   END IF;
   IF n.EXISTS(2) = FALSE THEN
      DBMS_OUTPUT.PUT_LINE('OK, element #2 has been deleted.');
   END IF;
   IF n.EXISTS(99) = FALSE THEN
      DBMS_OUTPUT.PUT_LINE('OK, element #99 does not exist at all.');
   END IF;
END;
/
```

Counting the Elements in a Collection (COUNT Method)

COUNT returns the number of elements that a collection currently contains.

Example 5–29 Counting Collection Elements With COUNT

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(2,4,6,8); -- Collection starts with 4 elements.
BEGIN
   DBMS_OUTPUT.PUT_LINE('There are ' || n.COUNT || ' elements in N.');
   n.EXTEND(3); -- Add 3 new elements at the end.
   DBMS_OUTPUT.PUT_LINE('Now there are ' || n.COUNT || ' elements in N.');
   n := NumList(86,99); -- Assign a completely new value with 2 elements.
   DBMS_OUTPUT.PUT_LINE('Now there are ' || n.COUNT || ' elements in N.');
   n.TRIM(2); -- Remove the last 2 elements, leaving none.
   DBMS_OUTPUT.PUT_LINE('Now there are ' || n.COUNT || ' elements in N.');
END;
/
```

COUNT is useful because the current size of a collection is not always known. For example, you can fetch a column of Oracle data into a nested table, where the number of elements depends on the size of the result set.

For varrays, COUNT always equals LAST. You can increase or decrease the size of a varray using the EXTEND and TRIM methods, so the value of COUNT can change, up to the value of the LIMIT method.

For nested tables, COUNT normally equals LAST. But, if you delete elements from the middle of a nested table, COUNT becomes smaller than LAST. When tallying elements, COUNT ignores deleted elements. Using DELETE with no parameters sets COUNT to 0.

Checking the Maximum Size of a Collection (LIMIT Method)

For nested tables and associative arrays, which have no declared size, LIMIT returns NULL. For varrays, LIMIT returns the maximum number of elements that a varray can contain. You specify this limit in the type definition, and can change it later with the TRIM and EXTEND methods.

Example 5–30 Checking the Maximum Size of a Collection With LIMIT

```
DECLARE
   TYPE dnames_var IS VARRAY(7) OF VARCHAR2(30);
   dept_names dnames_var := dnames_var('Shipping','Sales','Finance','Payroll');
BEGIN
   DBMS_OUTPUT.PUT_LINE('dept_names has ' || dept_names.COUNT
                        || ' elements now');
   DBMS_OUTPUT.PUT_LINE('dept_names''s type can hold a maximum of '
                         || dept_names.LIMIT || ' elements');
   DBMS_OUTPUT.PUT_LINE('The maximum number you can use with '
       || 'dept_names.EXTEND() is ' || (dept_names.LIMIT - dept_names.COUNT));
END;
/
```

Finding the First or Last Collection Element (FIRST and LAST Methods)

FIRST and LAST return the first and last (smallest and largest) index numbers in a collection that uses integer subscripts.

For an associative array with VARCHAR2 key values, the lowest and highest key values are returned. By default, the order is based on the binary values of the characters in the string. If the NLS_COMP initialization parameter is set to ANSI, the order is based on the locale-specific sort order specified by the NLS_SORT initialization parameter.

If the collection is empty, FIRST and LAST return NULL. If the collection contains only one element, FIRST and LAST return the same index value.

Example 5–31 shows how to use FIRST and LAST to iterate through the elements in a collection that has consecutive subscripts.

Example 5–31 Using FIRST and LAST With a Collection

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(1,3,5,7);
   counter INTEGER;
BEGIN
   DBMS_OUTPUT.PUT_LINE('N''s first subscript is ' || n.FIRST);
   DBMS_OUTPUT.PUT_LINE('N''s last subscript is ' || n.LAST);
-- When the subscripts are consecutive starting at 1,
-- it's simple to loop through them.
   FOR i IN n.FIRST .. n.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Element #' || i || ' = ' || n(i));
   END LOOP;
   n.DELETE(2); -- Delete second element.
-- When the subscripts have gaps or the collection might be uninitialized,
-- the loop logic is more extensive. We start at the first element, and
-- keep looking for the next element until there are no more.
   IF n IS NOT NULL THEN
      counter := n.FIRST;
      WHILE counter IS NOT NULL
      LOOP
         DBMS_OUTPUT.PUT_LINE('Element #' || counter || ' = ' || n(counter));
         counter := n.NEXT(counter);
      END LOOP;
   ELSE
```

```
      DBMS_OUTPUT.PUT_LINE('N is null, nothing to do.');
   END IF;
END;
/
```

For varrays, `FIRST` always returns 1 and `LAST` always equals `COUNT`.

For nested tables, normally `FIRST` returns 1 and `LAST` equals `COUNT`. But if you delete elements from the beginning of a nested table, `FIRST` returns a number larger than 1. If you delete elements from the middle of a nested table, `LAST` becomes larger than `COUNT`.

When scanning elements, `FIRST` and `LAST` ignore deleted elements.

Looping Through Collection Elements (PRIOR and NEXT Methods)

`PRIOR(n)` returns the index number that precedes index `n` in a collection. `NEXT(n)` returns the index number that succeeds index `n`. If `n` has no predecessor, `PRIOR(n)` returns `NULL`. If `n` has no successor, `NEXT(n)` returns `NULL`.

For associative arrays with `VARCHAR2` keys, these methods return the appropriate key value; ordering is based on the binary values of the characters in the string, unless the `NLS_COMP` initialization parameter is set to `ANSI`, in which case the ordering is based on the locale-specific sort order specified by the `NLS_SORT` initialization parameter.

These methods are more reliable than looping through a fixed set of subscript values, because elements might be inserted or deleted from the collection during the loop. This is especially true for associative arrays, where the subscripts might not be in consecutive order and so the sequence of subscripts might be (1,2,4,8,16) or ('A','E','I','O','U').

Example 5–32 Using PRIOR and NEXT to Access Collection Elements

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(1966,1971,1984,1989,1999);
BEGIN
   DBMS_OUTPUT.PUT_LINE('The element after #2 is #' || n.NEXT(2));
   DBMS_OUTPUT.PUT_LINE('The element before #2 is #' || n.PRIOR(2));
   n.DELETE(3); -- Delete an element to show how NEXT can handle gaps.
   DBMS_OUTPUT.PUT_LINE('Now the element after #2 is #' || n.NEXT(2));
   IF n.PRIOR(n.FIRST) IS NULL THEN
      DBMS_OUTPUT.PUT_LINE('Can''t get PRIOR of the first element or NEXT of the
last.');
   END IF;
END;
/
```

You can use `PRIOR` or `NEXT` to traverse collections indexed by any series of subscripts. Example 5–33 uses `NEXT` to traverse a nested table from which some elements have been deleted.

Example 5–33 Using NEXT to Access Elements of a Nested Table

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(1,3,5,7);
   counter INTEGER;
BEGIN
   n.DELETE(2); -- Delete second element.
```

```
-- When the subscripts have gaps, the loop logic is more extensive. We start at
-- the first element, and keep looking for the next element until there are no
more.
   counter := n.FIRST;
   WHILE counter IS NOT NULL
   LOOP
      DBMS_OUTPUT.PUT_LINE('Counting up: Element #' || counter || ' = ' ||
                           n(counter));
      counter := n.NEXT(counter);
   END LOOP;
-- Run the same loop in reverse order.
   counter := n.LAST;
   WHILE counter IS NOT NULL
   LOOP
      DBMS_OUTPUT.PUT_LINE('Counting down: Element #' || counter || ' = ' ||
                           n(counter));
      counter := n.PRIOR(counter);
   END LOOP;
END;
/
```

When traversing elements, `PRIOR` and `NEXT` skip over deleted elements.

Increasing the Size of a Collection (EXTEND Method)

To increase the size of a nested table or varray, use `EXTEND`.

This procedure has three forms:

- `EXTEND` appends one null element to a collection.
- `EXTEND(n)` appends `n` null elements to a collection.
- `EXTEND(n,i)` appends `n` copies of the *`i`*th element to a collection.

You cannot use `EXTEND` with index-by tables. You cannot use `EXTEND` to add elements to an uninitialized collection. If you impose the `NOT NULL` constraint on a `TABLE` or `VARRAY` type, you cannot apply the first two forms of `EXTEND` to collections of that type.

`EXTEND` operates on the internal size of a collection, which includes any deleted elements. This refers to deleted elements after using `DELETE(n)`, but not `DELETE` without parameters which completely removes all elements. If `EXTEND` encounters deleted elements, it includes them in its tally. PL/SQL keeps placeholders for deleted elements, so that you can re-create them by assigning new values.

Example 5–34 Using EXTEND to Increase the Size of a Collection

```
DECLARE
   TYPE NumList IS TABLE OF INTEGER;
   n NumList := NumList(2,4,6,8);
   x NumList := NumList(1,3);
   PROCEDURE print_numlist(the_list NumList) IS
      output VARCHAR2(128);
   BEGIN
      FOR i IN the_list.FIRST .. the_list.LAST
      LOOP
         output := output || NVL(TO_CHAR(the_list(i)),'NULL') || ' ';
      END LOOP;
      DBMS_OUTPUT.PUT_LINE(output);
   END;
BEGIN
```

```
   DBMS_OUTPUT.PUT_LINE('At first, N has ' || n.COUNT || ' elements.');
   n.EXTEND(5); -- Add 5 elements at the end.
   DBMS_OUTPUT.PUT_LINE('Now N has ' || n.COUNT || ' elements.');
-- Elements 5, 6, 7, 8, and 9 are all NULL.
   print_numlist(n);
   DBMS_OUTPUT.PUT_LINE('At first, X has ' || x.COUNT || ' elements.');
   x.EXTEND(4,2); -- Add 4 elements at the end.
   DBMS_OUTPUT.PUT_LINE('Now X has ' || x.COUNT || ' elements.');
-- Elements 3, 4, 5, and 6 are copies of element #2.
   print_numlist(x);
END;
/
```

When it includes deleted elements, the internal size of a nested table differs from the values returned by `COUNT` and `LAST`. This refers to deleted elements after using `DELETE(n)`, but not `DELETE` without parameters which completely removes all elements. For instance, if you initialize a nested table with five elements, then delete elements 2 and 5, the internal size is 5, `COUNT` returns 3, and `LAST` returns 4. All deleted elements, regardless of position, are treated alike.

Decreasing the Size of a Collection (TRIM Method)

This procedure has two forms:

- `TRIM` removes one element from the end of a collection.
- `TRIM(n)` removes `n` elements from the end of a collection.

If you want to remove all elements, use `DELETE` without parameters.

For example, this statement removes the last three elements from nested table `courses`:

Example 5–35 Using TRIM to Decrease the Size of a Collection

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(1,2,3,5,7,11);
   PROCEDURE print_numlist(the_list NumList) IS
      output VARCHAR2(128);
   BEGIN
      IF n.COUNT = 0 THEN
         DBMS_OUTPUT.PUT_LINE('No elements in collection.');
      ELSE
         FOR i IN the_list.FIRST .. the_list.LAST
         LOOP
            output := output || NVL(TO_CHAR(the_list(i)),'NULL') || ' ';
         END LOOP;
         DBMS_OUTPUT.PUT_LINE(output);
      END IF;
   END;
BEGIN
   print_numlist(n);
   n.TRIM(2); -- Remove last 2 elements.
   print_numlist(n);
   n.TRIM; -- Remove last element.
   print_numlist(n);
   n.TRIM(n.COUNT); -- Remove all remaining elements.
   print_numlist(n);
-- If too many elements are specified,
-- TRIM raises the exception SUBSCRIPT_BEYOND_COUNT.
```

```
   BEGIN
      n := NumList(1,2,3);
      n.TRIM(100);
      EXCEPTION
        WHEN SUBSCRIPT_BEYOND_COUNT THEN
          DBMS_OUTPUT.PUT_LINE('I guess there weren''t 100 elements that could be
trimmed.');
   END;
-- When elements are removed by DELETE, placeholders are left behind. TRIM counts
-- these placeholders as it removes elements from the end.
   n := NumList(1,2,3,4);
   n.DELETE(3);  -- delete element 3
-- At this point, n contains elements (1,2,4).
-- TRIMming the last 2 elements removes the 4 and the placeholder, not 4 and 2.
   n.TRIM(2);
   print_numlist(n);
END;
/
```

If `n` is too large, `TRIM(n)` raises `SUBSCRIPT_BEYOND_COUNT`.

`TRIM` operates on the internal size of a collection. If `TRIM` encounters deleted elements, it includes them in its tally. This refers to deleted elements after using `DELETE(n)`, but not `DELETE` without parameters which completely removes all elements.

Example 5–36   Using TRIM on Deleted Elements

```
DECLARE
   TYPE CourseList IS TABLE OF VARCHAR2(10);
   courses CourseList;
BEGIN
   courses := CourseList('Biol 4412', 'Psyc 3112', 'Anth 3001');
   courses.DELETE(courses.LAST);  -- delete element 3
   /* At this point, COUNT equals 2, the number of valid
      elements remaining. So, you might expect the next
      statement to empty the nested table by trimming
      elements 1 and 2. Instead, it trims valid element 2
      and deleted element 3 because TRIM includes deleted
      elements in its tally. */
   courses.TRIM(courses.COUNT);
   DBMS_OUTPUT.PUT_LINE(courses(1));  -- prints 'Biol 4412'
END;
/
```

In general, do not depend on the interaction between `TRIM` and `DELETE`. It is better to treat nested tables like fixed-size arrays and use only `DELETE`, or to treat them like stacks and use only `TRIM` and `EXTEND`.

Because PL/SQL does not keep placeholders for trimmed elements, you cannot replace a trimmed element simply by assigning it a new value.

Deleting Collection Elements (DELETE Method)

This procedure has various forms:

- `DELETE` with no parameters removes all elements from a collection, setting `COUNT` to 0.
- `DELETE(n)` removes the *n*th element from an associative array with a numeric key or a nested table. If the associative array has a string key, the element corresponding to the key value is deleted. If `n` is null, `DELETE(n)` does nothing.

- DELETE(m,n) removes all elements in the range m..n from an associative array or nested table. If m is larger than n or if m or n is null, DELETE(m,n) does nothing.

For example:

Example 5–37 Using the DELETE Method on a Collection

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n NumList := NumList(10,20,30,40,50,60,70,80,90,100);
   TYPE NickList IS TABLE OF VARCHAR2(64) INDEX BY VARCHAR2(32);
   nicknames NickList;
BEGIN
   n.DELETE(2);    -- deletes element 2
   n.DELETE(3,6);  -- deletes elements 3 through 6
   n.DELETE(7,7);  -- deletes element 7
   n.DELETE(6,3);  -- does nothing since 6 > 3
   n.DELETE;      -- deletes all elements
   nicknames('Bob') := 'Robert';
   nicknames('Buffy') := 'Esmerelda';
   nicknames('Chip') := 'Charles';
   nicknames('Dan') := 'Daniel';
   nicknames('Fluffy') := 'Ernestina';
   nicknames('Rob') := 'Robert';
-- following deletes element denoted by this key
   nicknames.DELETE('Chip');
-- following deletes elements with keys in this alphabetic range
   nicknames.DELETE('Buffy','Fluffy');
END;
/
```

Varrays always have consecutive subscripts, so you cannot delete individual elements except from the end by using the TRIM method. You can use DELETE without parameters to delete all elements.

If an element to be deleted does not exist, DELETE(n) simply skips it; no exception is raised. PL/SQL keeps placeholders for deleted elements, so you can replace a deleted element by assigning it a new value. This refers to deleted elements after using DELETE(n), but not DELETE without parameters which completely removes all elements.

DELETE lets you maintain sparse nested tables. You can store sparse nested tables in the database, just like any other nested tables.

The amount of memory allocated to a nested table can increase or decrease dynamically. As you delete elements, memory is freed page by page. If you delete the entire table, all the memory is freed.

Applying Methods to Collection Parameters

Within a subprogram, a collection parameter assumes the properties of the argument bound to it. You can apply the built-in collection methods (FIRST, LAST, COUNT, and so on) to such parameters. You can create general-purpose subprograms that take collection parameters and iterate through their elements, add or delete elements, and so on. For varray parameters, the value of LIMIT is always derived from the parameter type definition, regardless of the parameter mode.

Avoiding Collection Exceptions

Example 5–38 shows various collection exceptions that are predefined in PL/SQL. The example also includes notes on how to avoid the problems.

Example 5–38 Collection Exceptions

```
DECLARE
  TYPE WordList IS TABLE OF VARCHAR2(5);
  words WordList;
  err_msg VARCHAR2(100);
  PROCEDURE display_error IS
  BEGIN
    err_msg := SUBSTR(SQLERRM, 1, 100);
    DBMS_OUTPUT.PUT_LINE('Error message = ' || err_msg);
  END;
BEGIN
  BEGIN
    words(1) := 10; -- Raises COLLECTION_IS_NULL
--  A constructor has not been used yet.
--  Note: This exception applies to varrays and nested tables,
--  but not to associative arrays which do not need a constructor.
    EXCEPTION
      WHEN OTHERS THEN display_error;
  END;
--  After using a constructor, we can assign values to the elements.
    words := WordList('1st', '2nd', '3rd'); -- 3 elements created
--  Any expression that returns a VARCHAR2(5) is valid.
    words(3) := words(1) || '+2';
  BEGIN
    words(3) := 'longer than 5 characters'; -- Raises VALUE_ERROR
--  The assigned value is too long.
    EXCEPTION
      WHEN OTHERS THEN display_error;
  END;
  BEGIN
    words('B') := 'dunno'; -- Raises VALUE_ERROR
--  The subscript (B) of a nested table must be an integer.
--  Note: Also, NULL is not allowed as a subscript.
    EXCEPTION
      WHEN OTHERS THEN display_error;
  END;
  BEGIN
    words(0) := 'zero'; -- Raises SUBSCRIPT_OUTSIDE_LIMIT
--  Subscript 0 is outside the allowed subscript range.
    EXCEPTION
      WHEN OTHERS THEN display_error;
  END;
  BEGIN
    words(4) := 'maybe'; -- Raises SUBSCRIPT_BEYOND_COUNT
--  The subscript (4) exceeds the number of elements in the table.
--  To add new elements, call the EXTEND method first.
    EXCEPTION
      WHEN OTHERS THEN display_error;
  END;
  BEGIN
    words.DELETE(1);
    IF words(1) = 'First' THEN NULL; END IF; -- Raises NO_DATA_FOUND
--  The element with subcript (1) has been deleted.
    EXCEPTION
```

```
      WHEN OTHERS THEN display_error;
  END;
END;
/
```

Execution continues in Example 5–38 because the raised exceptions are handled in sub-blocks. See "Continuing after an Exception Is Raised" on page 10-15. For information about the use of SQLERRM with exception handling, see "Retrieving the Error Code and Error Message: SQLCODE and SQLERRM" on page 10-14.

The following list summarizes when a given exception is raised. See also "Summary of Predefined PL/SQL Exceptions" on page 10-4.

Collection Exception	**Raised when...**
`COLLECTION_IS_NULL`	you try to operate on an atomically null collection.
`NO_DATA_FOUND`	a subscript designates an element that was deleted, or a nonexistent element of an associative array.
`SUBSCRIPT_BEYOND_COUNT`	a subscript exceeds the number of elements in a collection.
`SUBSCRIPT_OUTSIDE_LIMIT`	a subscript is outside the allowed range.
`VALUE_ERROR`	a subscript is null or not convertible to the key type. This exception might occur if the key is defined as a `PLS_INTEGER` range, and the subscript is outside this range.

In some cases, you can pass invalid subscripts to a method without raising an exception. For instance, when you pass a null subscript to `DELETE(n)`, it does nothing. You can replace deleted elements by assigning values to them, without raising `NO_DATA_FOUND`. This refers to deleted elements after using `DELETE(n)`, but not `DELETE` without parameters which completely removes all elements. For example:

Example 5–39 How Invalid Subscripts are Handled With DELETE(n)

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   nums NumList := NumList(10,20,30);  -- initialize table
BEGIN
   nums.DELETE(-1);  -- does not raise SUBSCRIPT_OUTSIDE_LIMIT
   nums.DELETE(3);   -- delete 3rd element
   DBMS_OUTPUT.PUT_LINE(nums.COUNT);  -- prints 2
   nums(3) := 30;    -- allowed; does not raise NO_DATA_FOUND
   DBMS_OUTPUT.PUT_LINE(nums.COUNT);  -- prints 3
END;
/
```

Packaged collection types and local collection types are never compatible. For example, suppose you want to call the following packaged procedure:

Example 5–40 Incompatibility Between Package and Local Collection Types

```
CREATE PACKAGE pkg AS
   TYPE NumList IS TABLE OF NUMBER;
   PROCEDURE print_numlist (nums NumList);
END pkg;
/
CREATE PACKAGE BODY pkg AS
  PROCEDURE print_numlist (nums NumList) IS
  BEGIN
    FOR i IN nums.FIRST..nums.LAST LOOP
      DBMS_OUTPUT.PUT_LINE(nums(i));
    END LOOP;
  END;
END pkg;
/

DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   n1 pkg.NumList := pkg.NumList(2,4); -- type from the package.
   n2 NumList := NumList(6,8);         -- local type.
BEGIN
   pkg.print_numlist(n1); -- type from pkg is legal
-- The packaged procedure cannot accept a value of the local type (n2)
-- pkg.print_numlist(n2);  -- Causes a compilation error.
END;
/
```

The second procedure call fails, because the packaged and local VARRAY types are incompatible despite their identical definitions.

Defining and Declaring Records

To create records, you define a RECORD type, then declare records of that type. You can also create or find a table, view, or PL/SQL cursor with the values you want, and use the %ROWTYPE attribute to create a matching record.

You can define RECORD types in the declarative part of any PL/SQL block, subprogram, or package. When you define your own RECORD type, you can specify a NOT NULL constraint on fields, or give them default values. See "Record Definition" on page 13-95.

Example 5–42 and Example 5–42 illustrate record type declarations.

Example 5–41   Declaring and Initializing a Simple Record Type

```
DECLARE
   TYPE DeptRecTyp IS RECORD (
      deptid NUMBER(4) NOT NULL := 99,
      dname  departments.department_name%TYPE,
      loc    departments.location_id%TYPE,
      region regions%ROWTYPE );
   dept_rec DeptRecTyp;
BEGIN
   dept_rec.dname := 'PURCHASING';
END;
/
```

Example 5–42   Declaring and Initializing Record Types

```
DECLARE
-- Declare a record type with 3 fields.
  TYPE rec1_t IS RECORD (field1 VARCHAR2(16), field2 NUMBER, field3 DATE);
-- For any fields declared NOT NULL, we must supply a default value.
  TYPE rec2_t IS RECORD (id INTEGER NOT NULL := -1,
  name VARCHAR2(64) NOT NULL := '[anonymous]');
-- Declare record variables of the types declared
  rec1 rec1_t;
  rec2 rec2_t;
-- Declare a record variable that can hold a row from the EMPLOYEES table.
-- The fields of the record automatically match the names and
-- types of the columns.
-- Don't need a TYPE declaration in this case.
  rec3 employees%ROWTYPE;
-- Or we can mix fields that are table columns with user-defined fields.
  TYPE rec4_t IS RECORD (first_name employees.first_name%TYPE,
                         last_name employees.last_name%TYPE,
                         rating NUMBER);
  rec4 rec4_t;
BEGIN
-- Read and write fields using dot notation
  rec1.field1 := 'Yesterday';
  rec1.field2 := 65;
  rec1.field3 := TRUNC(SYSDATE-1);
-- We didn't fill in the name field, so it takes the default value declared
  DBMS_OUTPUT.PUT_LINE(rec2.name);
END;
/
```

To store a record in the database, you can specify it in an `INSERT` or `UPDATE` statement, if its fields match the columns in the table:

You can use `%TYPE` to specify a field type corresponding to a table column type. Your code keeps working even if the column type is changed (for example, to increase the length of a `VARCHAR2` or the precision of a `NUMBER`). Example 5–43 defines `RECORD` types to hold information about a department:

Example 5–43   Using %ROWTYPE to Declare a Record

```
DECLARE
-- Best: use %ROWTYPE instead of specifying each column.
-- Use <cursor>%ROWTYPE instead of <table>%ROWTYPE because
-- we only want some columns.
-- Declaring the cursor doesn't run the query, so no performance hit.
   CURSOR c1 IS SELECT department_id, department_name, location_id
      FROM departments;
   rec1 c1%ROWTYPE;
-- Use <column>%TYPE in field declarations to avoid problems if
-- the column types change.
   TYPE DeptRec2 IS RECORD (dept_id   departments.department_id%TYPE,
                            dept_name departments.department_name%TYPE,
                            dept_loc departments.location_id%TYPE);
   rec2 DeptRec2;
-- Final technique, writing out each field name and specifying the type directly,
-- is clumsy and unmaintainable for working with table data.
-- Use only for all-PL/SQL code.
   TYPE DeptRec3 IS RECORD (dept_id NUMBER,
                            dept_name VARCHAR2(14),
                            dept_loc VARCHAR2(13));
   rec3 DeptRec3;
BEGIN
   NULL;
END;
/
```

PL/SQL lets you define records that contain objects, collections, and other records (called nested records). However, records cannot be attributes of object types.

Using Records as Procedure Parameters and Function Return Values

Records are easy to process using stored procedures because you can pass just one parameter, instead of a separate parameter for each field. For example, you might fetch a table row from the `EMPLOYEES` table into a record, then pass that row as a parameter to a function that computed that employee's vacation allowance or some other abstract value. The function could access all the information about that employee by referring to the fields in the record.

The next example shows how to return a record from a function. To make the record type visible across multiple stored functions and stored procedures, declare the record type in a package specification.

Example 5–44 Returning a Record from a Function

```
DECLARE
   TYPE EmpRecTyp IS RECORD (
     emp_id       NUMBER(6),
     salary       NUMBER(8,2));
   CURSOR desc_salary RETURN EmpRecTyp IS
      SELECT employee_id, salary FROM employees ORDER BY salary DESC;
   emp_rec     EmpRecTyp;
   FUNCTION nth_highest_salary (n INTEGER) RETURN EmpRecTyp IS
   BEGIN
      OPEN desc_salary;
      FOR i IN 1..n LOOP
         FETCH desc_salary INTO emp_rec;
      END LOOP;
      CLOSE desc_salary;
      RETURN emp_rec;
   END nth_highest_salary;
BEGIN
   NULL;
END;
/
```

Like scalar variables, user-defined records can be declared as the formal parameters of procedures and functions:

Example 5–45 Using a Record as Parameter to a Procedure

```
DECLARE
   TYPE EmpRecTyp IS RECORD (
      emp_id       NUMBER(6),
      emp_sal      NUMBER(8,2) );
   PROCEDURE raise_salary (emp_info EmpRecTyp) IS
   BEGIN
      UPDATE employees SET salary = salary + salary * .10
             WHERE employee_id = emp_info.emp_id;
   END raise_salary;
BEGIN
   NULL;
END;
/
```

You can declare and reference nested records. That is, a record can be the component of another record.

Example 5–46 Declaring a Nested Record

```
DECLARE
```

```
   TYPE TimeTyp IS RECORD ( minutes SMALLINT, hours SMALLINT );
   TYPE MeetingTyp IS RECORD (
      day     DATE,
      time_of TimeTyp,             -- nested record
      dept    departments%ROWTYPE, -- nested record representing a table row
      place   VARCHAR2(20),
      purpose VARCHAR2(50) );
   meeting MeetingTyp;
   seminar MeetingTyp;
BEGIN
-- you can assign one nested record to another if they are of the same datatype
   seminar.time_of := meeting.time_of;
END;
/
```

Such assignments are allowed even if the containing records have different datatypes.

Assigning Values to Records

To set all the fields in a record to default values, assign to it an uninitialized record of the same type, as shown in Example 5–47.

Example 5–47 Assigning Default Values to a Record

```
DECLARE
   TYPE RecordTyp IS RECORD (field1 NUMBER,
                             field2 VARCHAR2(32) DEFAULT 'something');
   rec1 RecordTyp;
   rec2 RecordTyp;
BEGIN
-- At first, rec1 has the values we assign.
   rec1.field1 := 100; rec1.field2 := 'something else';
-- Assigning an empty record to rec1 resets fields to their default values.
-- Field1 is NULL and field2 is 'something' due to the DEFAULT clause
   rec1 := rec2;
   DBMS_OUTPUT.PUT_LINE('Field1 = ' || NVL(TO_CHAR(rec1.field1),'<NULL>') || ',
                         field2 = ' || rec1.field2);
END;
/
```

You can assign a value to a field in a record using an assignment statement with dot notation:

```
emp_info.last_name := 'Fields';
```

Note that values are assigned separately to each field of a record in Example 5–47. You cannot assign a list of values to a record using an assignment statement. There is no constructor-like notation for records.

You can assign values to all fields at once only if you assign a record to another record with the same datatype. Having fields that match exactly is not enough, as shown in Example 5–48.

Example 5–48 Assigning All the Fields of a Record in One Statement

```
DECLARE
-- Two identical type declarations.
   TYPE DeptRec1 IS RECORD ( dept_num  NUMBER(2), dept_name VARCHAR2(14));
   TYPE DeptRec2 IS RECORD ( dept_num  NUMBER(2), dept_name VARCHAR2(14));
   dept1_info DeptRec1;
   dept2_info DeptRec2;
   dept3_info DeptRec2;
BEGIN
-- Not allowed; different datatypes, even though fields are the same.
--      dept1_info := dept2_info;
-- This assignment is OK because the records have the same type.
   dept2_info := dept3_info;
END;
/
```

You can assign a %ROWTYPE record to a user-defined record if their fields match in number and order, and corresponding fields have the same datatypes:

```
DECLARE
   TYPE RecordTyp IS RECORD (last employees.last_name%TYPE,
                             id employees.employee_id%TYPE);
   CURSOR c1 IS SELECT last_name, employee_id FROM employees;
-- Rec1 and rec2 have different types. But because rec2 is based on a %ROWTYPE,
-- we can assign is to rec1 as long as they have the right number of fields and
-- the fields have the right datatypes.
   rec1 RecordTyp;
   rec2 c1%ROWTYPE;
BEGIN
   SELECT last_name, employee_id INTO rec2 FROM employees WHERE ROWNUM < 2;
   rec1 := rec2;
   DBMS_OUTPUT.PUT_LINE('Employee #' || rec1.id || ' = ' || rec1.last);
END;
/
```

You can also use the SELECT or FETCH statement to fetch column values into a record. The columns in the select-list must appear in the same order as the fields in your record.

Example 5–49 Using SELECT INTO to Assign Values in a Record

```
DECLARE
   TYPE RecordTyp IS RECORD (last employees.last_name%TYPE,
                             id employees.employee_id%TYPE);
   rec1 RecordTyp;
BEGIN
   SELECT last_name, employee_id INTO rec1 FROM employees WHERE ROWNUM < 2;
   DBMS_OUTPUT.PUT_LINE('Employee #' || rec1.id || ' = ' || rec1.last);
END;
/
```

Comparing Records

Records cannot be tested for nullity, or compared for equality, or inequality. If you want to make such comparisons, write your own function that accepts two records as parameters and does the appropriate checks or comparisons on the corresponding fields.

Inserting PL/SQL Records into the Database

A PL/SQL-only extension of the INSERT statement lets you insert records into database rows, using a single variable of type RECORD or %ROWTYPE in the VALUES clause instead of a list of fields. That makes your code more readable and maintainable.

If you issue the INSERT through the FORALL statement, you can insert values from an entire collection of records. The number of fields in the record must equal the number of columns listed in the INTO clause, and corresponding fields and columns must have compatible datatypes. To make sure the record is compatible with the table, you might find it most convenient to declare the variable as the type *table_name*%ROWTYPE.

Example 5–50 declares a record variable using a %ROWTYPE qualifier. You can insert this variable without specifying a column list. The %ROWTYPE declaration ensures that the record attributes have exactly the same names and types as the table columns.

Example 5–50 Inserting a PL/SQL Record Using %ROWTYPE

```
DECLARE
   dept_info departments%ROWTYPE;
BEGIN
-- department_id, department_name, and location_id are the table columns
-- The record picks up these names from the %ROWTYPE
  dept_info.department_id := 300;
  dept_info.department_name := 'Personnel';
  dept_info.location_id := 1700;
-- Using the %ROWTYPE means we can leave out the column list
-- (department_id, department_name, and location_id) from the INSERT statement
  INSERT INTO departments VALUES dept_info;
END;
/
```

Updating the Database with PL/SQL Record Values

A PL/SQL-only extension of the UPDATE statement lets you update database rows using a single variable of type RECORD or %ROWTYPE on the right side of the SET clause, instead of a list of fields.

If you issue the UPDATE through the FORALL statement, you can update a set of rows using values from an entire collection of records. Also with an UPDATE statement, you can specify a record in the RETURNING clause to retrieve new values into a record. If you issue the UPDATE through the FORALL statement, you can retrieve new values from a set of updated rows into a collection of records.

The number of fields in the record must equal the number of columns listed in the SET clause, and corresponding fields and columns must have compatible datatypes.

You can use the keyword ROW to represent an entire row, as shown in Example 5–51.

Example 5–51 Updating a Row Using a Record

```
DECLARE
   dept_info departments%ROWTYPE;
BEGIN
-- department_id, department_name, and location_id are the table columns
-- The record picks up these names from the %ROWTYPE.
  dept_info.department_id := 300;
  dept_info.department_name := 'Personnel';
  dept_info.location_id := 1700;
-- The fields of a %ROWTYPE can completely replace the table columns
-- The row will have values for the filled-in columns, and null
-- for any other columns
   UPDATE departments SET ROW = dept_info WHERE department_id = 300;
END;
/
```

The keyword ROW is allowed only on the left side of a SET clause. The argument to SET ROW must be a real PL/SQL record, not a subquery that returns a single row. The record can also contain collections or objects.

The INSERT, UPDATE, and DELETE statements can include a RETURNING clause, which returns column values from the affected row into a PL/SQL record variable. This eliminates the need to SELECT the row after an insert or update, or before a delete.

By default, you can use this clause only when operating on exactly one row. When you use bulk SQL, you can use the form RETURNING BULK COLLECT INTO to store the results in one or more collections.

Example 5–52 updates the salary of an employee and retrieves the employee's name, job title, and new salary into a record variable.

Example 5–52 Using the RETURNING Clause with a Record

```
DECLARE
   TYPE EmpRec IS RECORD (last_name   employees.last_name%TYPE,
                          salary      employees.salary%TYPE);
   emp_info EmpRec;
   emp_id   NUMBER := 100;
BEGIN
   UPDATE employees SET salary = salary * 1.1 WHERE employee_id = emp_id
      RETURNING last_name, salary INTO emp_info;
   DBMS_OUTPUT.PUT_LINE('Just gave a raise to ' || emp_info.last_name ||
      ', who now makes ' || emp_info.salary);
   ROLLBACK;
END;
/
```

Restrictions on Record Inserts and Updates

Currently, the following restrictions apply to record inserts/updates:

- Record variables are allowed only in the following places:
  - On the right side of the SET clause in an UPDATE statement
  - In the VALUES clause of an INSERT statement
  - In the INTO subclause of a RETURNING clause

  Record variables are not allowed in a SELECT list, WHERE clause, GROUP BY clause, or ORDER BY clause.
- The keyword ROW is allowed only on the left side of a SET clause. Also, you cannot use ROW with a subquery.
- In an UPDATE statement, only one SET clause is allowed if ROW is used.
- If the VALUES clause of an INSERT statement contains a record variable, no other variable or value is allowed in the clause.
- If the INTO subclause of a RETURNING clause contains a record variable, no other variable or value is allowed in the subclause.
- The following are not supported:
  - Nested record types
  - Functions that return a record
  - Record inserts and updates using the EXECUTE IMMEDIATE statement.

Querying Data into Collections of Records

You can use the BULK COLLECT clause with a SELECT INTO or FETCH statement to retrieve a set of rows into a collection of records.

Example 5–53 Using BULK COLLECT With a SELECT INTO Statement

```
DECLARE
   TYPE EmployeeSet IS TABLE OF employees%ROWTYPE;
   underpaid EmployeeSet; -- Holds set of rows from EMPLOYEES table.
   CURSOR c1 IS SELECT first_name, last_name FROM employees;
   TYPE NameSet IS TABLE OF c1%ROWTYPE;
   some_names NameSet; -- Holds set of partial rows from EMPLOYEES table.
BEGIN
-- With one query, we bring all the relevant data into the collection of records.
   SELECT * BULK COLLECT INTO underpaid FROM employees
      WHERE salary < 5000 ORDER BY salary DESC;
-- Now we can process the data by examining the collection, or passing it to
-- a separate procedure, instead of writing a loop to FETCH each row.
   DBMS_OUTPUT.PUT_LINE(underpaid.COUNT || ' people make less than 5000.');
   FOR i IN underpaid.FIRST .. underpaid.LAST
   LOOP
     DBMS_OUTPUT.PUT_LINE(underpaid(i).last_name || ' makes ' ||
                          underpaid(i).salary);
   END LOOP;
-- We can also bring in just some of the table columns.
-- Here we get the first and last names of 10 arbitrary employees.
   SELECT first_name, last_name BULK COLLECT INTO some_names FROM employees
      WHERE ROWNUM < 11;
   FOR i IN some_names.FIRST .. some_names.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Employee = ' || some_names(i).first_name || ' ' ||
some_names(i).last_name);
   END LOOP;
END;
/
```

6

Performing SQL Operations from PL/SQL

This chapter shows how PL/SQL supports the SQL commands, functions, and operators that let you manipulate Oracle data.

This chapter contains these topics:

- Overview of SQL Support in PL/SQL
- Managing Cursors in PL/SQL
- Querying Data with PL/SQL
- Using Subqueries
- Using Cursor Variables (REF CURSORs)
- Using Cursor Expressions
- Overview of Transaction Processing in PL/SQL
- Doing Independent Units of Work with Autonomous Transactions

Overview of SQL Support in PL/SQL

By extending SQL, PL/SQL offers a unique combination of power and ease of use. You can manipulate Oracle data flexibly and safely because PL/SQL fully supports all SQL data manipulation statements (except `EXPLAIN PLAN`), transaction control statements, functions, pseudocolumns, and operators. PL/SQL also conforms to the current ANSI/ISO SQL standard.

In addition to static SQL discussed in this chapter, PL/SQL also supports dynamic SQL, which enables you to execute SQL data definition, data control, and session control statements dynamically. See Chapter 7, "Performing SQL Operations with Native Dynamic SQL".

Data Manipulation

To manipulate Oracle data you can include DML operations, such as `INSERT`, `UPDATE`, and `DELETE` statements, directly in PL/SQL programs, without any special notation, as shown in Example 6–1. You can also include the SQL `COMMIT` statement directly in a PL/SQL program; see "Overview of Transaction Processing in PL/SQL" on page 6-30. See also `COMMIT` in the *Oracle Database SQL Reference*.

Example 6–1 Data Manipulation With PL/SQL

```
CREATE TABLE employees_temp AS SELECT employee_id, first_name, last_name
       FROM employees;
DECLARE
```

```
  emp_id          employees_temp.employee_id%TYPE;
  emp_first_name  employees_temp.first_name%TYPE;
  emp_last_name   employees_temp.last_name%TYPE;
BEGIN
   INSERT INTO employees_temp VALUES(299, 'Bob', 'Henry');
   UPDATE employees_temp SET first_name = 'Robert' WHERE employee_id = 299;
   DELETE FROM employees_temp WHERE employee_id = 299
     RETURNING first_name, last_name INTO emp_first_name, emp_last_name;
   COMMIT;
   DBMS_OUTPUT.PUT_LINE( emp_first_name  || ' ' || emp_last_name);
END;
/
```

To find out how many rows are affected by DML statements, you can check the value of `SQL%ROWCOUNT` as shown in Example 6–2.

Example 6–2 Checking SQL%ROWCOUNT After an UPDATE

```
CREATE TABLE employees_temp AS SELECT * FROM employees;
BEGIN
  UPDATE employees_temp SET salary = salary * 1.05 WHERE salary < 5000;
  DBMS_OUTPUT.PUT_LINE('Updated ' || SQL%ROWCOUNT || ' salaries.');
END;
/
```

Wherever you would use literal values, or bind variables in some other programming language, you can directly substitute PL/SQL variables as shown in Example 6–3.

Example 6–3 Substituting PL/SQL Variables

```
CREATE TABLE employees_temp AS SELECT first_name, last_name FROM employees;
DECLARE
   x VARCHAR2(20) := 'my_first_name';
   y VARCHAR2(25) := 'my_last_name';
BEGIN
   INSERT INTO employees_temp VALUES(x, y);
   UPDATE employees_temp SET last_name = x WHERE first_name = y;
   DELETE FROM employees_temp WHERE first_name = x;
   COMMIT;
END;
/
```

With this notation, you can use variables in place of values in the `WHERE` clause. To use variables in place of table names, column names, and so on, requires the `EXECUTE IMMEDIATE` statement that is explained in "Using the EXECUTE IMMEDIATE Statement in PL/SQL" on page 7-2.

For information on the use of PL/SQL records with SQL to update and insert data, see "Inserting PL/SQL Records into the Database" on page 5-33 and "Updating the Database with PL/SQL Record Values" on page 5-34.

For additional information on assigning values to PL/SQL variables, see "Assigning a SQL Query Result to a PL/SQL Variable" on page 2-19.

Note: When issuing a data manipulation (DML) statement in PL/SQL, there are some situations when the value of a variable is undefined after the statement is executed. These include:

- If a `FETCH` or `SELECT` statement raises any exception, then the values of the define variables after that statement are undefined.
- If a DML statement affects zero rows, the values of the `OUT` binds after the DML executes are undefined. This does not apply to a `BULK` or multirow operation.

Transaction Control

Oracle is transaction oriented; that is, Oracle uses transactions to ensure data integrity. A transaction is a series of SQL data manipulation statements that does a logical unit of work. For example, two `UPDATE` statements might credit one bank account and debit another. It is important not to allow one operation to succeed while the other fails.

At the end of a transaction that makes database changes, Oracle makes all the changes permanent or undoes them all. If your program fails in the middle of a transaction, Oracle detects the error and rolls back the transaction, restoring the database to its former state.

You use the `COMMIT`, `ROLLBACK`, `SAVEPOINT`, and `SET TRANSACTION` commands to control transactions. `COMMIT` makes permanent any database changes made during the current transaction. `ROLLBACK` ends the current transaction and undoes any changes made since the transaction began. `SAVEPOINT` marks the current point in the processing of a transaction. Used with `ROLLBACK`, `SAVEPOINT` undoes part of a transaction. `SET TRANSACTION` sets transaction properties such as read-write access and isolation level. See "Overview of Transaction Processing in PL/SQL" on page 6-30.

SQL Functions

Example 6–4 shows some queries that call SQL functions.

Example 6–4 Calling the SQL COUNT Function in PL/SQL

```
DECLARE
  job_count NUMBER;
  emp_count NUMBER;
BEGIN
  SELECT COUNT(DISTINCT job_id) INTO job_count FROM employees;
  SELECT COUNT(*) INTO emp_count FROM employees;
END;
/
```

SQL Pseudocolumns

PL/SQL recognizes the SQL pseudocolumns `CURRVAL`, `LEVEL`, `NEXTVAL`, `ROWID`, and `ROWNUM`. However, there are limitations on the use of pseudocolumns, including the restriction on the use of some pseudocolumns in assignments or conditional tests. For additional information, including restrictions, on the use of SQL pseudocolumns, see *Oracle Database SQL Reference*.

CURRVAL and NEXTVAL

A sequence is a schema object that generates sequential numbers. When you create a sequence, you can specify its initial value and an increment. `CURRVAL` returns the current value in a specified sequence. Before you can reference `CURRVAL` in a session, you must use `NEXTVAL` to generate a number. A reference to `NEXTVAL` stores the current sequence number in `CURRVAL`. `NEXTVAL` increments the sequence and returns the next value. To get the current or next value in a sequence, use dot notation:

```
sequence_name.CURRVAL
sequence_name.NEXTVAL
```

Each time you reference the `NEXTVAL` value of a sequence, the sequence is incremented immediately and permanently, whether you commit or roll back the transaction.

After creating a sequence, you can use it to generate unique sequence numbers for transaction processing. You can use `CURRVAL` and `NEXTVAL` only in a `SELECT` list, the `VALUES` clause, and the `SET` clause. Example 6–5 shows how to generate a new sequence number and refer to that same number in more than one statement.

Example 6–5 Using CURRVAL and NEXTVAL

```
CREATE TABLE employees_temp AS SELECT employee_id, first_name, last_name
  FROM employees;
CREATE TABLE employees_temp2 AS SELECT employee_id, first_name, last_name
  FROM employees;

DECLARE
   seq_value   NUMBER;
BEGIN
-- Display initial value of NEXTVAL
-- This is invalid: seq_value := employees_seq.NEXTVAL;
   SELECT employees_seq.NEXTVAL INTO seq_value FROM dual;
   DBMS_OUTPUT.PUT_LINE ('Initial sequence value: ' || TO_CHAR(seq_value));
-- The NEXTVAL value is the same no matter what table you select from
-- You usually use NEXTVAL to create unique numbers when inserting data.
   INSERT INTO employees_temp VALUES (employees_seq.NEXTVAL, 'Lynette', 'Smith');
-- If you need to store the same value somewhere else, you use CURRVAL
   INSERT INTO employees_temp2 VALUES (employees_seq.CURRVAL, 'Morgan', 'Smith');
-- Because NEXTVAL values might be referenced by different users and
-- applications, and some NEXTVAL values might not be stored in the
-- database, there might be gaps in the sequence
-- The following uses the stored value of the CURRVAL in seq_value to specify
-- the record to delete because CURRVAL (or NEXTVAL) cannot used in a WHERE clause
-- This is invalid: WHERE employee_id = employees_seq.CURRVAL;
   SELECT employees_seq.CURRVAL INTO seq_value FROM dual;
   DELETE FROM employees_temp2 WHERE employee_id = seq_value;
-- The following udpates the employee_id with NEXTVAL for the specified record
   UPDATE employees_temp SET employee_id = employees_seq.NEXTVAL
     WHERE first_name = 'Lynette' AND last_name = 'Smith';
-- Display end value of CURRVAL
   SELECT employees_seq.CURRVAL INTO seq_value FROM dual;
   DBMS_OUTPUT.PUT_LINE ('Ending sequence value: ' || TO_CHAR(seq_value));
END;
/
```

LEVEL

You use LEVEL with the SELECT CONNECT BY statement to organize rows from a database table into a tree structure. You might use sequence numbers to give each row a unique identifier, and refer to those identifiers from other rows to set up parent-child relationships. LEVEL returns the level number of a node in a tree structure. The root is level 1, children of the root are level 2, grandchildren are level 3, and so on.

In the START WITH clause, you specify a condition that identifies the root of the tree. You specify the direction in which the query traverses the tree (down from the root or up from the branches) with the PRIOR operator.

ROWID

ROWID returns the rowid (binary address) of a row in a database table. You can use variables of type UROWID to store rowids in a readable format.

When you select or fetch a physical rowid into a UROWID variable, you can use the function ROWIDTOCHAR, which converts the binary value to a character string. You can compare the UROWID variable to the ROWID pseudocolumn in the WHERE clause of an UPDATE or DELETE statement to identify the latest row fetched from a cursor. For an example, see "Fetching Across Commits" on page 6-35.

ROWNUM

ROWNUM returns a number indicating the order in which a row was selected from a table. The first row selected has a ROWNUM of 1, the second row has a ROWNUM of 2, and so on. If a SELECT statement includes an ORDER BY clause, ROWNUMs are assigned to the retrieved rows before the sort is done; use a subselect to get the first *n* sorted rows. The value of ROWNUM increases only when a row is retrieved, so the only meaningful uses of ROWNUM in a WHERE clause are:

```
... WHERE ROWNUM < constant;
... WHERE ROWNUM <= constant;
```

You can use ROWNUM in an UPDATE statement to assign unique values to each row in a table, or in the WHERE clause of a SELECT statement to limit the number of rows retrieved, as shown in Example 6–6.

Example 6–6 Using ROWNUM

```
CREATE TABLE employees_temp AS SELECT * FROM employees;
DECLARE
   CURSOR c1 IS SELECT employee_id, salary FROM employees_temp
      WHERE salary > 2000 AND ROWNUM <= 10;  -- 10 arbitrary rows
   CURSOR c2 IS SELECT * FROM
     (SELECT employee_id, salary FROM employees_temp
       WHERE salary > 2000 ORDER BY salary DESC)
     WHERE ROWNUM < 5;  -- first 5 rows, in sorted order
BEGIN
-- Each row gets assigned a different number
  UPDATE employees_temp SET employee_id = ROWNUM;
END;
/
```

SQL Operators

PL/SQL lets you use all the SQL comparison, set, and row operators in SQL statements. This section briefly describes some of these operators. For more information, see *Oracle Database SQL Reference*.

Comparison Operators

Typically, you use comparison operators in the `WHERE` clause of a data manipulation statement to form predicates, which compare one expression to another and yield `TRUE`, `FALSE`, or `NULL`. You can use the comparison operators in the following list to form predicates. You can combine predicates using the logical operators `AND`, `OR`, and `NOT`.

Operator	Description
`ALL`	Compares a value to each value in a list or returned by a subquery and yields `TRUE` if all of the individual comparisons yield `TRUE`.
`ANY`, `SOME`	Compares a value to each value in a list or returned by a subquery and yields `TRUE` if any of the individual comparisons yields `TRUE`.
`BETWEEN`	Tests whether a value lies in a specified range.
`EXISTS`	Returns `TRUE` if a subquery returns at least one row.
`IN`	Tests for set membership.
`IS NULL`	Tests for nulls.
`LIKE`	Tests whether a character string matches a specified pattern, which can include wildcards.

Set Operators

Set operators combine the results of two queries into one result. `INTERSECT` returns all distinct rows selected by both queries. `MINUS` returns all distinct rows selected by the first query but not by the second. `UNION` returns all distinct rows selected by either query. `UNION ALL` returns all rows selected by either query, including all duplicates.

Row Operators

Row operators return or reference particular rows. `ALL` retains duplicate rows in the result of a query or in an aggregate expression. `DISTINCT` eliminates duplicate rows from the result of a query or from an aggregate expression. `PRIOR` refers to the parent row of the current row returned by a tree-structured query.

Managing Cursors in PL/SQL

PL/SQL uses implicit and explicit cursors. PL/SQL declares a cursor implicitly for all SQL data manipulation statements, including queries that return only one row. If you want precise control over query processing, you can declare an explicit cursor in the declarative part of any PL/SQL block, subprogram, or package. You must declare an explicit cursor for queries that return more than one row.

Implicit Cursors

Implicit cursors are managed automatically by PL/SQL so you are not required to write any code to handle these cursors. However, you can track information about the execution of an implicit cursor through its cursor attributes.

Attributes of Implicit Cursors

Implicit cursor attributes return information about the execution of DML and DDL statements, such INSERT, UPDATE, DELETE, SELECT INTO, COMMIT, or ROLLBACK statements. The cursor attributes are %FOUND, %ISOPEN %NOTFOUND, and %ROWCOUNT. The values of the cursor attributes always refer to the most recently executed SQL statement. Before Oracle opens the SQL cursor, the implicit cursor attributes yield NULL.

The SQL cursor has another attribute, %BULK_ROWCOUNT, designed for use with the FORALL statement. For more information, see "Counting Rows Affected by FORALL with the %BULK_ROWCOUNT Attribute" on page 11-12.

%FOUND Attribute: Has a DML Statement Changed Rows?

Until a SQL data manipulation statement is executed, %FOUND yields NULL. Thereafter, %FOUND yields TRUE if an INSERT, UPDATE, or DELETE statement affected one or more rows, or a SELECT INTO statement returned one or more rows. Otherwise, %FOUND yields FALSE. In Example 6–7, you use %FOUND to insert a row if a delete succeeds.

Example 6–7 Using SQL%FOUND

```
CREATE TABLE dept_temp AS SELECT * FROM departments;
DECLARE
  dept_no NUMBER(4) := 270;
BEGIN
  DELETE FROM dept_temp WHERE department_id = dept_no;
  IF SQL%FOUND THEN  -- delete succeeded
    INSERT INTO dept_temp VALUES (270, 'Personnel', 200, 1700);
  END IF;
END;
/
```

%ISOPEN Attribute: Always FALSE for Implicit Cursors

Oracle closes the SQL cursor automatically after executing its associated SQL statement. As a result, %ISOPEN always yields FALSE.

%NOTFOUND Attribute: Has a DML Statement Failed to Change Rows?

%NOTFOUND is the logical opposite of %FOUND. %NOTFOUND yields TRUE if an INSERT, UPDATE, or DELETE statement affected no rows, or a SELECT INTO statement returned no rows. Otherwise, %NOTFOUND yields FALSE.

%ROWCOUNT Attribute: How Many Rows Affected So Far?

%ROWCOUNT yields the number of rows affected by an INSERT, UPDATE, or DELETE statement, or returned by a SELECT INTO statement. %ROWCOUNT yields 0 if an INSERT, UPDATE, or DELETE statement affected no rows, or a SELECT INTO statement returned no rows. In Example 6–8, %ROWCOUNT returns the number of rows that have been deleted.

Example 6–8 Using SQL%ROWCOUNT

```
CREATE TABLE employees_temp AS SELECT * FROM employees;
DECLARE
  mgr_no NUMBER(6) := 122;
BEGIN
  DELETE FROM employees_temp WHERE manager_id = mgr_no;
  DBMS_OUTPUT.PUT_LINE('Number of employees deleted: ' || TO_CHAR(SQL%ROWCOUNT));
END;
/
```

If a `SELECT INTO` statement returns more than one row, PL/SQL raises the predefined exception `TOO_MANY_ROWS` and `%ROWCOUNT` yields `1`, not the actual number of rows that satisfy the query.

The value of the `SQL%ROWCOUNT` attribute refers to the most recently executed SQL statement from PL/SQL. To save an attribute value for later use, assign it to a local variable immediately.

The `SQL%ROWCOUNT` attribute is not related to the state of a transaction. When a rollback to a savepoint is performed, the value of `SQL%ROWCOUNT` is not restored to the old value before the savepoint was taken. Also, when an autonomous transaction is exited, `SQL%ROWCOUNT` is not restored to the original value in the parent transaction.

Guidelines for Using Attributes of Implicit Cursors

The following are considerations when using attributes of implicit cursors:

- The values of the cursor attributes always refer to the most recently executed SQL statement, wherever that statement is. It might be in a different scope (for example, in a sub-block). To save an attribute value for later use, assign it to a local variable immediately. Doing other operations, such as procedure calls, might change the value of the variable before you can test it.
- The `%NOTFOUND` attribute is not useful in combination with the `SELECT INTO` statement:
  - If a `SELECT INTO` statement fails to return a row, PL/SQL raises the predefined exception `NO_DATA_FOUND` immediately, interrupting the flow of control before you can check `%NOTFOUND`.
  - A `SELECT INTO` statement that calls a SQL aggregate function always returns a value or a null. After such a statement, the `%NOTFOUND` attribute is always `FALSE`, so checking it is unnecessary.

Explicit Cursors

When you need precise control over query processing, you can explicitly declare a cursor in the declarative part of any PL/SQL block, subprogram, or package.

You use three commands to control a cursor: `OPEN`, `FETCH`, and `CLOSE`. First, you initialize the cursor with the `OPEN` statement, which identifies the result set. Then, you can execute `FETCH` repeatedly until all rows have been retrieved, or you can use the `BULK COLLECT` clause to fetch all rows at once. When the last row has been processed, you release the cursor with the `CLOSE` statement.

This technique requires more code than other techniques such as the implicit cursor FOR loop. Its advantage is flexibility. You can:

- Process several queries in parallel by declaring and opening multiple cursors.
- Process multiple rows in a single loop iteration, skip rows, or split the processing into more than one loop.

Declaring a Cursor

You must declare a cursor before referencing it in other statements. You give the cursor a name and associate it with a specific query. You can optionally declare a return type for the cursor, such as *`table_name`*`%ROWTYPE`. You can optionally specify parameters that you use in the `WHERE` clause instead of referring to local variables. These parameters can have default values. Example 6–9 shows how you can declare cursors.

Example 6–9 Declaring a Cursor

```
DECLARE
  my_emp_id     NUMBER(6);      -- variable for employee_id
  my_job_id     VARCHAR2(10);   -- variable for job_id
  my_sal        NUMBER(8,2);    -- variable for salary
  CURSOR c1 IS SELECT employee_id, job_id, salary FROM employees
      WHERE salary > 2000;
  my_dept   departments%ROWTYPE;  -- variable for departments row
  CURSOR c2 RETURN departments%ROWTYPE IS
      SELECT * FROM departments WHERE department_id = 110;
```

The cursor is not a PL/SQL variable: you cannot assign values to a cursor or use it in an expression. Cursors and variables follow the same scoping rules. Naming cursors after database tables is possible but not recommended.

A cursor can take parameters, which can appear in the associated query wherever constants can appear. The formal parameters of a cursor must be `IN` parameters; they supply values in the query, but do not return any values from the query. You cannot impose the constraint `NOT NULL` on a cursor parameter.

As the following example shows, you can initialize cursor parameters to default values. You can pass different numbers of actual parameters to a cursor, accepting or overriding the default values as you please. Also, you can add new formal parameters without having to change existing references to the cursor.

```
DECLARE
   CURSOR c1 (low  NUMBER DEFAULT 0, high NUMBER DEFAULT 99) IS
              SELECT * FROM departments WHERE department_id > low
              AND department_id < high;
```

Cursor parameters can be referenced only within the query specified in the cursor declaration. The parameter values are used by the associated query when the cursor is opened.

Opening a Cursor

Opening the cursor executes the query and identifies the result set, which consists of all rows that meet the query search criteria. For cursors declared using the `FOR UPDATE` clause, the `OPEN` statement also locks those rows. An example of the `OPEN` statement follows:

```
DECLARE
   CURSOR c1 IS SELECT employee_id, last_name, job_id, salary FROM employees
      WHERE salary > 2000;
BEGIN
  OPEN C1;
```

Rows in the result set are retrieved by the `FETCH` statement, not when the `OPEN` statement is executed.

Fetching with a Cursor

Unless you use the `BULK COLLECT` clause, discussed in "Fetching with a Cursor" on page 6-9, the `FETCH` statement retrieves the rows in the result set one at a time. Each fetch retrieves the current row and advances the cursor to the next row in the result set. You can store each column in a separate variable, or store the entire row in a record that has the appropriate fields, usually declared using `%ROWTYPE`.

For each column value returned by the query associated with the cursor, there must be a corresponding, type-compatible variable in the `INTO` list. Typically, you use the `FETCH` statement with a `LOOP` and `EXIT WHEN .. NOTFOUND` statements, as shown in Example 6–10. Note the use of built-in regular expression functions in the queries.

Example 6–10 Fetching With a Cursor

```
DECLARE
  v_jobid     employees.job_id%TYPE;     -- variable for job_id
  v_lastname  employees.last_name%TYPE;  -- variable for last_name
  CURSOR c1 IS SELECT last_name, job_id FROM employees
                 WHERE REGEXP_LIKE (job_id, 'S[HT]_CLERK');
  v_employees employees%ROWTYPE;         -- record variable for row
  CURSOR c2 is SELECT * FROM employees
                 WHERE REGEXP_LIKE (job_id, '[ACADFIMKSA]_M[ANGR]');
BEGIN
  OPEN c1; -- open the cursor before fetching
  LOOP
    FETCH c1 INTO v_lastname, v_jobid; -- fetches 2 columns into variables
    EXIT WHEN c1%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE( RPAD(v_lastname, 25, ' ') || v_jobid );
  END LOOP;
  CLOSE c1;
  DBMS_OUTPUT.PUT_LINE( '-------------------------------------' );
  OPEN c2;
  LOOP
    FETCH c2 INTO v_employees; -- fetches entire row into the v_employees record
    EXIT WHEN c2%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE( RPAD(v_employees.last_name, 25, ' ') ||
                               v_employees.job_id );
  END LOOP;
  CLOSE c2;
END;
/
```

The query can reference PL/SQL variables within its scope. Any variables in the query are evaluated only when the cursor is opened. In Example 6–11, each retrieved salary is multiplied by `2`, even though `factor` is incremented after every fetch.

Example 6–11 Referencing PL/SQL Variables Within Its Scope

```
DECLARE
  my_sal employees.salary%TYPE;
  my_job employees.job_id%TYPE;
  factor INTEGER := 2;
  CURSOR c1 IS
    SELECT factor*salary FROM employees WHERE job_id = my_job;
BEGIN
   OPEN c1;  -- factor initially equals 2
   LOOP
      FETCH c1 INTO my_sal;
      EXIT WHEN c1%NOTFOUND;
      factor := factor + 1;  -- does not affect FETCH
   END LOOP;
   CLOSe c1;
END;
```

```
/
```

To change the result set or the values of variables in the query, you must close and reopen the cursor with the input variables set to their new values. However, you can use a different INTO list on separate fetches with the same cursor. Each fetch retrieves another row and assigns values to the target variables, as shown inExample 6–12.

Example 6–12 Fetching the Same Cursor Into Different Variables

```
DECLARE
   CURSOR c1 IS SELECT last_name FROM employees ORDER BY last_name;
   name1 employees.last_name%TYPE;
   name2 employees.last_name%TYPE;
   name3 employees.last_name%TYPE;
BEGIN
   OPEN c1;
   FETCH c1 INTO name1;  -- this fetches first row
   FETCH c1 INTO name2;  -- this fetches second row
   FETCH c1 INTO name3;  -- this fetches third row
   CLOSE c1;
END;
/
```

If you fetch past the last row in the result set, the values of the target variables are undefined. Eventually, the FETCH statement fails to return a row. When that happens, no exception is raised. To detect the failure, use the cursor attribute %FOUND or %NOTFOUND. For more information, see "Using Cursor Expressions" on page 6-28.

Fetching Bulk Data with a Cursor

The BULK COLLECT clause lets you fetch all rows from the result set at once. See "Retrieving Query Results into Collections with the BULK COLLECT Clause" on page 11-15. In Example 6–13, you bulk-fetch from a cursor into two collections.

Example 6–13 Fetching Bulk Data With a Cursor

```
DECLARE
  TYPE IdsTab IS TABLE OF employees.employee_id%TYPE;
  TYPE NameTab IS TABLE OF employees.last_name%TYPE;
  ids  IdsTab;
  names NameTab;
  CURSOR c1 IS
    SELECT employee_id, last_name FROM employees WHERE job_id = 'ST_CLERK';
BEGIN
  OPEN c1;
  FETCH c1 BULK COLLECT INTO ids, names;
  CLOsE c1;
-- Here is where you process the elements in the collections
  FOR i IN ids.FIRST .. ids.LAST
    LOOP
      IF ids(i) > 140 THEN
          DBMS_OUTPUT.PUT_LINE( ids(i) );
       END IF;
    END LOOP;
  FOR i IN names.FIRST .. names.LAST
    LOOP
      IF names(i) LIKE '%Ma%' THEN
          DBMS_OUTPUT.PUT_LINE( names(i) );
       END IF;
    END LOOP;
```

```
END;
/
```

Closing a Cursor

The CLOSE statement disables the cursor, and the result set becomes undefined. Once a cursor is closed, you can reopen it, which runs the query again with the latest values of any cursor parameters and variables referenced in the WHERE clause. Any other operation on a closed cursor raises the predefined exception INVALID_CURSOR.

Attributes of Explicit Cursors

Every explicit cursor and cursor variable has four attributes: %FOUND, %ISOPEN %NOTFOUND, and %ROWCOUNT. When appended to the cursor or cursor variable name, these attributes return useful information about the execution of a SQL statement. You can use cursor attributes in procedural statements but not in SQL statements.

Explicit cursor attributes return information about the execution of a multi-row query. When an explicit cursor or a cursor variable is opened, the rows that satisfy the associated query are identified and form the result set. Rows are fetched from the result set.

%FOUND Attribute: Has a Row Been Fetched?

After a cursor or cursor variable is opened but before the first fetch, %FOUND returns NULL. After any fetches, it returns TRUE if the last fetch returned a row, or FALSE if the last fetch did not return a row. Example 6–14 uses %FOUND to select an action.

Example 6–14 Using %FOUND

```
DECLARE
   CURSOR c1 IS SELECT last_name, salary FROM employees WHERE ROWNUM < 11;
   my_ename employees.last_name%TYPE;
   my_salary employees.salary%TYPE;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO my_ename, my_salary;
    IF c1%FOUND THEN  -- fetch succeeded
      DBMS_OUTPUT.PUT_LINE('Name = ' || my_ename || ', salary = ' || my_salary);
    ELSE  -- fetch failed, so exit loop
      EXIT;
    END IF;
  END LOOP;
END;
/
```

If a cursor or cursor variable is not open, referencing it with %FOUND raises the predefined exception INVALID_CURSOR.

%ISOPEN Attribute: Is the Cursor Open?

%ISOPEN returns TRUE if its cursor or cursor variable is open; otherwise, %ISOPEN returns FALSE. Example 6–15 uses %ISOPEN to select an action.

Example 6–15 Using %ISOPEN

```
DECLARE
   CURSOR c1 IS SELECT last_name, salary FROM employees WHERE ROWNUM < 11;
   the_name employees.last_name%TYPE;
   the_salary employees.salary%TYPE;
```

```
BEGIN
   IF c1%ISOPEN = FALSE THEN  -- cursor was not already open
      OPEN c1;
   END IF;
   FETCH c1 INTO the_name, the_salary;
   CLOSE c1;
END;
/
```

%NOTFOUND Attribute: Has a Fetch Failed?

`%NOTFOUND` is the logical opposite of `%FOUND`. `%NOTFOUND` yields `FALSE` if the last fetch returned a row, or `TRUE` if the last fetch failed to return a row. In Example 6–16, you use `%NOTFOUND` to exit a loop when `FETCH` fails to return a row.

Example 6–16 Using %NOTFOUND

```
DECLARE
   CURSOR c1 IS SELECT last_name, salary FROM employees WHERE ROWNUM < 11;
   my_ename employees.last_name%TYPE;
   my_salary employees.salary%TYPE;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO my_ename, my_salary;
    IF c1%NOTFOUND THEN -- fetch failed, so exit loop
-- Another form of this test is "EXIT WHEN c1%NOTFOUND OR c1%NOTFOUND IS NULL;"
       EXIT;
    ELSE   -- fetch succeeded
      DBMS_OUTPUT.PUT_LINE('Name = ' || my_ename || ', salary = ' || my_salary);
    END IF;
   END LOOP;
END;
/
```

Before the first fetch, `%NOTFOUND` returns `NULL`. If `FETCH` never executes successfully, the loop is never exited, because the `EXIT WHEN` statement executes only if its `WHEN` condition is true. To be safe, you might want to use the following `EXIT` statement instead:

```
EXIT WHEN c1%NOTFOUND OR c1%NOTFOUND IS NULL;
```

If a cursor or cursor variable is not open, referencing it with `%NOTFOUND` raises an `INVALID_CURSOR` exception.

%ROWCOUNT Attribute: How Many Rows Fetched So Far?

When its cursor or cursor variable is opened, `%ROWCOUNT` is zeroed. Before the first fetch, `%ROWCOUNT` yields `0`. Thereafter, it yields the number of rows fetched so far. The number is incremented if the last fetch returned a row. Example 6–17 uses `%ROWCOUNT` to test if more than ten rows have been fetched.

Example 6–17 Using %ROWCOUNT

```
DECLARE
   CURSOR c1 IS SELECT last_name FROM employees WHERE ROWNUM < 11;
   name employees.last_name%TYPE;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO name;
      EXIT WHEN c1%NOTFOUND OR c1%NOTFOUND IS NULL;
      DBMS_OUTPUT.PUT_LINE(c1%ROWCOUNT || '. ' || name);
      IF c1%ROWCOUNT = 5 THEN
         DBMS_OUTPUT.PUT_LINE('--- Fetched 5th record ---');
      END IF;
   END LOOP;
   CLOSE c1;
END;
/
```

If a cursor or cursor variable is not open, referencing it with `%ROWCOUNT` raises `INVALID_CURSOR`.

Table 6–1 shows what each cursor attribute returns before and after you execute an `OPEN`, `FETCH`, or `CLOSE` statement.

Table 6–1 Cursor Attribute Values

		%FOUND	%ISOPEN	%NOTFOUND	%ROWCOUNT
OPEN	before	exception	`FALSE`	exception	exception
	after	`NULL`	`TRUE`	`NULL`	0
First FETCH	before	`NULL`	`TRUE`	`NULL`	0
	after	`TRUE`	`TRUE`	`FALSE`	1
Next FETCH(es)	before	`TRUE`	`TRUE`	`FALSE`	1
	after	`TRUE`	`TRUE`	`FALSE`	data dependent
Last FETCH	before	`TRUE`	`TRUE`	`FALSE`	data dependent
	after	`FALSE`	`TRUE`	`TRUE`	data dependent
CLOSE	before	`FALSE`	`TRUE`	`TRUE`	data dependent
	after	exception	`FALSE`	exception	exception

The following applies to the information in Table 6–1:

- Referencing `%FOUND`, `%NOTFOUND`, or `%ROWCOUNT` before a cursor is opened or after it is closed raises `INVALID_CURSOR`.
- After the first `FETCH`, if the result set was empty, `%FOUND` yields `FALSE`, `%NOTFOUND` yields `TRUE`, and `%ROWCOUNT` yields 0.

Querying Data with PL/SQL

PL/SQL lets you perform queries (`SELECT` statements in SQL) and access individual fields or entire rows from the result set. In traditional database programming, you process query results using an internal data structure called a cursor. In most situations, PL/SQL can manage the cursor for you, so that code to process query results is straightforward and compact. This section discusses how to process both simple queries where PL/SQL manages everything, and complex queries where you interact with the cursor.

Selecting At Most One Row: SELECT INTO Statement

If you expect a query to only return one row, you can write a regular SQL `SELECT` statement with an additional `INTO` clause specifying the PL/SQL variable to hold the result.

If the query might return more than one row, but you do not care about values after the first, you can restrict any result set to a single row by comparing the ROWNUM value. If the query might return no rows at all, use an exception handler to specify any actions to take when no data is found.

If you just want to check whether a condition exists in your data, you might be able to code the query with the COUNT(*) operator, which always returns a number and never raises the NO_DATA_FOUND exception.

Selecting Multiple Rows: BULK COLLECT Clause

If you need to bring a large quantity of data into local PL/SQL variables, rather than looping through a result set one row at a time, you can use the BULK COLLECT clause. When you query only certain columns, you can store all the results for each column in a separate collection variable. When you query all the columns of a table, you can store the entire result set in a collection of records, which makes it convenient to loop through the results and refer to different columns. See Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11.

This technique can be very fast, but also very memory-intensive. If you use it often, you might be able to improve your code by doing more of the work in SQL:

- If you only need to loop once through the result set, use a FOR loop as described in the following sections. This technique avoids the memory overhead of storing a copy of the result set.
- If you are looping through the result set to scan for certain values or filter the results into a smaller set, do this scanning or filtering in the original query instead. You can add more WHERE clauses in simple cases, or use set operators such as INTERSECT and MINUS if you are comparing two or more sets of results.
- If you are looping through the result set and running another query or a DML statement for each result row, you can probably find a more efficient technique. For queries, look at including subqueries or EXISTS or NOT EXISTS clauses in the original query. For DML statements, look at the FORALL statement, which is much faster than coding these statements inside a regular loop.

Looping Through Multiple Rows: Cursor FOR Loop

Perhaps the most common case of a query is one where you issue the SELECT statement, then immediately loop once through the rows of the result set. PL/SQL lets you use a simple FOR loop for this kind of query:

The iterator variable for the FOR loop does not need to be declared in advance. It is a %ROWTYPE record whose field names match the column names from the query, and that exists only during the loop. When you use expressions rather than explicit column names, use column aliases so that you can refer to the corresponding values inside the loop.

Performing Complicated Query Processing: Explicit Cursors

For full control over query processing, you can use explicit cursors in combination with the OPEN, FETCH, and CLOSE statements.

You might want to specify a query in one place but retrieve the rows somewhere else, even in another subprogram. Or you might want to choose very different query parameters, such as ORDER BY or GROUP BY clauses, depending on the situation. Or you might want to process some rows differently than others, and so need more than a simple loop.

Because explicit cursors are so flexible, you can choose from different notations depending on your needs. The following sections describe all the query-processing features that explicit cursors provide.

Querying Data with PL/SQL: Implicit Cursor FOR Loop

With PL/SQL, it is very simple to issue a query, retrieve each row of the result into a `%ROWTYPE` record, and process each row in a loop:

- You include the text of the query directly in the `FOR` loop.
- PL/SQL creates a record variable with fields corresponding to the columns of the result set.
- You refer to the fields of this record variable inside the loop. You can perform tests and calculations, display output, or store the results somewhere else.

Here is an example that you can run in SQL*Plus. It does a query to get the name and job Id of employees with manager Ids greater than 120.

```
BEGIN
  FOR item IN
  ( SELECT last_name, job_id FROM employees WHERE job_id LIKE '%CLERK%'
       AND manager_id > 120 )
  LOOP
    DBMS_OUTPUT.PUT_LINE('Name = ' || item.last_name || ', Job = ' ||
                         item.job_id);
  END LOOP;
END;
/
```

Before each iteration of the `FOR` loop, PL/SQL fetches into the implicitly declared record. The sequence of statements inside the loop is executed once for each row that satisfies the query. When you leave the loop, the cursor is closed automatically. The cursor is closed even if you use an `EXIT` or `GOTO` statement to leave the loop before all rows are fetched, or an exception is raised inside the loop. See "LOOP Statements" on page 13-72.

Querying Data with PL/SQL: Explicit Cursor FOR Loops

If you need to reference the same query from different parts of the same procedure, you can declare a cursor that specifies the query, and process the results using a FOR loop.

```
DECLARE
 CURSOR c1 IS SELECT last_name, job_id FROM employees
                WHERE job_id LIKE '%CLERK%' AND manager_id > 120;
BEGIN
  FOR item IN c1
  LOOP
    DBMS_OUTPUT.PUT_LINE('Name = ' || item.last_name || ', Job = ' ||
                         item.job_id);
  END LOOP;
END;
/
```

See also: "LOOP Statements" on page 13-72

Defining Aliases for Expression Values in a Cursor FOR Loop

In a cursor FOR loop, PL/SQL creates a %ROWTYPE record with fields corresponding to columns in the result set. The fields have the same names as corresponding columns in the SELECT list.

The select list might contain an expression, such as a column plus a constant, or two columns concatenated together. If so, use a column alias to give unique names to the appropriate columns.

In Example 6–18, full_name and dream_salary are aliases for expressions in the query:

Example 6–18 Using an Alias For Expressions in a Query

```
BEGIN
  FOR item IN
  ( SELECT first_name || ' ' || last_name AS full_name,
      salary * 10 AS dream_salary FROM employees WHERE ROWNUM <= 5 )
  LOOP
    DBMS_OUTPUT.PUT_LINE(item.full_name || ' dreams of making ' ||
                         item.dream_salary);
  END LOOP;
END;
/
```

Using Subqueries

A subquery is a query (usually enclosed by parentheses) that appears within another SQL data manipulation statement. The statement acts upon the single value or set of values returned by the subquery. For example:

- You can use a subquery to find the MAX(), MIN(), or AVG() value for a column, and use that single value in a comparison in a WHERE clause.
- You can use a subquery to find a set of values, and use this values in an IN or NOT IN comparison in a WHERE clause. This technique can avoid joins.
- You can filter a set of values with a subquery, and apply other operations like ORDER BY and GROUP BY in the outer query.
- You can use a subquery in place of a table name, in the FROM clause of a query. This technique lets you join a table with a small set of rows from another table, instead of joining the entire tables.
- You can create a table or insert into a table, using a set of rows defined by a subquery.

Example 6–19 is illustrates two subqueries used in cursor declarations.

Example 6–19 Using a Subquery in a Cursor

```
DECLARE
  CURSOR c1 IS
-- main query returns only rows where the salary is greater than the average
    SELECT employee_id, last_name FROM employees
      WHERE salary > (SELECT AVG(salary) FROM employees);
  CURSOR c2 IS
-- subquery returns all the rows in descending order of salary
-- main query returns just the top 10 highest-paid employees
   SELECT * FROM
     (SELECT last_name, salary FROM employees ORDER BY salary DESC, last_name)
     WHERE ROWNUM < 11;
BEGIN
  FOR person IN c1
  LOOP
    DBMS_OUTPUT.PUT_LINE('Above-average salary: ' || person.last_name);
  END LOOP;
  FOR person IN c2
  LOOP
    DBMS_OUTPUT.PUT_LINE('Highest paid: ' || person.last_name ||
                         ' $' || person.salary);
  END LOOP;
-- subquery identifies a set of rows to use with CREATE TABLE or INSERT
END;
/
```

Using a subquery in the `FROM` clause, the query in Example 6–20 returns the number and name of each department with five or more employees.

Example 6–20 Using a Subquery in a FROM Clause

```
DECLARE
  CURSOR c1 IS
    SELECT t1.department_id, department_name, staff
      FROM departments t1,
      ( SELECT department_id, COUNT(*) as staff
          FROM employees GROUP BY department_id) t2
    WHERE
      t1.department_id = t2.department_id
      AND staff >= 5;
BEGIN
   FOR dept IN c1
   LOOP
     DBMS_OUTPUT.PUT_LINE('Department = ' || dept.department_name ||
                          ', staff = ' || dept.staff);
   END LOOP;
END;
/
```

Using Correlated Subqueries

While a subquery is evaluated only once for each table, a correlated subquery is evaluated once for each row. Example 6–21 returns the name and salary of each employee whose salary exceeds the departmental average. For each row in the table, the correlated subquery computes the average salary for the corresponding department.

Example 6–21 Using a Correlated Subquery

```
DECLARE
-- For each department, find the average salary. Then find all the employees in
--  that department making more than that average salary.
  CURSOR c1 IS
    SELECT department_id, last_name, salary FROM employees t
    WHERE salary >
      ( SELECT AVG(salary) FROM employees WHERE t.department_id = department_id )
    ORDER BY department_id;
BEGIN
  FOR person IN c1
  LOOP
    DBMS_OUTPUT.PUT_LINE('Making above-average salary = ' || person.last_name);
  END LOOP;
END;
/
```

Writing Maintainable PL/SQL Queries

Instead of referring to local variables, you can declare a cursor that accepts parameters, and pass values for those parameters when you open the cursor. If the query is usually issued with certain values, you can make those values the defaults. You can use either positional notation or named notation to pass the parameter values.

Example 6–22 displays the wages paid to employees earning over a specified wage in a specified department.

Example 6–22 Passing Parameters to a Cursor FOR Loop

```
DECLARE
  CURSOR c1 (job VARCHAR2, max_wage NUMBER) IS
    SELECT * FROM employees WHERE job_id = job AND salary > max_wage;
BEGIN
  FOR person IN c1('CLERK', 3000)
  LOOP
     -- process data record
    DBMS_OUTPUT.PUT_LINE('Name = ' || person.last_name || ', salary = ' ||
                         person.salary || ', Job Id = ' || person.job_id );
  END LOOP;
END;
/
```

In Example 6–23, several ways are shown to open a cursor.

Example 6–23 Passing Parameters to Explicit Cursors

```
DECLARE
  emp_job      employees.job_id%TYPE := 'ST_CLERK';
  emp_salary   employees.salary%TYPE := 3000;
  my_record employees%ROWTYPE;
  CURSOR c1 (job VARCHAR2, max_wage NUMBER) IS
    SELECT * FROM employees WHERE job_id = job and salary > max_wage;
BEGIN
-- Any of the following statements opens the cursor:
-- OPEN c1('ST_CLERK', 3000); OPEN c1('ST_CLERK', emp_salary);
-- OPEN c1(emp_job, 3000); OPEN c1(emp_job, emp_salary);
  OPEN c1(emp_job, emp_salary);
  LOOP
     FETCH c1 INTO my_record;
     EXIT WHEN c1%NOTFOUND;
     -- process data record
     DBMS_OUTPUT.PUT_LINE('Name = ' || my_record.last_name || ', salary = ' ||
                      my_record.salary || ', Job Id = ' || my_record.job_id );
  END LOOP;
END;
/
```

To avoid confusion, use different names for cursor parameters and the PL/SQL variables that you pass into those parameters.

Formal parameters declared with a default value do not need a corresponding actual parameter. If you omit them, they assume their default values when the `OPEN` statement is executed.

Using Cursor Variables (REF CURSORs)

Like a cursor, a cursor variable points to the current row in the result set of a multi-row query. A cursor variable is more flexible because it is not tied to a specific query. You can open a cursor variable for any query that returns the right set of columns.

You pass a cursor variable as a parameter to local and stored subprograms. Opening the cursor variable in one subprogram, and processing it in a different subprogram, helps to centralize data retrieval. This technique is also useful for multi-language applications, where a PL/SQL subprogram might return a result set to a subprogram written in a different language, such as Java or Visual Basic.

Cursor variables are available to every PL/SQL client. For example, you can declare a cursor variable in a PL/SQL host environment such as an OCI or Pro*C program, then pass it as an input host variable (bind variable) to PL/SQL. Application development tools such as Oracle Forms, which have a PL/SQL engine, can use cursor variables entirely on the client side. Or, you can pass cursor variables back and forth between a client and the database server through remote procedure calls.

What Are Cursor Variables (REF CURSORs)?

Cursor variables are like pointers to result sets. You use them when you want to perform a query in one subprogram, and process the results in a different subprogram (possibly one written in a different language). A cursor variable has datatype `REF CURSOR`, and you might see them referred to informally as `REF CURSOR`s.

Unlike an explicit cursor, which always refers to the same query work area, a cursor variable can refer to different work areas. You cannot use a cursor variable where a cursor is expected, or vice versa.

Why Use Cursor Variables?

You use cursor variables to pass query result sets between PL/SQL stored subprograms and various clients. PL/SQL and its clients share a pointer to the query work area in which the result set is stored. For example, an OCI client, Oracle Forms application, and Oracle database server can all refer to the same work area.

A query work area remains accessible as long as any cursor variable points to it, as you pass the value of a cursor variable from one scope to another. For example, if you pass a host cursor variable to a PL/SQL block embedded in a Pro*C program, the work area to which the cursor variable points remains accessible after the block completes.

If you have a PL/SQL engine on the client side, calls from client to server impose no restrictions. For example, you can declare a cursor variable on the client side, open and fetch from it on the server side, then continue to fetch from it back on the client side. You can also reduce network traffic by having a PL/SQL block open or close several host cursor variables in a single round trip.

Declaring REF CURSOR Types and Cursor Variables

To create cursor variables, you define a `REF CURSOR` type, then declare cursor variables of that type. You can define `REF CURSOR` types in any PL/SQL block, subprogram, or package. In the following example, you declare a `REF CURSOR` type that represents a result set from the `DEPARTMENTS` table:

```
DECLARE
  TYPE DeptCurTyp IS REF CURSOR RETURN departments%ROWTYPE;
```

REF CURSOR types can be strong (with a return type) or weak (with no return type). Strong REF CURSOR types are less error prone because the PL/SQL compiler lets you associate a strongly typed cursor variable only with queries that return the right set of columns. Weak REF CURSOR types are more flexible because the compiler lets you associate a weakly typed cursor variable with any query. Because there is no type checking with a weak REF CURSOR, all such types are interchangeable. Instead of creating a new type, you can use the predefined type SYS_REFCURSOR.

Once you define a REF CURSOR type, you can declare cursor variables of that type in any PL/SQL block or subprogram.

```
DECLARE
   TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;  -- strong
   TYPE genericcurtyp IS REF CURSOR;  -- weak
   cursor1 empcurtyp;
   cursor2 genericcurtyp;
   my_cursor SYS_REFCURSOR; -- didn't need to declare a new type
   TYPE deptcurtyp IS REF CURSOR RETURN departments%ROWTYPE;
   dept_cv deptcurtyp;  -- declare cursor variable
```

To avoid declaring the same REF CURSOR type in each subprogram that uses it, you can put the REF CURSOR declaration in a package spec. You can declare cursor variables of that type in the corresponding package body, or within your own procedure or function.

In the RETURN clause of a REF CURSOR type definition, you can use %ROWTYPE to refer to a strongly typed cursor variable, as shown in Example 6–24.

Example 6–24 Cursor Variable Returning a %ROWTYPE Variable

```
DECLARE
   TYPE TmpCurTyp IS REF CURSOR RETURN employees%ROWTYPE;
   tmp_cv TmpCurTyp;  -- declare cursor variable
   TYPE EmpCurTyp IS REF CURSOR RETURN tmp_cv%ROWTYPE;
   emp_cv EmpCurTyp;  -- declare cursor variable
```

You can also use %ROWTYPE to provide the datatype of a record variable, as shown in Example 6–25.

Example 6–25 Using the %ROWTYPE Attribute to Provide the Datatype

```
DECLARE
   dept_rec departments%ROWTYPE;  -- declare record variable
   TYPE DeptCurTyp IS REF CURSOR RETURN dept_rec%TYPE;
   dept_cv DeptCurTyp;  -- declare cursor variable
```

Example 6–26 specifies a user-defined RECORD type in the RETURN clause:

Example 6–26 Cursor Variable Returning a Record Type

```
DECLARE
   TYPE EmpRecTyp IS RECORD (
      employee_id NUMBER,
      last_name VARCHAR2(25),
      salary   NUMBER(8,2));
   TYPE EmpCurTyp IS REF CURSOR RETURN EmpRecTyp;
   emp_cv EmpCurTyp;  -- declare cursor variable
```

Passing Cursor Variables As Parameters

You can declare cursor variables as the formal parameters of functions and procedures. Example 6–27 defines a REF CURSOR type, then declares a cursor variable of that type as a formal parameter.

Example 6–27 Passing a REF CURSOR as a Parameter

```
DECLARE
   TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
   emp empcurtyp;
-- after result set is built, process all the rows inside a single procedure
--  rather than calling a procedure for each row
   PROCEDURE process_emp_cv (emp_cv IN empcurtyp) IS
      person employees%ROWTYPE;
   BEGIN
      DBMS_OUTPUT.PUT_LINE('-----');
      DBMS_OUTPUT.PUT_LINE('Here are the names from the result set:');
      LOOP
         FETCH emp_cv INTO person;
         EXIT WHEN emp_cv%NOTFOUND;
         DBMS_OUTPUT.PUT_LINE('Name = ' || person.first_name ||
                              ' ' || person.last_name);
      END LOOP;
   END;
BEGIN
-- First find 10 arbitrary employees.
  OPEN emp FOR SELECT * FROM employees WHERE ROWNUM < 11;
  process_emp_cv(emp);
  CLOSE emp;
-- find employees matching a condition.
  OPEN emp FOR SELECT * FROM employees WHERE last_name LIKE 'R%';
  process_emp_cv(emp);
  CLOSE emp;
END;
/
```

Like all pointers, cursor variables increase the possibility of parameter aliasing. See "Overloading Subprogram Names" on page 8-10.

Controlling Cursor Variables: OPEN-FOR, FETCH, and CLOSE

You use three statements to control a cursor variable: OPEN-FOR, FETCH, and CLOSE. First, you OPEN a cursor variable FOR a multi-row query. Then, you FETCH rows from the result set. When all the rows are processed, you CLOSE the cursor variable.

Opening a Cursor Variable

The OPEN-FOR statement associates a cursor variable with a multi-row query, executes the query, and identifies the result set. The cursor variable can be declared directly in PL/SQL, or in a PL/SQL host environment such as an OCI program. For the syntax of the OPEN-FOR statement, see "OPEN-FOR Statement" on page 13-82.

The SELECT statement for the query can be coded directly in the statement, or can be a string variable or string literal. When you use a string as the query, it can include placeholders for bind variables, and you specify the corresponding values with a USING clause.

This section discusses the static SQL case, in which `select_statement` is used. For the dynamic SQL case, in which `dynamic_string` is used, see "OPEN-FOR Statement" on page 13-82.

Unlike cursors, cursor variables take no parameters. Instead, you can pass whole queries (not just parameters) to a cursor variable. The query can reference host variables and PL/SQL variables, parameters, and functions.

Example 6–28 opens a cursor variable. Notice that you can apply cursor attributes (`%FOUND`, `%NOTFOUND`, `%ISOPEN`, and `%ROWCOUNT`) to a cursor variable.

Example 6–28 Checking If a Cursor Variable is Open

```
DECLARE
   TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
   emp_cv empcurtyp;
BEGIN
   IF NOT emp_cv%ISOPEN THEN  -- open cursor variable
      OPEN emp_cv FOR SELECT * FROM employees;
   END IF;
   CLOSE emp_cv;
END;
/
```

Other `OPEN-FOR` statements can open the same cursor variable for different queries. You need not close a cursor variable before reopening it. Note that consecutive `OPEN`s of a static cursor raise the predefined exception `CURSOR_ALREADY_OPEN`. When you reopen a cursor variable for a different query, the previous query is lost.

Typically, you open a cursor variable by passing it to a stored procedure that declares an `IN OUT` parameter that is a cursor variable. In Example 6–29 the procedure opens a cursor variable.

Example 6–29 Stored Procedure to Open a Ref Cursor

```
CREATE PACKAGE emp_data AS
  TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
  PROCEDURE open_emp_cv (emp_cv IN OUT empcurtyp);
END emp_data;
/
CREATE PACKAGE BODY emp_data AS
  PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp) IS
  BEGIN
    OPEN emp_cv FOR SELECT * FROM employees;
  END open_emp_cv;
END emp_data;
/
```

You can also use a standalone stored procedure to open the cursor variable. Define the `REF CURSOR` type in a package, then reference that type in the parameter declaration for the stored procedure.

To centralize data retrieval, you can group type-compatible queries in a stored procedure. In Example 6–30, the packaged procedure declares a selector as one of its formal parameters. When called, the procedure opens the cursor variable `emp_cv` for the chosen query.

Example 6–30 Stored Procedure to Open Ref Cursors with Different Queries

```
CREATE PACKAGE emp_data AS
   TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
   PROCEDURE open_emp_cv (emp_cv IN OUT empcurtyp, choice INT);
END emp_data;
/
CREATE PACKAGE BODY emp_data AS
   PROCEDURE open_emp_cv (emp_cv IN OUT empcurtyp, choice INT) IS
   BEGIN
      IF choice = 1 THEN
         OPEN emp_cv FOR SELECT * FROM employees WHERE commission_pct IS NOT NULL;
      ELSIF choice = 2 THEN
         OPEN emp_cv FOR SELECT * FROM employees WHERE salary > 2500;
      ELSIF choice = 3 THEN
         OPEN emp_cv FOR SELECT * FROM employees WHERE department_id = 100;
      END IF;
   END;
END emp_data;
/
```

For more flexibility, a stored procedure can execute queries with different return types, shown in Example 6–31.

Example 6–31   Cursor Variable with Different Return Types

```
CREATE PACKAGE admin_data AS
   TYPE gencurtyp IS REF CURSOR;
   PROCEDURE open_cv (generic_cv IN OUT gencurtyp, choice INT);
END admin_data;
/
CREATE PACKAGE BODY admin_data AS
   PROCEDURE open_cv (generic_cv IN OUT gencurtyp, choice INT) IS
   BEGIN
      IF choice = 1 THEN
         OPEN generic_cv FOR SELECT * FROM employees;
      ELSIF choice = 2 THEN
         OPEN generic_cv FOR SELECT * FROM departments;
      ELSIF choice = 3 THEN
         OPEN generic_cv FOR SELECT * FROM jobs;
      END IF;
   END;
END admin_data;
/
```

Using a Cursor Variable as a Host Variable

You can declare a cursor variable in a PL/SQL host environment such as an OCI or Pro*C program. To use the cursor variable, you must pass it as a host variable to PL/SQL. In the following Pro*C example, you pass a host cursor variable and selector to a PL/SQL block, which opens the cursor variable for the chosen query.

```
EXEC SQL BEGIN DECLARE SECTION;
  ...
  /* Declare host cursor variable. */
  SQL_CURSOR generic_cv;
  int        choice;
EXEC SQL END DECLARE SECTION;
...
/* Initialize host cursor variable. */
EXEC SQL ALLOCATE :generic_cv;
...
/* Pass host cursor variable and selector to PL/SQL block. */
```

```
EXEC SQL EXECUTE
BEGIN
  IF :choice = 1 THEN
    OPEN :generic_cv FOR SELECT * FROM employees;
  ELSIF :choice = 2 THEN
    OPEN :generic_cv FOR SELECT * FROM departments;
  ELSIF :choice = 3 THEN
    OPEN :generic_cv FOR SELECT * FROM jobs;
  END IF;
END;
END-EXEC;
```

Host cursor variables are compatible with any query return type. They behave just like weakly typed PL/SQL cursor variables.

Fetching from a Cursor Variable

The `FETCH` statement retrieves rows from the result set of a multi-row query. It works the same with cursor variables as with explicit cursors. Example 6–32 fetches rows one at a time from a cursor variable into a record.

Example 6–32 Fetching from a Cursor Variable into a Record

```
DECLARE
   TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
   emp_cv empcurtyp;
   emp_rec employees%ROWTYPE;
BEGIN
   OPEN emp_cv FOR SELECT * FROM employees WHERE employee_id < 120;
   LOOP
      FETCH emp_cv INTO emp_rec; -- fetch from cursor variable
      EXIT WHEN emp_cv%NOTFOUND; -- exit when last row is fetched
      -- process data record
      DBMS_OUTPUT.PUT_LINE('Name = ' || emp_rec.first_name || ' ' ||
                           emp_rec.last_name);
   END LOOP;
   CLOSE emp_cv;
END;
/
```

Using the `BULK COLLECT` clause, you can bulk fetch rows from a cursor variable into one or more collections as shown in Example 6–33.

Example 6–33 Fetching from a Cursor Variable into Collections

```
DECLARE
   TYPE empcurtyp IS REF CURSOR;
   TYPE namelist IS TABLE OF employees.last_name%TYPE;
   TYPE sallist IS TABLE OF employees.salary%TYPE;
   emp_cv empcurtyp;
   names  namelist;
   sals   sallist;
BEGIN
   OPEN emp_cv FOR SELECT last_name, salary FROM employees
        WHERE job_id = 'SA_REP';
   FETCH emp_cv BULK COLLECT INTO names, sals;
   CLOSE emp_cv;
-- loop through the names and sals collections
   FOR i IN names.FIRST .. names.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Name = ' || names(i) || ', salary = ' || sals(i));
   END LOOP;
END;
/
```

Any variables in the associated query are evaluated only when the cursor variable is opened. To change the result set or the values of variables in the query, reopen the cursor variable with the variables set to new values. You can use a different INTO clause on separate fetches with the same cursor variable. Each fetch retrieves another row from the same result set.

PL/SQL makes sure the return type of the cursor variable is compatible with the INTO clause of the FETCH statement. If there is a mismatch, an error occurs at compile time if the cursor variable is strongly typed, or at run time if it is weakly typed. At run time, PL/SQL raises the predefined exception ROWTYPE_MISMATCH *before* the first fetch. If you trap the error and execute the FETCH statement using a different (compatible) INTO clause, no rows are lost.

When you declare a cursor variable as the formal parameter of a subprogram that fetches from the cursor variable, you must specify the IN or IN OUT mode. If the subprogram also opens the cursor variable, you must specify the IN OUT mode.

If you try to fetch from a closed or never-opened cursor variable, PL/SQL raises the predefined exception INVALID_CURSOR.

Closing a Cursor Variable

The CLOSE statement disables a cursor variable and makes the associated result set undefined. Close the cursor variable after the last row is processed.

When declaring a cursor variable as the formal parameter of a subprogram that closes the cursor variable, you must specify the IN or IN OUT mode. If you try to close an already-closed or never-opened cursor variable, PL/SQL raises the predefined exception INVALID_CURSOR.

Reducing Network Traffic When Passing Host Cursor Variables to PL/SQL

When passing host cursor variables to PL/SQL, you can reduce network traffic by grouping OPEN-FOR statements. For example, the following PL/SQL block opens multiple cursor variables in a single round trip:

```
/* anonymous PL/SQL block in host environment */
BEGIN
  OPEN :emp_cv FOR SELECT * FROM employees;
  OPEN :dept_cv FOR SELECT * FROM departments;
  OPEN :loc_cv FOR SELECT * FROM locations;
END;
/
```

This technique might be useful in Oracle Forms, for instance, when you want to populate a multi-block form. When you pass host cursor variables to a PL/SQL block for opening, the query work areas to which they point remain accessible after the block completes, so your OCI or Pro*C program can use these work areas for ordinary cursor operations. For example, you open several such work areas in a single round trip:

```
BEGIN
  OPEN :c1 FOR SELECT 1 FROM dual;
  OPEN :c2 FOR SELECT 1 FROM dual;
  OPEN :c3 FOR SELECT 1 FROM dual;
END;
/
```

The cursors assigned to c1, c2, and c3 behave normally, and you can use them for any purpose. When finished, release the cursors as follows:

```
BEGIN
  CLOSE :c1; CLOSE :c2; CLOSE :c3;
END;
/
```

Avoiding Errors with Cursor Variables

If both cursor variables involved in an assignment are strongly typed, they must have exactly the same datatype (not just the same return type). If one or both cursor variables are weakly typed, they can have different datatypes.

If you try to fetch from, close, or refer to cursor attributes of a cursor variable that does not point to a query work area, PL/SQL raises the INVALID_CURSOR exception. You can make a cursor variable (or parameter) point to a query work area in two ways:

- OPEN the cursor variable FOR the query.
- Assign to the cursor variable the value of an already OPENed host cursor variable or PL/SQL cursor variable.

If you assign an unopened cursor variable to another cursor variable, the second one remains invalid even after you open the first one.

Be careful when passing cursor variables as parameters. At run time, PL/SQL raises ROWTYPE_MISMATCH if the return types of the actual and formal parameters are incompatible.

Restrictions on Cursor Variables

Currently, cursor variables are subject to the following restrictions:

- You cannot declare cursor variables in a package specification, as illustrated in Example 6–34.
- If you bind a host cursor variable into PL/SQL from an OCI client, you cannot fetch from it on the server side unless you also open it there on the same server call.
- You cannot use comparison operators to test cursor variables for equality, inequality, or nullity.
- Database columns cannot store the values of cursor variables. There is no equivalent type to use in a CREATE TABLE statement.
- You cannot store cursor variables in an associative array, nested table, or varray.
- Cursors and cursor variables are not interoperable; that is, you cannot use one where the other is expected. For example, you cannot reference a cursor variable in a cursor FOR loop.

Example 6–34 Declaration of Cursor Variables in a Package

```
CREATE PACKAGE emp_data AS
  TYPE EmpCurTyp IS REF CURSOR RETURN employees%ROWTYPE;
-- emp_cv EmpCurTyp; -- not allowed
```

```
  PROCEDURE open_emp_cv;
END emp_data;
/
CREATE PACKAGE BODY emp_data AS
-- emp_cv EmpCurTyp; -- not allowed
PROCEDURE open_emp_cv IS
  emp_cv EmpCurTyp; -- this is legal
  BEGIN
    OPEN emp_cv FOR SELECT * FROM employees;
  END open_emp_cv;
END emp_data;
/
```

Note:

- Using a `REF CURSOR` variable in a server-to-server RPC results in an error. However, a `REF CURSOR` variable is permitted in a server-to-server RPC if the remote database is a non-Oracle database accessed through a Procedural Gateway.
- LOB parameters are not permitted in a server-to-server RPC.

Using Cursor Expressions

A cursor expression returns a nested cursor. Each row in the result set can contain values as usual, plus cursors produced by subqueries involving the other values in the row. A single query can return a large set of related values retrieved from multiple tables. You can process the result set with nested loops that fetch first from the rows of the result set, then from any nested cursors within those rows.

PL/SQL supports queries with cursor expressions as part of cursor declarations, `REF CURSOR` declarations and ref cursor variables. You can also use cursor expressions in dynamic SQL queries. Here is the syntax:

`CURSOR(`*`subquery`*`)`

A nested cursor is implicitly opened when the containing row is fetched from the parent cursor. The nested cursor is closed only when:

- The nested cursor is explicitly closed by the user
- The parent cursor is reexecuted
- The parent cursor is closed
- The parent cursor is canceled
- An error arises during a fetch on one of its parent cursors. The nested cursor is closed as part of the clean-up.

Restrictions on Cursor Expressions

The following are restrictions on cursor expressions:

- You cannot use a cursor expression with an implicit cursor.
- Cursor expressions can appear only:
  - In a `SELECT` statement that is not nested in any other query expression, except when it is a subquery of the cursor expression itself.

  - As arguments to table functions, in the FROM clause of a SELECT statement.
- Cursor expressions can appear only in the outermost SELECT list of the query specification.
- Cursor expressions cannot appear in view declarations.
- You cannot perform BIND and EXECUTE operations on cursor expressions.

Example of Cursor Expressions

In Example 6–35, we find a specified location ID, and a cursor from which we can fetch all the departments in that location. As we fetch each department's name, we also get another cursor that lets us fetch their associated employee details from another table.

Example 6–35 Using a Cursor Expression

```
DECLARE
   TYPE emp_cur_typ IS REF CURSOR;
   emp_cur emp_cur_typ;
   dept_name departments.department_name%TYPE;
   emp_name employees.last_name%TYPE;
   CURSOR c1 IS SELECT
      department_name,
-- second item in the result set is another result set,
-- which is represented as a ref cursor and labelled "employees".
      CURSOR
      ( SELECT e.last_name FROM employees e
         WHERE e.department_id = d.department_id) employees
      FROM departments d WHERE department_name like 'A%';
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO dept_name, emp_cur;
      EXIT WHEN c1%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE('Department: ' || dept_name);
-- for each row in the result set, the result set from a subquery is processed
-- the set could be passed to a procedure for processing rather than the loop
      LOOP
         FETCH emp_cur INTO emp_name;
         EXIT WHEN emp_cur%NOTFOUND;
         DBMS_OUTPUT.PUT_LINE('-- Employee: ' || emp_name);
      END LOOP;
   END LOOP;
   CLOSE c1;
END;
/
```

Constructing REF CURSORs with Cursor Subqueries

You can use cursor subqueries, also know as cursor expressions, to pass sets of rows as parameters to functions. For example, this statement passes a parameter to the StockPivot function consisting of a REF CURSOR that represents the rows returned by the cursor subquery:

```
SELECT * FROM TABLE(StockPivot(
              CURSOR(SELECT * FROM StockTable)));
```

Cursor subqueries are often used with table functions, which are explained in "Setting Up Transformations with Pipelined Functions" on page 11-31.

Overview of Transaction Processing in PL/SQL

This section explains transaction processing with PL/SQL using SQL `COMMIT`, `SAVEPOINT`, and `ROLLBACK` statements that ensure the consistency of a database. You can include these SQL statements directly in your PL/SQL programs. Transaction processing is an Oracle feature, available through all programming languages, that lets multiple users work on the database concurrently, and ensures that each user sees a consistent version of data and that all changes are applied in the right order.

You usually do not need to write extra code to prevent problems with multiple users accessing data concurrently. Oracle uses locks to control concurrent access to data, and locks only the minimum amount of data necessary, for as little time as possible. You can request locks on tables or rows if you really do need this level of control. You can choose from several modes of locking such as `row share` and `exclusive`.

For information on transactions, see *Oracle Database Concepts*. For information on the SQL `COMMIT`, `SAVEPOINT`, and `ROLLBACK` statements, see the *Oracle Database SQL Reference*.

Using COMMIT in PL/SQL

The `COMMIT` statement ends the current transaction, making any changes made during that transaction permanent, and visible to other users. Transactions are not tied to PL/SQL `BEGIN-END` blocks. A block can contain multiple transactions, and a transaction can span multiple blocks.

Example 6–36 illustrates a transaction that transfers money from one bank account to another. It is important that the money come out of one account, and into the other, at exactly the same moment. Otherwise, a problem partway through might make the money be lost from both accounts or be duplicated in both accounts.

Example 6–36 Using COMMIT With the WRITE Clause

```
CREATE TABLE accounts (account_id NUMBER(6), balance NUMBER (10,2));
INSERT INTO accounts VALUES (7715, 6350.00);
INSERT INTO accounts VALUES (7720, 5100.50);
DECLARE
  transfer NUMBER(8,2) := 250;
BEGIN
  UPDATE accounts SET balance = balance - transfer WHERE account_id = 7715;
  UPDATE accounts SET balance = balance + transfer WHERE account_id = 7720;
  COMMIT COMMENT 'Transfer From 7715 to 7720' WRITE IMMEDIATE NOWAIT;
END;
/
```

The optional `COMMENT` clause lets you specify a comment to be associated with a distributed transaction. If a network or machine fails during the commit, the state of the distributed transaction might be unknown or in doubt. In that case, Oracle stores the text specified by `COMMENT` in the data dictionary along with the transaction ID.

Asynchronous commit provides more control for the user with the `WRITE` clause. This option specifies the priority with which the redo information generated by the commit operation is written to the redo log.

For more information on using `COMMIT`, see "Committing Transactions" in *Oracle Database Application Developer's Guide - Fundamentals*. For information about distributed transactions, see *Oracle Database Concepts*. See also "COMMIT Statement" on page 13-24.

Using ROLLBACK in PL/SQL

The ROLLBACK statement ends the current transaction and undoes any changes made during that transaction. If you make a mistake, such as deleting the wrong row from a table, a rollback restores the original data. If you cannot finish a transaction because an exception is raised or a SQL statement fails, a rollback lets you take corrective action and perhaps start over.

Example 6–37 inserts information about an employee into three different database tables. If an INSERT statement tries to store a duplicate employee number, the predefined exception DUP_VAL_ON_INDEX is raised. To make sure that changes to all three tables are undone, the exception handler executes a ROLLBACK.

Example 6–37 Using ROLLBACK

```
CREATE TABLE emp_name AS SELECT employee_id, last_name FROM employees;
CREATE UNIQUE INDEX empname_ix ON emp_name (employee_id);
CREATE TABLE emp_sal AS SELECT employee_id, salary FROM employees;
CREATE UNIQUE INDEX empsal_ix ON emp_sal (employee_id);
CREATE TABLE emp_job AS SELECT employee_id, job_id FROM employees;
CREATE UNIQUE INDEX empjobid_ix ON emp_job (employee_id);

DECLARE
   emp_id       NUMBER(6);
   emp_lastname VARCHAR2(25);
   emp_salary   NUMBER(8,2);
   emp_jobid    VARCHAR2(10);
BEGIN
   SELECT employee_id, last_name, salary, job_id INTO emp_id, emp_lastname,
     emp_salary, emp_jobid FROM employees WHERE employee_id = 120;
   INSERT INTO emp_name VALUES (emp_id, emp_lastname);
   INSERT INTO emp_sal VALUES (emp_id, emp_salary);
   INSERT INTO emp_job VALUES (emp_id, emp_jobid);
EXCEPTION
   WHEN DUP_VAL_ON_INDEX THEN
      ROLLBACK;
      DBMS_OUTPUT.PUT_LINE('Inserts have been rolled back');
END;
/
```

See also "ROLLBACK Statement" on page 13-103.

Using SAVEPOINT in PL/SQL

SAVEPOINT names and marks the current point in the processing of a transaction. Savepoints let you roll back part of a transaction instead of the whole transaction. The number of active savepoints for each session is unlimited.

Example 6–38 marks a savepoint before doing an insert. If the INSERT statement tries to store a duplicate value in the employee_id column, the predefined exception DUP_VAL_ON_INDEX is raised. In that case, you roll back to the savepoint, undoing just the insert.

Example 6–38 Using SAVEPOINT With ROLLBACK

```
CREATE TABLE emp_name AS SELECT employee_id, last_name, salary FROM employees;
CREATE UNIQUE INDEX empname_ix ON emp_name (employee_id);

DECLARE
   emp_id        employees.employee_id%TYPE;
   emp_lastname  employees.last_name%TYPE;
   emp_salary    employees.salary%TYPE;
BEGIN
   SELECT employee_id, last_name, salary INTO emp_id, emp_lastname,
     emp_salary FROM employees WHERE employee_id = 120;
   UPDATE emp_name SET salary = salary * 1.1 WHERE employee_id = emp_id;
   DELETE FROM emp_name WHERE employee_id = 130;
   SAVEPOINT do_insert;
   INSERT INTO emp_name VALUES (emp_id, emp_lastname, emp_salary);
EXCEPTION
   WHEN DUP_VAL_ON_INDEX THEN
      ROLLBACK TO do_insert;
      DBMS_OUTPUT.PUT_LINE('Insert has been rolled back');
END;
/
```

When you roll back to a savepoint, any savepoints marked after that savepoint are erased. The savepoint to which you roll back is not erased. A simple rollback or commit erases all savepoints.

If you mark a savepoint within a recursive subprogram, new instances of the `SAVEPOINT` statement are executed at each level in the recursive descent, but you can only roll back to the most recently marked savepoint.

Savepoint names are undeclared identifiers. Reusing a savepoint name within a transaction moves the savepoint from its old position to the current point in the transaction. This means that a rollback to the savepoint affects only the current part of your transaction, as shown in Example 6–39.

Example 6–39 Reusing a SAVEPOINT With ROLLBACK

```
CREATE TABLE emp_name AS SELECT employee_id, last_name, salary FROM employees;
CREATE UNIQUE INDEX empname_ix ON emp_name (employee_id);

DECLARE
   emp_id        employees.employee_id%TYPE;
   emp_lastname  employees.last_name%TYPE;
   emp_salary    employees.salary%TYPE;
BEGIN
   SELECT employee_id, last_name, salary INTO emp_id, emp_lastname,
     emp_salary FROM employees WHERE employee_id = 120;
   SAVEPOINT my_savepoint;
   UPDATE emp_name SET salary = salary * 1.1 WHERE employee_id = emp_id;
   DELETE FROM emp_name WHERE employee_id = 130;
   SAVEPOINT my_savepoint;  -- move my_savepoint to current poin
   INSERT INTO emp_name VALUES (emp_id, emp_lastname, emp_salary);
EXCEPTION
   WHEN DUP_VAL_ON_INDEX THEN
      ROLLBACK TO my_savepoint;
      DBMS_OUTPUT.PUT_LINE('Transaction rolled back.');
END;
/
```

See also "SAVEPOINT Statement" on page 13-106.

How Oracle Does Implicit Rollbacks

Before executing an `INSERT`, `UPDATE`, or `DELETE` statement, Oracle marks an implicit savepoint (unavailable to you). If the statement fails, Oracle rolls back to the savepoint. Usually, just the failed SQL statement is rolled back, not the whole transaction. If the statement raises an unhandled exception, the host environment determines what is rolled back.

Oracle can also roll back single SQL statements to break deadlocks. Oracle signals an error to one of the participating transactions and rolls back the current statement in that transaction.

Before executing a SQL statement, Oracle must parse it, that is, examine it to make sure it follows syntax rules and refers to valid schema objects. Errors detected while executing a SQL statement cause a rollback, but errors detected while parsing the statement do not.

If you exit a stored subprogram with an unhandled exception, PL/SQL does not assign values to `OUT` parameters, and does not do any rollback.

Ending Transactions

You should explicitly commit or roll back every transaction. Whether you issue the commit or rollback in your PL/SQL program or from a client program depends on the application logic. If you do not commit or roll back a transaction explicitly, the client environment determines its final state.

For example, in the SQL*Plus environment, if your PL/SQL block does not include a `COMMIT` or `ROLLBACK` statement, the final state of your transaction depends on what you do after running the block. If you execute a data definition, data control, or `COMMIT` statement or if you issue the `EXIT`, `DISCONNECT`, or `QUIT` command, Oracle commits the transaction. If you execute a `ROLLBACK` statement or abort the SQL*Plus session, Oracle rolls back the transaction.

Setting Transaction Properties with SET TRANSACTION

You use the `SET TRANSACTION` statement to begin a read-only or read-write transaction, establish an isolation level, or assign your current transaction to a specified rollback segment. Read-only transactions are useful for running multiple queries while other users update the same tables.

During a read-only transaction, all queries refer to the same snapshot of the database, providing a multi-table, multi-query, read-consistent view. Other users can continue to query or update data as usual. A commit or rollback ends the transaction. In Example 6–40 a store manager uses a read-only transaction to gather order totals for the day, the past week, and the past month. The totals are unaffected by other users updating the database during the transaction.

Example 6–40 Using SET TRANSACTION to Begin a Read-only Transaction

```
DECLARE
   daily_order_total   NUMBER(12,2);
   weekly_order_total  NUMBER(12,2);
   monthly_order_total NUMBER(12,2);
BEGIN
   COMMIT; -- ends previous transaction
   SET TRANSACTION READ ONLY NAME 'Calculate Order Totals';
   SELECT SUM (order_total) INTO daily_order_total FROM orders
     WHERE order_date = SYSDATE;
   SELECT SUM (order_total) INTO weekly_order_total FROM orders
     WHERE order_date = SYSDATE - 7;
   SELECT SUM (order_total) INTO monthly_order_total FROM orders
     WHERE order_date = SYSDATE - 30;
   COMMIT; -- ends read-only transaction
```

```
END;
/
```

The SET TRANSACTION statement must be the first SQL statement in a read-only transaction and can only appear once in a transaction. If you set a transaction to READ ONLY, subsequent queries see only changes committed before the transaction began. The use of READ ONLY does not affect other users or transactions.

Restrictions on SET TRANSACTION

Only the SELECT INTO, OPEN, FETCH, CLOSE, LOCK TABLE, COMMIT, and ROLLBACK statements are allowed in a read-only transaction. Queries cannot be FOR UPDATE.

Overriding Default Locking

By default, Oracle locks data structures for you automatically, which is a major strength of the Oracle database: different applications can read and write to the same data without harming each other's data or coordinating with each other.

You can request data locks on specific rows or entire tables if you need to override default locking. Explicit locking lets you deny access to data for the duration of a transaction.:

- With the LOCK TABLE statement, you can explicitly lock entire tables.
- With the SELECT FOR UPDATE statement, you can explicitly lock specific rows of a table to make sure they do not change after you have read them. That way, you can check which or how many rows will be affected by an UPDATE or DELETE statement before issuing the statement, and no other application can change the rows in the meantime.

Using FOR UPDATE

When you declare a cursor that will be referenced in the CURRENT OF clause of an UPDATE or DELETE statement, you must use the FOR UPDATE clause to acquire exclusive row locks. An example follows:

```
DECLARE
   CURSOR c1 IS SELECT employee_id, salary FROM employees
      WHERE job_id = 'SA_REP' AND commission_pct > .10
      FOR UPDATE NOWAIT;
```

The SELECT ... FOR UPDATE statement identifies the rows that will be updated or deleted, then locks each row in the result set. This is useful when you want to base an update on the existing values in a row. In that case, you must make sure the row is not changed by another user before the update.

The optional keyword NOWAIT tells Oracle not to wait if requested rows have been locked by another user. Control is immediately returned to your program so that it can do other work before trying again to acquire the lock. If you omit the keyword NOWAIT, Oracle waits until the rows are available.

All rows are locked when you open the cursor, not as they are fetched. The rows are unlocked when you commit or roll back the transaction. Since the rows are no longer locked, you cannot fetch from a FOR UPDATE cursor after a commit. For a workaround, see "Fetching Across Commits" on page 6-35.

When querying multiple tables, you can use the FOR UPDATE clause to confine row locking to particular tables. Rows in a table are locked only if the FOR UPDATE OF clause refers to a column in that table. For example, the following query locks rows in the `employees` table but not in the `departments` table:

```
DECLARE
  CURSOR c1 IS SELECT last_name, department_name FROM employees, departments
    WHERE employees.department_id = departments.department_id
          AND job_id = 'SA_MAN'
      FOR UPDATE OF salary;
```

As shown in Example 6–41, you use the `CURRENT OF` clause in an `UPDATE` or `DELETE` statement to refer to the latest row fetched from a cursor.

Example 6–41 Using CURRENT OF to Update the Latest Row Fetched From a Cursor

```
DECLARE
   my_emp_id NUMBER(6);
   my_job_id VARCHAR2(10);
   my_sal    NUMBER(8,2);
   CURSOR c1 IS SELECT employee_id, job_id, salary FROM employees FOR UPDATE;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO my_emp_id, my_job_id, my_sal;
      IF my_job_id = 'SA_REP' THEN
        UPDATE employees SET salary = salary * 1.02 WHERE CURRENT OF c1;
      END IF;
      EXIT WHEN c1%NOTFOUND;
   END LOOP;
END;
/
```

Using LOCK TABLE

You use the `LOCK TABLE` statement to lock entire database tables in a specified lock mode so that you can share or deny access to them. Row share locks allow concurrent access to a table; they prevent other users from locking the entire table for exclusive use. Table locks are released when your transaction issues a commit or rollback.

```
LOCK TABLE employees IN ROW SHARE MODE NOWAIT;
```

The lock mode determines what other locks can be placed on the table. For example, many users can acquire row share locks on a table at the same time, but only one user at a time can acquire an exclusive lock. While one user has an exclusive lock on a table, no other users can insert, delete, or update rows in that table. For more information about lock modes, see *Oracle Database Application Developer's Guide - Fundamentals*.

A table lock never keeps other users from querying a table, and a query never acquires a table lock. Only if two different transactions try to modify the same row will one transaction wait for the other to complete.

Fetching Across Commits

PL/SQL raises an exception if you try to fetch from a `FOR UPDATE` cursor after doing a commit. The `FOR UPDATE` clause locks the rows when you open the cursor, and unlocks them when you commit.

```
DECLARE
-- if "FOR UPDATE OF salary" is included on following line, an error is raised
   CURSOR c1 IS SELECT * FROM employees;
   emp_rec  employees%ROWTYPE;
BEGIN
   OPEN c1;
   LOOP
     FETCH c1 INTO emp_rec; -- FETCH fails on the second iteration with FOR UPDATE
     EXIT WHEN c1%NOTFOUND;
     IF emp_rec.employee_id = 105 THEN
       UPDATE employees SET salary = salary * 1.05 WHERE employee_id = 105;
     END IF;
     COMMIT;  -- releases locks
   END LOOP;
END;
/
```

If you want to fetch across commits, use the `ROWID` pseudocolumn to mimic the `CURRENT OF` clause. Select the rowid of each row into a `UROWID` variable, then use the rowid to identify the current row during subsequent updates and deletes.

Example 6–42 Fetching Across COMMITs Using ROWID

```
DECLARE
   CURSOR c1 IS SELECT last_name, job_id, rowid FROM employees;
   my_lastname   employees.last_name%TYPE;
   my_jobid      employees.job_id%TYPE;
   my_rowid      UROWID;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO my_lastname, my_jobid, my_rowid;
      EXIT WHEN c1%NOTFOUND;
      UPDATE employees SET salary = salary * 1.02 WHERE rowid = my_rowid;
      -- this mimics WHERE CURRENT OF c1
      COMMIT;
   END LOOP;
   CLOSE c1;
END;
/
```

Because the fetched rows are not locked by a `FOR UPDATE` clause, other users might unintentionally overwrite your changes. The extra space needed for read consistency is not released until the cursor is closed, which can slow down processing for large updates.

The next example shows that you can use the `%ROWTYPE` attribute with cursors that reference the `ROWID` pseudocolumn:

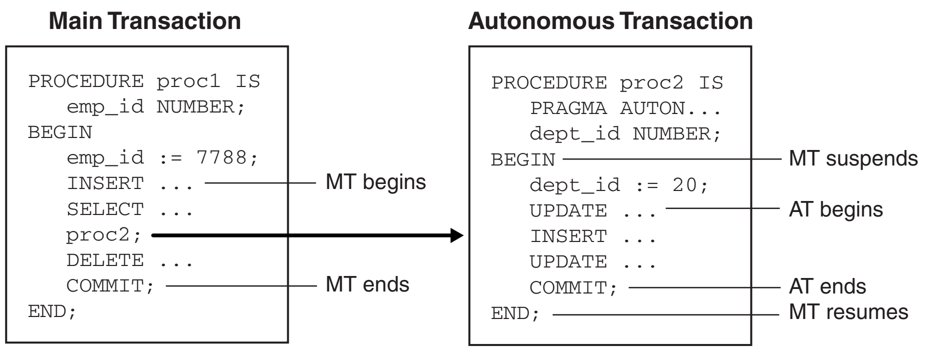
```
DECLARE
   CURSOR c1 IS SELECT employee_id, last_name, salary, rowid FROM employees;
   emp_rec c1%ROWTYPE;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO emp_rec;
      EXIT WHEN c1%NOTFOUND;
      IF emp_rec.salary = 0 THEN
         DELETE FROM employees WHERE rowid = emp_rec.rowid;
      END IF;
   END LOOP;
   CLOSE c1;
END;
/
```

Doing Independent Units of Work with Autonomous Transactions

An autonomous transaction is an independent transaction started by another transaction, the main transaction. Autonomous transactions do SQL operations and commit or roll back, without committing or rolling back the main transaction. For example, if you write auditing data to a log table, you want to commit the audit data even if the operation you are auditing later fails; if something goes wrong recording the audit data, you do not want the main operation to be rolled back.

Figure 6–1 shows how control flows from the main transaction (MT) to an autonomous transaction (AT) and back again.

Figure 6–1 Transaction Control Flow



```
PROCEDURE proc1 IS
   emp_id NUMBER;
BEGIN
   emp_id := 7788;
   INSERT ...
   SELECT ...
   proc2;
   DELETE ...
   COMMIT;
END;
```

```
PROCEDURE proc2 IS
   PRAGMA AUTON...
   dept_id NUMBER;
BEGIN
   dept_id := 20;
   UPDATE ...
   INSERT ...
   UPDATE ...
   COMMIT;
END;
```

Advantages of Autonomous Transactions

Once started, an autonomous transaction is fully independent. It shares no locks, resources, or commit-dependencies with the main transaction. You can log events, increment retry counters, and so on, even if the main transaction rolls back.

More important, autonomous transactions help you build modular, reusable software components. You can encapsulate autonomous transactions within stored procedures. A calling application does not need to know whether operations done by that stored procedure succeeded or failed.

Defining Autonomous Transactions

To define autonomous transactions, you use 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
- Database triggers

You can code the pragma anywhere in the declarative section of a routine. But, for readability, code the pragma at the top of the section. The syntax is `PRAGMA AUTONOMOUS_TRANSACTION`.

Example 6–43 marks a packaged function as autonomous. 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.

Example 6–43 Declaring an Autonomous Function in a Package

```
CREATE OR REPLACE PACKAGE emp_actions AS  -- package specification
   FUNCTION raise_salary (emp_id NUMBER, sal_raise NUMBER) RETURN NUMBER;
END emp_actions;
/
CREATE OR REPLACE PACKAGE BODY emp_actions AS  -- package body
-- code for function raise_salary
   FUNCTION raise_salary (emp_id NUMBER, sal_raise NUMBER) RETURN NUMBER IS
     PRAGMA AUTONOMOUS_TRANSACTION;
     new_sal NUMBER(8,2);
   BEGIN
     UPDATE employees SET salary = salary + sal_raise WHERE employee_id = emp_id;
     COMMIT;
     SELECT salary INTO new_sal FROM employees WHERE employee_id = emp_id;
     RETURN new_sal;
   END raise_salary;
END emp_actions;
/
```

Example 6–44 marks a standalone procedure as autonomous.

Example 6–44 Declaring an Autonomous Standalone Procedure

```
CREATE PROCEDURE lower_salary (emp_id NUMBER, amount NUMBER) AS
  PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
  UPDATE employees SET salary = salary - amount WHERE employee_id = emp_id;
  COMMIT;
END lower_salary;
/
```

Example 6–45 marks a PL/SQL block as autonomous. However, you cannot mark a nested PL/SQL block as autonomous.

Example 6–45 Declaring an Autonomous PL/SQL Block

```
DECLARE
  PRAGMA AUTONOMOUS_TRANSACTION;
  emp_id NUMBER(6);
  amount NUMBER(6,2);
BEGIN
  emp_id := 200;
  amount := 200;
  UPDATE employees SET salary = salary - amount WHERE employee_id = emp_id;
  COMMIT;
END;
/
```

Example 6–46 marks a database trigger as autonomous. Unlike regular triggers, autonomous triggers can contain transaction control statements such as `COMMIT` and `ROLLBACK`.

Example 6–46 Declaring an Autonomous Trigger

```
CREATE TABLE emp_audit ( emp_audit_id NUMBER(6), up_date DATE,
                         new_sal NUMBER(8,2), old_sal NUMBER(8,2) );

CREATE OR REPLACE TRIGGER audit_sal
   AFTER UPDATE OF salary ON employees FOR EACH ROW
DECLARE
```

```
   PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
-- bind variables are used here for values
   INSERT INTO emp_audit VALUES( :old.employee_id, SYSDATE,
                                 :new.salary, :old.salary );
  COMMIT;
END;
/
```

Comparison of Autonomous Transactions and Nested Transactions

Although an autonomous transaction is started by another transaction, it is not a nested transaction:

- It does not share transactional resources (such as locks) with the main transaction.
- It does not depend on the main transaction. For example, if the main transaction rolls back, nested transactions roll back, but autonomous transactions do not.
- Its committed changes are visible to other transactions immediately. (A nested transaction's committed changes are not visible to other transactions until the main transaction commits.)
- Exceptions raised in an autonomous transaction cause a transaction-level rollback, not a statement-level rollback.

Transaction Context

The main transaction shares its context with nested routines, but not with autonomous transactions. When one autonomous routine calls another (or itself recursively), the routines share no transaction context. When an autonomous routine calls a non-autonomous routine, the routines share the same transaction context.

Transaction Visibility

Changes made by an autonomous transaction become visible to other transactions when the autonomous transaction commits. These changes become visible to the main transaction when it resumes, if its isolation level is set to `READ COMMITTED` (the default).

If you set the isolation level of the main transaction to `SERIALIZABLE`, changes made by its autonomous transactions are *not* visible to the main transaction when it resumes:

```
SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
```

Controlling Autonomous Transactions

The first SQL statement in an autonomous routine begins a transaction. When one transaction ends, the next SQL statement begins another transaction. All SQL statements executed since the last commit or rollback make up the current transaction. To control autonomous transactions, use the following statements, which apply only to the current (active) transaction:

- `COMMIT`
- `ROLLBACK [TO savepoint_name]`
- `SAVEPOINT savepoint_name`
- `SET TRANSACTION`

Note:

- Transaction properties set in the main transaction apply only to that transaction, not to its autonomous transactions, and vice versa.
- Cursor attributes are not affected by autonomous transactions.

Entering and Exiting

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

To exit normally, you must explicitly commit or roll back all autonomous transactions. If the routine (or any routine called by it) has pending transactions, an exception is raised, and the pending transactions are rolled back.

Committing and Rolling Back

`COMMIT` and `ROLLBACK` end the active autonomous transaction but do not exit the autonomous routine. When one transaction ends, the next SQL statement begins another transaction. A single autonomous routine could contain several autonomous transactions, if it issued several `COMMIT` statements.

Using Savepoints

The scope of a savepoint is the transaction in which it is defined. Savepoints defined in the main transaction are unrelated to savepoints defined in its autonomous transactions. In fact, the main transaction and an autonomous transaction can use the same savepoint names.

You can roll back only to savepoints marked in the current transaction. In an autonomous transaction, you cannot roll back to a savepoint marked in the main transaction. To do so, you must resume the main transaction by exiting the autonomous routine.

When in the main transaction, rolling back to a savepoint marked before you started an autonomous transaction does *not* roll back the autonomous transaction. Remember, autonomous transactions are fully independent of the main transaction.

Avoiding Errors with Autonomous Transactions

To avoid some common errors, keep the following points in mind:

- If an autonomous transaction attempts to access a resource held by the main transaction, a deadlock can occur. Oracle raises an exception in the autonomous transaction, which is rolled back if the exception goes unhandled.
- The Oracle initialization parameter `TRANSACTIONS` specifies the maximum number of concurrent transactions. That number might be exceeded because an autonomous transaction runs concurrently with the main transaction.
- If you try to exit an active autonomous transaction without committing or rolling back, Oracle raises an exception. If the exception goes unhandled, the transaction is rolled back.

Using Autonomous Triggers

Among other things, you can use database triggers to log events transparently. Suppose you want to track all inserts into a table, even those that roll back. In Example 6–47, you use a trigger to insert duplicate rows into a shadow table. Because it is autonomous, the trigger can commit changes to the shadow table whether or not you commit changes to the main table.

Example 6–47 Using Autonomous Triggers

```
CREATE TABLE emp_audit ( emp_audit_id NUMBER(6), up_date DATE,
                         new_sal NUMBER(8,2), old_sal NUMBER(8,2) );

-- create an autonomous trigger that inserts into the audit table before
-- each update of salary in the employees table
CREATE OR REPLACE TRIGGER audit_sal
   BEFORE UPDATE OF salary ON employees FOR EACH ROW
DECLARE
   PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
  INSERT INTO emp_audit VALUES( :old.employee_id, SYSDATE,
                                :new.salary, :old.salary );
  COMMIT;
END;
/
-- update the salary of an employee, and then commit the insert
UPDATE employees SET salary = salary * 1.05 WHERE employee_id = 115;
COMMIT;

-- update another salary, then roll back the update
UPDATE employees SET salary = salary * 1.05 WHERE employee_id = 116;
ROLLBACK;

-- show that both committed and rolled-back updates add rows to audit table
SELECT * FROM emp_audit WHERE emp_audit_id = 115 OR emp_audit_id = 116;
```

Unlike regular triggers, autonomous triggers can execute DDL statements using native dynamic SQL, discussed in Chapter 7, "Performing SQL Operations with Native Dynamic SQL". In the following example, trigger `drop_temp_table` drops a temporary database table after a row is inserted in table `emp_audit`.

```
CREATE TABLE emp_audit ( emp_audit_id NUMBER(6), up_date DATE,
                         new_sal NUMBER(8,2), old_sal NUMBER(8,2) );
CREATE TABLE temp_audit ( emp_audit_id NUMBER(6), up_date DATE);

CREATE OR REPLACE TRIGGER drop_temp_table
   AFTER INSERT ON emp_audit
DECLARE
   PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
   EXECUTE IMMEDIATE 'DROP TABLE temp_audit';
   COMMIT;
END;
/
```

For more information about database triggers, see *Oracle Database Application Developer's Guide - Fundamentals*.

Calling Autonomous Functions from SQL

A function called from SQL statements must obey certain rules meant to control side effects. See "Controlling Side Effects of PL/SQL Subprograms" on page 8-23. To check for violations of the rules, you can use the pragma `RESTRICT_REFERENCES`. The pragma asserts that a function does not read or write database tables or package variables. For more information, See *Oracle Database Application Developer's Guide - Fundamentals*.

However, by definition, autonomous routines never violate the rules `read no database state (RNDS)` and `write no database state (WNDS)` no matter what they do. This can be useful, as Example 6–48 shows. When you call the packaged function `log_msg` from a query, it inserts a message into database table `debug_output` without violating the rule `write no database state`.

Example 6–48 Calling an Autonomous Function

```
-- create the debug table
CREATE TABLE debug_output (msg VARCHAR2(200));

-- create the package spec
CREATE PACKAGE debugging AS
   FUNCTION log_msg (msg VARCHAR2) RETURN VARCHAR2;
   PRAGMA RESTRICT_REFERENCES(log_msg, WNDS, RNDS);
END debugging;
/
-- create the package body
CREATE PACKAGE BODY debugging AS
   FUNCTION log_msg (msg VARCHAR2) RETURN VARCHAR2 IS
      PRAGMA AUTONOMOUS_TRANSACTION;
   BEGIN
      -- the following insert does not violate the constraint
      -- WNDS because this is an autonomous routine
      INSERT INTO debug_output VALUES (msg);
      COMMIT;
      RETURN msg;
   END;
END debugging;
/
-- call the packaged function from a query
DECLARE
   my_emp_id    NUMBER(6);
   my_last_name VARCHAR2(25);
   my_count     NUMBER;
BEGIN
   my_emp_id := 120;
   SELECT debugging.log_msg(last_name) INTO my_last_name FROM employees
      WHERE employee_id = my_emp_id;
-- even if you roll back in this scope, the insert into 'debug_output' remains
-- committed because it is part of an autonomous transaction
   ROLLBACK;
END;
/
```

7 Performing SQL Operations with Native Dynamic SQL

This chapter describes how to use native dynamic SQL (dynamic SQL for short) with PL/SQL to make your programs more flexible, by building and processing SQL statements at run time.

With dynamic SQL, you can directly execute most types of SQL statement, including data definition and data control statements. You can build statements in which you do not know table names, `WHERE` clauses, and other information in advance.

This chapter contains these topics:

For additional information about dynamic SQL, see *Oracle Database Application Developer's Guide - Fundamentals*.

Why Use Dynamic SQL with PL/SQL?

Dynamic SQL enables you to build SQL statements dynamically at runtime. You can create more general purpose, flexible applications by using dynamic SQL because the full text of a SQL statement may be unknown at compilation.

To process most dynamic SQL statements, you use the `EXECUTE IMMEDIATE` statement. To process a multi-row query (`SELECT` statement), you use the `OPEN-FOR`, `FETCH`, and `CLOSE` statements.

You need dynamic SQL in the following situations:

- You want to execute a SQL data definition statement (such as `CREATE`), a data control statement (such as `GRANT`), or a session control statement (such as `ALTER SESSION`). Unlike `INSERT`, `UPDATE`, and `DELETE` statements, these statements cannot be included directly in a PL/SQL program.
- You want more flexibility. For example, you might want to pass the name of a schema object as a parameter to a procedure. You might want to build different search conditions for the `WHERE` clause of a `SELECT` statement.
- You want to issue a query where you do not know the number, names, or datatypes of the columns in advance. In this case, you use the `DBMS_SQL` package rather than the `OPEN-FOR` statement.

If you have older code that uses the `DBMS_SQL` package, the techniques described in this chapter using `EXECUTE IMMEDIATE` and `OPEN-FOR` generally provide better performance, more readable code, and extra features such as support for objects and collections.

For a comparison of dynamic SQL with `DBMS_SQL`, see *Oracle Database Application Developer's Guide - Fundamentals*. For information on the `DBMS_SQL` package, see *Oracle Database PL/SQL Packages and Types Reference*.

Note: Native dynamic SQL using the `EXECUTE IMMEDIATE` and `OPEN-FOR` statements is faster and requires less coding than the `DBMS_SQL` package. However, the `DBMS_SQL` package should be used in these situations:

- There is an unknown number of input or output variables, such as the number of column values returned by a query, that are used in a dynamic SQL statement (Method 4 for dynamic SQL).
- The dynamic code is too large to fit inside a 32K bytes `VARCHAR2` variable.

Using the EXECUTE IMMEDIATE Statement in PL/SQL

The `EXECUTE IMMEDIATE` statement prepares (parses) and immediately executes a dynamic SQL statement or an anonymous PL/SQL block. The main argument to `EXECUTE IMMEDIATE` is the string containing the SQL statement to execute. You can build up the string using concatenation, or use a predefined string.

Except for multi-row queries, the dynamic string can contain any SQL statement or any PL/SQL block. The string can also contain placeholders, arbitrary names preceded by a colon, for bind arguments. In this case, you specify which PL/SQL variables correspond to the placeholders with the `INTO`, `USING`, and `RETURNING INTO` clauses.

When constructing a single SQL statement in a dynamic string, do not include a semicolon (;) at the end inside the quotation mark. When constructing a PL/SQL anonymous block, include the semicolon at the end of each PL/SQL statement and at the end of the anonymous block; there will be a semicolon immediately before the end of the string literal, and another following the closing single quotation mark.

You can only use placeholders in places where you can substitute variables in the SQL statement, such as conditional tests in `WHERE` clauses. You cannot use placeholders for the names of schema objects. For the right way, see "Passing Schema Object Names As Parameters" on page 7-8.

Used only for single-row queries, the `INTO` clause specifies the variables or record into which column values are retrieved. For each value retrieved by the query, there must be a corresponding, type-compatible variable or field in the `INTO` clause.

Used only for DML statements that have a `RETURNING` clause (without a `BULK COLLECT` clause), the `RETURNING INTO` clause specifies the variables into which column values are returned. For each value returned by the DML statement, there must be a corresponding, type-compatible variable in the `RETURNING INTO` clause.

You can place all bind arguments in the `USING` clause. The default parameter mode is `IN`. For DML statements that have a `RETURNING` clause, you can place `OUT` arguments in the `RETURNING INTO` clause without specifying the parameter mode. If you use both the `USING` clause and the `RETURNING INTO` clause, the `USING` clause can contain only `IN` arguments.

At run time, bind arguments replace corresponding placeholders in the dynamic string. Every placeholder must be associated with a bind argument in the `USING` clause and/or `RETURNING INTO` clause. You can use numeric, character, and string literals as bind arguments, but you cannot use Boolean literals (`TRUE`, `FALSE`, and `NULL`). To pass nulls to the dynamic string, you must use a workaround. See "Passing Nulls to Dynamic SQL" on page 7-10.

Dynamic SQL supports all the SQL datatypes. For example, define variables and bind arguments can be collections, `LOB`s, instances of an object type, and refs.

As a rule, dynamic SQL does not support PL/SQL-specific types. For example, define variables and bind arguments cannot be Booleans or associative arrays. The only exception is that a PL/SQL record can appear in the `INTO` clause.

You can execute a dynamic SQL statement repeatedly using new values for the bind arguments. However, you incur some overhead because `EXECUTE IMMEDIATE` re-prepares the dynamic string before every execution.

For more information on `EXECUTE IMMEDIATE`, see "EXECUTE IMMEDIATE Statement" on page 13-41.

Example 7–1 illustrates several uses of dynamic SQL.

Example 7–1 Examples of Dynamic SQL

```
CREATE OR REPLACE PROCEDURE raise_emp_salary (column_value NUMBER,
                             emp_column VARCHAR2, amount NUMBER) IS
   v_column VARCHAR2(30);
   sql_stmt  VARCHAR2(200);
BEGIN
-- determine if a valid column name has been given as input
  SELECT COLUMN_NAME INTO v_column FROM USER_TAB_COLS
    WHERE TABLE_NAME = 'EMPLOYEES' AND COLUMN_NAME = emp_column;
  sql_stmt := 'UPDATE employees SET salary = salary + :1 WHERE '
               || v_column || ' = :2';
  EXECUTE IMMEDIATE sql_stmt USING amount, column_value;
  IF SQL%ROWCOUNT > 0 THEN
    DBMS_OUTPUT.PUT_LINE('Salaries have been updated for: ' || emp_column
                        || ' = ' || column_value);
  END IF;
  EXCEPTION
  WHEN NO_DATA_FOUND THEN
    DBMS_OUTPUT.PUT_LINE ('Invalid Column: ' || emp_column);
END raise_emp_salary;
/

DECLARE
   plsql_block       VARCHAR2(500);
BEGIN
-- note the semi-colons (;) inside the quotes '...'
  plsql_block := 'BEGIN raise_emp_salary(:cvalue, :cname, :amt); END;';
  EXECUTE IMMEDIATE plsql_block USING 110, 'DEPARTMENT_ID', 10;
  EXECUTE IMMEDIATE 'BEGIN raise_emp_salary(:cvalue, :cname, :amt); END;'
      USING 112, 'EMPLOYEE_ID', 10;
END;
/

DECLARE
   sql_stmt          VARCHAR2(200);
   v_column          VARCHAR2(30) := 'DEPARTMENT_ID';
   dept_id           NUMBER(4) := 46;
   dept_name         VARCHAR2(30) := 'Special Projects';
   mgr_id            NUMBER(6) := 200;
   loc_id            NUMBER(4) := 1700;
BEGIN
-- note that there is no semi-colon (;) inside the quotes '...'
  EXECUTE IMMEDIATE 'CREATE TABLE bonus (id NUMBER, amt NUMBER)';
  sql_stmt := 'INSERT INTO departments VALUES (:1, :2, :3, :4)';
  EXECUTE IMMEDIATE sql_stmt USING dept_id, dept_name, mgr_id, loc_id;
  EXECUTE IMMEDIATE 'DELETE FROM departments WHERE ' || v_column || ' = :num'
      USING dept_id;
  EXECUTE IMMEDIATE 'ALTER SESSION SET SQL_TRACE TRUE';
  EXECUTE IMMEDIATE 'DROP TABLE bonus';
END;
/
```

In Example 7–2, a standalone procedure accepts the name of a database table and an optional `WHERE`-clause condition. If you omit the condition, the procedure deletes all rows from the table. Otherwise, the procedure deletes only those rows that meet the condition.

Example 7–2 Dynamic SQL Procedure that Accepts Table Name and WHERE Clause

```
CREATE TABLE employees_temp AS SELECT * FROM employees;

CREATE OR REPLACE PROCEDURE delete_rows (
   table_name IN VARCHAR2,
   condition  IN VARCHAR2 DEFAULT NULL) AS
   where_clause  VARCHAR2(100) := ' WHERE ' || condition;
   v_table      VARCHAR2(30);
BEGIN
-- first make sure that the table actually exists; if not, raise an exception
  SELECT OBJECT_NAME INTO v_table FROM USER_OBJECTS
    WHERE OBJECT_NAME = UPPER(table_name) AND OBJECT_TYPE = 'TABLE';
   IF condition IS NULL THEN where_clause := NULL; END IF;
   EXECUTE IMMEDIATE 'DELETE FROM ' || v_table || where_clause;
  EXCEPTION
  WHEN NO_DATA_FOUND THEN
    DBMS_OUTPUT.PUT_LINE ('Invalid table: ' || table_name);
END;
/
BEGIN
  delete_rows('employees_temp', 'employee_id = 111');
END;
/
```

Specifying Parameter Modes for Bind Variables in Dynamic SQL Strings

With the `USING` clause, the mode defaults to `IN`, so you do not need to specify a parameter mode for input bind arguments.

With the `RETURNING INTO` clause, the mode is `OUT`, so you cannot specify a parameter mode for output bind arguments.

You must specify the parameter mode in more complicated cases, such as this one where you call a procedure from a dynamic PL/SQL block:

```
CREATE PROCEDURE create_dept (
   deptid IN OUT NUMBER,
   dname  IN VARCHAR2,
   mgrid  IN NUMBER,
   locid  IN NUMBER) AS
BEGIN
   SELECT departments_seq.NEXTVAL INTO deptid FROM dual;
   INSERT INTO departments VALUES (deptid, dname, mgrid, locid);
END;
/
```

To call the procedure from a dynamic PL/SQL block, you must specify the `IN OUT` mode for the bind argument associated with formal parameter `deptid`, as shown in Example 7–3.

Example 7–3   Using IN OUT Bind Arguments to Specify Substitutions

```
DECLARE
   plsql_block VARCHAR2(500);
   new_deptid  NUMBER(4);
   new_dname   VARCHAR2(30) := 'Advertising';
   new_mgrid   NUMBER(6) := 200;
   new_locid   NUMBER(4) := 1700;
BEGIN
   plsql_block := 'BEGIN create_dept(:a, :b, :c, :d); END;';
   EXECUTE IMMEDIATE plsql_block
      USING IN OUT new_deptid, new_dname, new_mgrid, new_locid;
END;
/
```

Using Bulk Dynamic SQL in PL/SQL

Bulk SQL passes entire collections back and forth, not just individual elements. This technique improves performance by minimizing the number of context switches between the PL/SQL and SQL engines. You can use a single statement instead of a loop that issues a SQL statement in every iteration.

Using the following commands, clauses, and cursor attribute, your applications can construct bulk SQL statements, then execute them dynamically at run time:

`BULK FETCH` statement
`BULK EXECUTE IMMEDIATE` statement
`FORALL` statement
`COLLECT INTO` clause
`RETURNING INTO` clause
`%BULK_ROWCOUNT` cursor attribute

The static versions of these statements, clauses, and cursor attribute are discussed in "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8. Refer to that section for background information.

Using Dynamic SQL with Bulk SQL

Bulk binding lets Oracle bind a variable in a SQL statement to a collection of values. The collection type can be any PL/SQL collection type: index-by table, nested table, or varray. The collection elements must have a SQL datatype such as `CHAR`, `DATE`, or `NUMBER`. Three statements support dynamic bulk binds: `EXECUTE IMMEDIATE`, `FETCH`, and `FORALL`.

EXECUTE IMMEDIATE

You can use the `BULK COLLECT INTO` clause with the `EXECUTE IMMEDIATE` statement to store values from each column of a query's result set in a separate collection.

You can use the `RETURNING BULK COLLECT INTO` clause with the `EXECUTE IMMEDIATE` statement to store the results of an `INSERT`, `UPDATE`, or `DELETE` statement in a set of collections.

FETCH

You can use the `BULK COLLECT INTO` clause with the `FETCH` statement to store values from each column of a cursor in a separate collection.

FORALL

You can put an `EXECUTE IMMEDIATE` statement with the `RETURNING BULK COLLECT INTO` inside a `FORALL` statement. You can store the results of all the `INSERT`, `UPDATE`, or `DELETE` statements in a set of collections.

You can pass subscripted collection elements to the `EXECUTE IMMEDIATE` statement through the `USING` clause. You cannot concatenate the subscripted elements directly into the string argument to `EXECUTE IMMEDIATE`; for example, you cannot build a collection of table names and write a `FORALL` statement where each iteration applies to a different table.

Examples of Dynamic Bulk Binds

This sections contains examples of dynamic bulk binds.You can bind define variables in a dynamic query using the `BULK COLLECT INTO` clause. As shown in Example 7–4, you can use that clause in a bulk `FETCH` or bulk `EXECUTE IMMEDIATE` statement.

Example 7–4 Dynamic SQL with BULK COLLECT INTO Clause

```
DECLARE
   TYPE EmpCurTyp IS REF CURSOR;
   TYPE NumList IS TABLE OF NUMBER;
   TYPE NameList IS TABLE OF VARCHAR2(25);
   emp_cv EmpCurTyp;
   empids NumList;
   enames NameList;
   sals   NumList;
BEGIN
   OPEN emp_cv FOR 'SELECT employee_id, last_name FROM employees';
   FETCH emp_cv BULK COLLECT INTO empids, enames;
   CLOSE emp_cv;
   EXECUTE IMMEDIATE 'SELECT salary FROM employees'
      BULK COLLECT INTO sals;
END;
/
```

Only `INSERT`, `UPDATE`, and `DELETE` statements can have output bind variables. You bulk-bind them with the `RETURNING BULK COLLECT INTO` clause of `EXECUTE IMMEDIATE`, as shown in Example 7–5.

Example 7–5 Dynamic SQL with RETURNING BULK COLLECT INTO Clause

```
DECLARE
   TYPE NameList IS TABLE OF VARCHAR2(15);
   enames    NameList;
   bonus_amt NUMBER := 50;
   sql_stmt  VARCHAR(200);
BEGIN
   sql_stmt := 'UPDATE employees SET salary = salary + :1
                RETURNING last_name INTO :2';
   EXECUTE IMMEDIATE sql_stmt
      USING bonus_amt RETURNING BULK COLLECT INTO enames;
END;
/
```

To bind the input variables in a SQL statement, you can use the FORALL statement and USING clause, as shown in Example 7–6. The SQL statement cannot be a query.

Example 7–6 Dynamic SQL Inside FORALL Statement

```
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   TYPE NameList IS TABLE OF VARCHAR2(15);
   empids NumList;
   enames NameList;
BEGIN
   empids := NumList(101,102,103,104,105);
   FORALL i IN 1..5
      EXECUTE IMMEDIATE
        'UPDATE employees SET salary = salary * 1.04 WHERE employee_id = :1
         RETURNING last_name INTO :2'
         USING empids(i) RETURNING BULK COLLECT INTO enames;
END;
/
```

Guidelines for Using Dynamic SQL with PL/SQL

This section shows you how to take full advantage of dynamic SQL and how to avoid some common pitfalls.

Note: When using dynamic SQL with PL/SQL, be aware of the risks of SQL injection, which is a possible security issue. For more information on SQL injection and possible problems, see *Oracle Database Application Developer's Guide - Fundamentals*. You can also search for "SQL injection" on the Oracle Technology Network at http://www.oracle.com/technology/

Building a Dynamic Query with Dynamic SQL

You use three statements to process a dynamic multi-row query: OPEN-FOR, FETCH, and CLOSE. First, you OPEN a cursor variable FOR a multi-row query. Then, you FETCH rows from the result set one at a time. When all the rows are processed, you CLOSE the cursor variable. For more information about cursor variables, see "Using Cursor Variables (REF CURSORs)" on page 6-20.

When to Use or Omit the Semicolon with Dynamic SQL

When building up a single SQL statement in a string, do not include any semicolon at the end.

When building up a PL/SQL anonymous block, include the semicolon at the end of each PL/SQL statement and at the end of the anonymous block. For example:

```
BEGIN
   EXECUTE IMMEDIATE 'BEGIN DBMS_OUTPUT.PUT_LINE(''semicolons''); END;';
END;
/
```

Improving Performance of Dynamic SQL with Bind Variables

When you code `INSERT`, `UPDATE`, `DELETE`, and `SELECT` statements directly in PL/SQL, PL/SQL turns the variables into bind variables automatically, to make the statements work efficiently with SQL. When you build up such statements in dynamic SQL, you need to specify the bind variables yourself to get the same performance.

In the following example, Oracle opens a different cursor for each distinct value of `emp_id`. This can lead to resource contention and poor performance as each statement is parsed and cached.

```
CREATE PROCEDURE fire_employee (emp_id NUMBER) AS
BEGIN
   EXECUTE IMMEDIATE
      'DELETE FROM employees WHERE employee_id = ' || TO_CHAR(emp_id);
END;
/
```

You can improve performance by using a bind variable, which allows Oracle to reuse the same cursor for different values of `emp_id`:

```
CREATE PROCEDURE fire_employee (emp_id NUMBER) AS
BEGIN
   EXECUTE IMMEDIATE
      'DELETE FROM employees WHERE employee_id = :id' USING emp_id;
END;
/
```

Passing Schema Object Names As Parameters

Suppose you need a procedure that accepts the name of any database table, then drops that table from your schema. You must build a string with a statement that includes the object names, then use `EXECUTE IMMEDIATE` to execute the statement:

```
CREATE TABLE employees_temp AS SELECT last_name FROM employees;
CREATE PROCEDURE drop_table (table_name IN VARCHAR2) AS
BEGIN
  EXECUTE IMMEDIATE 'DROP TABLE ' || table_name;
END;
/
```

Use concatenation to build the string, rather than trying to pass the table name as a bind variable through the `USING` clause.

In addition, if you need to call a procedure whose name is unknown until runtime, you can pass a parameter identifying the procedure. For example, the following procedure can call another procedure (`drop_table`) by specifying the procedure name when executed.

```
CREATE PROCEDURE run_proc (proc_name IN VARCHAR2, table_name IN VARCHAR2) AS
BEGIN
   EXECUTE IMMEDIATE 'CALL "' || proc_name || '" ( :proc_name )' using table_name;
```

```
END;
/
```

If you want to drop a table with the `drop_table` procedure, you can run the procedure as follows. Note that the procedure name is capitalized.

```
CREATE TABLE employees_temp AS SELECT last_name FROM employees;
BEGIN
  run_proc('DROP_TABLE', 'employees_temp');
END;
/
```

Using Duplicate Placeholders with Dynamic SQL

Placeholders in a dynamic SQL statement are associated with bind arguments in the `USING` clause by position, not by name. If you specify a sequence of placeholders like `:a, :a, :b, :b`, you must include four items in the `USING` clause. For example, given the dynamic string

```
sql_stmt := 'INSERT INTO payroll VALUES (:x, :x, :y, :x)';
```

the fact that the name X is repeated is not significant. You can code the corresponding `USING` clause with four different bind variables:

```
EXECUTE IMMEDIATE sql_stmt USING a, a, b, a;
```

If the dynamic statement represents a PL/SQL block, the rules for duplicate placeholders are different. Each unique placeholder maps to a single item in the `USING` clause. If the same placeholder appears two or more times, all references to that name correspond to one bind argument in the `USING` clause. In Example 7–7, all references to the placeholder `x` are associated with the first bind argument a, and the second unique placeholder `y` is associated with the second bind argument b.

Example 7–7 Using Duplicate Placeholders With Dynamic SQL

```
CREATE PROCEDURE calc_stats(w NUMBER, x NUMBER, y NUMBER, z NUMBER) IS
BEGIN
  DBMS_OUTPUT.PUT_LINE(w + x + y + z);
END;
/
DECLARE
   a NUMBER := 4;
   b NUMBER := 7;
   plsql_block VARCHAR2(100);
BEGIN
   plsql_block := 'BEGIN calc_stats(:x, :x, :y, :x); END;';
   EXECUTE IMMEDIATE plsql_block USING a, b;
END;
/
```

Using Cursor Attributes with Dynamic SQL

The SQL cursor attributes `%FOUND`, `%ISOPEN`, `%NOTFOUND`, and `%ROWCOUNT` work when you issue an `INSERT`, `UPDATE`, `DELETE`, or single-row `SELECT` statement in dynamic SQL:

```
BEGIN
  EXECUTE IMMEDIATE 'DELETE FROM employees WHERE employee_id > 1000';
  DBMS_OUTPUT.PUT_LINE('Number of employees deleted: ' || TO_CHAR(SQL%ROWCOUNT));
```

```
END;
/
```

Likewise, when appended to a cursor variable name, the cursor attributes return information about the execution of a multi-row query:

Example 7–8   Accessing %ROWCOUNT For an Explicit Cursor

```
DECLARE
  TYPE cursor_ref IS REF CURSOR;
  c1 cursor_ref;
  TYPE emp_tab IS TABLE OF employees%ROWTYPE;
  rec_tab emp_tab;
  rows_fetched NUMBER;
BEGIN
  OPEN c1 FOR 'SELECT * FROM employees';
  FETCH c1 BULK COLLECT INTO rec_tab;
  rows_fetched := c1%ROWCOUNT;
  DBMS_OUTPUT.PUT_LINE('Number of employees fetched: ' || TO_CHAR(rows_fetched));
END;
/
```

For more information about cursor attributes, see "Managing Cursors in PL/SQL" on page 6-6.

Passing Nulls to Dynamic SQL

The literal NULL is not allowed in the USING clause. To work around this restriction, replace the keyword NULL with an uninitialized variable:

```
CREATE TABLE employees_temp AS SELECT * FROM EMPLOYEES;
DECLARE
   a_null CHAR(1); -- set to NULL automatically at run time
BEGIN
   EXECUTE IMMEDIATE 'UPDATE employees_temp SET commission_pct = :x' USING a_null;
END;
/
```

Using Database Links with Dynamic SQL

PL/SQL subprograms can execute dynamic SQL statements that use database links to refer to objects on remote databases:

```
CREATE PROCEDURE delete_dept (db_link VARCHAR2, dept_id INTEGER) IS
BEGIN
   EXECUTE IMMEDIATE 'DELETE FROM departments@' || db_link ||
      ' WHERE department_id = :num' USING dept_id;
END;
/
-- delete department id 41 in the departments table on the remote DB hr_db
CALL delete_dept('hr_db', 41);
```

The targets of remote procedure calls (RPCs) can contain dynamic SQL statements. For example, suppose the following standalone function, which returns the number of rows in a table, resides on the hr_db database in London:

```
CREATE FUNCTION row_count (tab_name VARCHAR2) RETURN NUMBER AS
   rows NUMBER;
BEGIN
```

```
   EXECUTE IMMEDIATE 'SELECT COUNT(*) FROM ' || tab_name INTO rows;
   RETURN rows;
END;
/
-- From an anonymous block, you might call the function remotely, as follows:
DECLARE
   emp_count INTEGER;
BEGIN
   emp_count := row_count@hr_db('employees');
   DBMS_OUTPUT.PUT_LINE(emp_count);
END;
/
```

Using Invoker Rights with Dynamic SQL

Dynamic SQL lets you write schema-management procedures that can be centralized in one schema, and can be called from other schemas and operate on the objects in those schemas. For example, this procedure can drop any kind of database object:

```
CREATE OR REPLACE PROCEDURE drop_it (kind IN VARCHAR2, name IN VARCHAR2)
  AUTHID CURRENT_USER AS
BEGIN
   EXECUTE IMMEDIATE 'DROP ' || kind || ' ' || name;
END;
/
```

Let's say that this procedure is part of the HR schema. Without the AUTHID clause, the procedure would always drop objects in the HR schema, regardless of who calls it. Even if you pass a fully qualified object name, this procedure would not have the privileges to make changes in other schemas.

The AUTHID clause lifts both of these restrictions. It lets the procedure run with the privileges of the user that invokes it, and makes unqualified references refer to objects in that user's schema.

For details, see "Using Invoker's Rights Versus Definer's Rights (AUTHID Clause)" on page 8-15.

Using Pragma RESTRICT_REFERENCES with Dynamic SQL

A function called from SQL statements must obey certain rules meant to control side effects. (See "Controlling Side Effects of PL/SQL Subprograms" on page 8-23.) To check for violations of the rules, you can use the pragma RESTRICT_REFERENCES. The pragma asserts that a function does not read or write database tables or package variables. (For more information, See *Oracle Database Application Developer's Guide - Fundamentals*.)

If the function body contains a dynamic INSERT, UPDATE, or DELETE statement, the function always violates the rules write no database state (WNDS) and read no database state (RNDS). PL/SQL cannot detect those side-effects automatically, because dynamic SQL statements are checked at run time, not at compile time. In an EXECUTE IMMEDIATE statement, only the INTO clause can be checked at compile time for violations of RNDS.

Avoiding Deadlocks with Dynamic SQL

In a few situations, executing a SQL data definition statement results in a deadlock. For example, the following procedure causes a deadlock because it attempts to drop itself. To avoid deadlocks, never try to ALTER or DROP a subprogram or package while you are still using it.

```
CREATE OR REPLACE PROCEDURE calc_bonus (emp_id NUMBER) AS
BEGIN
   EXECUTE IMMEDIATE 'DROP PROCEDURE calc_bonus'; -- deadlock!
END;
/
```

Backward Compatibility of the USING Clause

When a dynamic INSERT, UPDATE, or DELETE statement has a RETURNING clause, output bind arguments can go in the RETURNING INTO clause or the USING clause. In new applications, use the RETURNING INTO clause. In old applications, you can continue to use the USING clause.

Using Dynamic SQL With PL/SQL Records and Collections

You can use dynamic SQL with records and collections. As shown in Example 7–9, you can fetch rows from the result set of a dynamic multi-row query into a record:

Example 7–9 Dynamic SQL Fetching into a Record

```
DECLARE
   TYPE EmpCurTyp IS REF CURSOR;
   emp_cv   EmpCurTyp;
   emp_rec  employees%ROWTYPE;
   sql_stmt VARCHAR2(200);
   v_job   VARCHAR2(10) := 'ST_CLERK';
BEGIN
   sql_stmt := 'SELECT * FROM employees WHERE job_id = :j';
   OPEN emp_cv FOR sql_stmt USING v_job;
   LOOP
     FETCH emp_cv INTO emp_rec;
     EXIT WHEN emp_cv%NOTFOUND;
     DBMS_OUTPUT.PUT_LINE('Name: ' || emp_rec.last_name || ' Job Id: ' ||
                          emp_rec.job_id);
   END LOOP;
   CLOSE emp_cv;
END;
/
```

For an example of using dynamic SQL with object types, see "Using Dynamic SQL With Objects" on page 12-11.

8 Using PL/SQL Subprograms

This chapter shows you how to turn sets of statements into reusable subprograms. Subprograms are like building blocks for modular, maintainable applications.

This chapter contains these topics:

What Are Subprograms?

Subprograms are named PL/SQL blocks that can be called with a set of parameters. PL/SQL has two types of subprograms, procedures and functions. Generally, you use a procedure to perform an action and a function to compute a value.

Similar to anonymous blocks, subprograms have:

- A declarative part, with declarations of types, cursors, constants, variables, exceptions, and nested subprograms. These items are local and cease to exist when the subprogram ends.
- An executable part, with statements that assign values, control execution, and manipulate Oracle data.
- An optional exception-handling part, which deals with runtime error conditions.

Example 8–1 shows a string-manipulation procedure `double` that accepts both input and output parameters, and handles potential errors.

Example 8–1 Simple PL/SQL Procedure

```
DECLARE
  in_string  VARCHAR2(100) := 'This is my test string.';
  out_string VARCHAR2(200);
  PROCEDURE double ( original IN VARCHAR2, new_string OUT VARCHAR2 ) AS
    BEGIN
      new_string := original || ' + ' || original;
      EXCEPTION
      WHEN VALUE_ERROR THEN
        DBMS_OUTPUT.PUT_LINE('Output buffer not long enough.');
    END;
BEGIN
  double(in_string, out_string);
  DBMS_OUTPUT.PUT_LINE(in_string || ' - ' || out_string);
END;
/
```

Example 8–2 shows a numeric function `square` that declares a local variable to hold temporary results, and returns a value when finished.

Example 8–2 Simple PL/SQL Function

```
DECLARE
  FUNCTION square(original NUMBER)
    RETURN NUMBER AS original_squared NUMBER;
    BEGIN
      original_squared := original * original;
      RETURN original_squared;
    END;
BEGIN
  DBMS_OUTPUT.PUT_LINE(square(100));
END;
/
```

Note:

- The SQL `CREATE FUNCTION` statement lets you create standalone functions that are stored in an Oracle database. For information, see `CREATE FUNCTION` in *Oracle Database SQL Reference*.
- The SQL `CREATE PROCEDURE` statement lets you create standalone procedures that are stored in the database. For information, see `CREATE PROCEDURE` in *Oracle Database SQL Reference*.
- You can execute the `CREATE FUNCTION` or `CREATE PROCEDURE` statement interactively from SQL*Plus, or from a program using native dynamic SQL. See Chapter 7, "Performing SQL Operations with Native Dynamic SQL".

Advantages of PL/SQL Subprograms

Subprograms let you extend the PL/SQL language. Procedures act like new statements. Functions act like new expressions and operators.

Subprograms let you break a program down into manageable, well-defined modules. You can use top-down design and the stepwise refinement approach to problem solving.

Subprograms promote reusability. Once tested, a subprogram can be reused in any number of applications. You can call PL/SQL subprograms from many different environments, so that you do not have to reinvent the wheel each time you use a new language or API to access the database.

Subprograms promote maintainability. You can change the internals of a subprogram without changing other subprograms that call it. Subprograms play a big part in other maintainability features, such as packages and object types.

Dummy subprograms (stubs) let you defer the definition of procedures and functions until after testing the main program. You can design applications from the top down, thinking abstractly, without worrying about implementation details.

When you use PL/SQL subprograms to define an API, you can make your code even more reusable and maintainable by grouping the subprograms into a PL/SQL package. For more information about packages, see Chapter 9, "Using PL/SQL Packages".

Understanding PL/SQL Procedures

A procedure is a subprogram that performs a specific action. You specify the name of the procedure, its parameters, its local variables, and the `BEGIN-END` block that contains its code and handles any exceptions. For information on the syntax of the `PROCEDURE` declaration, see "Procedure Declaration" on page 13-90.

For each parameter, you specify:

- Its name.
- Its parameter mode (`IN`, `OUT`, or `IN OUT`). If you omit the mode, the default is `IN`. The optional `NOCOPY` keyword speeds up processing of large `OUT` or `IN OUT` parameters.
- Its datatype. You specify only the type, not any length or precision constraints.
- Optionally, its default value.

You can specify whether the procedure executes using the schema and permissions of the user who defined it, or the user who calls it. For more information, see "Using Invoker's Rights Versus Definer's Rights (AUTHID Clause)" on page 8-15.

You can specify whether it should be part of the current transaction, or execute in its own transaction where it can `COMMIT` or `ROLLBACK` without ending the transaction of the caller. For more information, see "Doing Independent Units of Work with Autonomous Transactions" on page 6-37.

A procedure has two parts: the specification (spec for short) and the body. The procedure spec begins with the keyword `PROCEDURE` and ends with the procedure name or a parameter list, followed by the reserved word `IS` (or `AS`). Parameter declarations are optional. Procedures that take no parameters are written without parentheses.

The procedure body begins with the reserved word `IS` (or `AS`) and ends with the keyword `END` followed by an optional procedure name. The procedure body has three parts: a declarative part, an executable part, and an optional exception-handling part.

The declarative part contains local declarations. The keyword `DECLARE` is used for anonymous PL/SQL blocks, but not procedures. The executable part contains statements, which are placed between the keywords `BEGIN` and `EXCEPTION` (or `END`). At least one statement must appear in the executable part of a procedure. You can use the `NULL` statement to define a placeholder procedure or specify that the procedure does nothing. The exception-handling part contains exception handlers, which are placed between the keywords EXCEPTION and END.

A procedure is called as a PL/SQL statement. For example, you might call the procedure raise_salary as follows:

```
raise_salary(emp_id, amount);
```

Understanding PL/SQL Functions

A function is a subprogram that computes a value. Functions and procedures are structured alike, except that functions have a RETURN clause. Functions have a number of optional keywords, used to declare a special class of functions known as table functions. They are typically used for transforming large amounts of data in data warehousing applications. For information on the syntax of the FUNCTION declaration, see "Function Declaration" on page 13-59.

The AUTHID clause determines whether a stored function executes with the privileges of its owner (the default) or current user and whether its unqualified references to schema objects are resolved in the schema of the owner or current user. You can override the default behavior by specifying CURRENT_USER.

The PARALLEL_ENABLE option declares that a stored function can be used safely in the slave sessions of parallel DML evaluations. The state of a main (logon) session is never shared with slave sessions. Each slave session has its own state, which is initialized when the session begins. The function result should not depend on the state of session (static) variables. Otherwise, results might vary across sessions.

The DETERMINISTIC option helps the optimizer avoid redundant function calls. If a stored function was called previously with the same arguments, the optimizer can elect to use the previous result. For more information and possible limitations of the DETERMINISTIC option, see CREATE FUNCTION in *Oracle Database SQL Reference*.

The pragma AUTONOMOUS_TRANSACTION instructs the PL/SQL compiler to mark a function as autonomous (independent). Autonomous transactions let you suspend the main transaction, do SQL operations, commit or roll back those operations, then resume the main transaction.

You cannot constrain (with NOT NULL for example) the datatype of a parameter or a function return value. However, you can use a workaround to size-constrain them indirectly. See "Understanding PL/SQL Procedures" on page 8-3.

Like a procedure, a function has two parts: the spec and the body. The function spec begins with the keyword FUNCTION and ends with the RETURN clause, which specifies the datatype of the return value. Parameter declarations are optional. Functions that take no parameters are written without parentheses.

The function body begins with the keyword IS (or AS) and ends with the keyword END followed by an optional function name. The function body has three parts: a declarative part, an executable part, and an optional exception-handling part.

The declarative part contains local declarations, which are placed between the keywords IS and BEGIN. The keyword DECLARE is not used. The executable part contains statements, which are placed between the keywords BEGIN and EXCEPTION (or END). One or more RETURN statements must appear in the executable part of a function. The exception-handling part contains exception handlers, which are placed between the keywords EXCEPTION and END.

A function is called as part of an expression. For example:

```
IF sal_ok(new_sal, new_title) THEN ...
```

Using the RETURN Statement

The RETURN statement immediately ends the execution of a subprogram and returns control to the caller. Execution continues with the statement following the subprogram call. (Do not confuse the RETURN statement with the RETURN clause in a function spec, which specifies the datatype of the return value.)

A subprogram can contain several RETURN statements. The subprogram does not have to conclude with a RETURN statement. Executing any RETURN statement completes the subprogram immediately.

In procedures, a RETURN statement does not return a value and so cannot contain an expression. The statement returns control to the caller before the end of the procedure.

In functions, a RETURN statement must contain an expression, which is evaluated when the RETURN statement is executed. The resulting value is assigned to the function identifier, which acts like a variable of the type specified in the RETURN clause. See the use of the RETURN statement in Example 8–2 on page 8-2.

The expression in a function RETURN statement can be arbitrarily complex:

```
CREATE OR REPLACE FUNCTION half_of_square(original NUMBER)
  RETURN NUMBER IS
BEGIN
   RETURN (original * original)/2 + (original * 4);
END half_of_square;
/
```

In a function, there must be at least one execution path that leads to a RETURN statement. Otherwise, you get a `function returned without value` error at run time.

Declaring Nested PL/SQL Subprograms

You can declare subprograms in any PL/SQL block, subprogram, or package. The subprograms must go at the end of the declarative section, after all other items.

You must declare a subprogram before calling it. This requirement can make it difficult to declare several nested subprograms that call each other.

You can declare interrelated nested subprograms using a forward declaration: a subprogram spec terminated by a semicolon, with no body.

Although the formal parameter list appears in the forward declaration, it must also appear in the subprogram body. You can place the subprogram body anywhere after the forward declaration, but they must appear in the same program unit.

Example 8–3 Forward Declaration for a Nested Subprogram

```
DECLARE
   PROCEDURE proc1(number1 NUMBER);  -- forward declaration
   PROCEDURE proc2(number2 NUMBER) IS
      BEGIN
        proc1(number2);  -- calls proc1
      END;
   PROCEDURE proc1(number1 NUMBER) IS
     BEGIN
      proc2 (number1);  -- calls proc2
     END;
BEGIN
  NULL;
```

```
END;
/
```

Passing Parameters to PL/SQL Subprograms

This section explains how to pass information in and out of PL/SQL subprograms using parameters:

- Actual Versus Formal Subprogram Parameters
- Using Positional, Named, or Mixed Notation for Subprogram Parameters
- Specifying Subprogram Parameter Modes
- Using Default Values for Subprogram Parameters

Actual Versus Formal Subprogram Parameters

Subprograms pass information using parameters:

- The variables declared in a subprogram specification and referenced in the subprogram body are formal parameters.
- The variables or expressions passed from the calling subprogram are actual parameters.

A good programming practice is to use different names for actual and formal parameters.

When you call a procedure, the actual parameters are evaluated and the results are assigned to the corresponding formal parameters. If necessary, before assigning the value of an actual parameter to a formal parameter, PL/SQL converts the datatype of the value. For example, if you pass a number when the procedure expects a string, PL/SQL converts the parameter so that the procedure receives a string.

The actual parameter and its corresponding formal parameter must have compatible datatypes. For instance, PL/SQL cannot convert between the `DATE` and `NUMBER` datatypes, or convert a string to a number if the string contains extra characters such as dollar signs.

The procedure in Example 8–4 declares two formal parameters named `emp_id` and `amount` and the procedure call specifies actual parameters `emp_num` and `bonus`.

Example 8–4 Formal Parameters and Actual Parameters

```
DECLARE
  emp_num NUMBER(6) := 120;
  bonus   NUMBER(6) := 100;
  merit   NUMBER(4) := 50;
  PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER) IS
    BEGIN
      UPDATE employees SET salary = salary + amount WHERE employee_id = emp_id;
  END raise_salary;
BEGIN
  raise_salary(emp_num, bonus); -- procedure call specifies actual parameters
  raise_salary(emp_num, merit + bonus); -- expressions can be used as parameters
END;
/
```

Using Positional, Named, or Mixed Notation for Subprogram Parameters

When calling a subprogram, you can write the actual parameters using either:

- Positional notation. You specify the same parameters in the same order as they are declared in the procedure.

  This notation is compact, but if you specify the parameters (especially literals) in the wrong order, the bug can be hard to detect. You must change your code if the procedure's parameter list changes.

- Named notation. You specify the name of each parameter along with its value. An arrow (=>) serves as the association operator. The order of the parameters is not significant.

  This notation is more verbose, but makes your code easier to read and maintain. You can sometimes avoid changing your code if the procedure's parameter list changes, for example if the parameters are reordered or a new optional parameter is added. Named notation is a good practice to use for any code that calls someone else's API, or defines an API for someone else to use.

- Mixed notation. You specify the first parameters with positional notation, then switch to named notation for the last parameters.

  You can use this notation to call procedures that have some required parameters, followed by some optional parameters.

Example 8–5 shows equivalent procedure calls using positional, named, and mixed notation.

Example 8–5 Subprogram Calls Using Positional, Named, and Mixed Notation

```
DECLARE
  emp_num NUMBER(6) := 120;
  bonus   NUMBER(6) := 50;
  PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER) IS
    BEGIN
      UPDATE employees SET salary = salary + amount WHERE employee_id = emp_id;
  END raise_salary;
BEGIN
  raise_salary(emp_num, bonus); -- positional procedure call for actual parameters
  raise_salary(amount => bonus, emp_id => emp_num); -- named parameters
  raise_salary(emp_num, amount => bonus); -- mixed parameters
END;
/
```

Specifying Subprogram Parameter Modes

You use parameter modes to define the behavior of formal parameters. The three parameter modes are `IN` (the default), `OUT`, and `IN OUT`.

Any parameter mode can be used with any subprogram. Avoid using the `OUT` and `IN OUT` modes with functions. To have a function return multiple values is a poor programming practice. Also, functions should be free from side effects, which change the values of variables not local to the subprogram.

Using the IN Mode

An `IN` parameter lets you pass values to the subprogram being called. Inside the subprogram, an `IN` parameter acts like a constant. It cannot be assigned a value.

You can pass a constant, literal, initialized variable, or expression as an IN parameter.

`IN` parameters can be initialized to default values, which are used if those parameters are omitted from the subprogram call. For more information, see "Using Default Values for Subprogram Parameters" on page 8-9.

Using the OUT Mode

An `OUT` parameter returns a value to the caller of a subprogram. Inside the subprogram, an `OUT` parameter acts like a variable. You can change its value, and reference the value after assigning it:

Example 8–6 Using the OUT Mode

```
DECLARE
  emp_num       NUMBER(6) := 120;
  bonus         NUMBER(6) := 50;
  emp_last_name VARCHAR2(25);
  PROCEDURE raise_salary (emp_id IN NUMBER, amount IN NUMBER,
                          emp_name OUT VARCHAR2) IS
    BEGIN
      UPDATE employees SET salary = salary + amount WHERE employee_id = emp_id;
      SELECT last_name INTO emp_name FROM employees WHERE employee_id = emp_id;
  END raise_salary;
BEGIN
  raise_salary(emp_num, bonus, emp_last_name);
  DBMS_OUTPUT.PUT_LINE('Salary has been updated for: ' || emp_last_name);
END;
/
```

You must pass a variable, not a constant or an expression, to an `OUT` parameter. Its previous value is lost unless you specify the `NOCOPY` keyword or the subprogram exits with an unhandled exception. See "Using Default Values for Subprogram Parameters" on page 8-9.

Like variables, `OUT` formal parameters are initialized to `NULL`. The datatype of an `OUT` formal parameter cannot be a subtype defined as `NOT NULL`, such as the built-in subtypes `NATURALN` and `POSITIVEN`. Otherwise, when you call the subprogram, PL/SQL raises `VALUE_ERROR`.

Before exiting a subprogram, assign values to all `OUT` formal parameters. Otherwise, the corresponding actual parameters will be null. If you exit successfully, PL/SQL assigns values to the actual parameters. If you exit with an unhandled exception, PL/SQL does not assign values to the actual parameters.

Using the IN OUT Mode

An `IN OUT` parameter passes initial values to a subprogram and returns updated values to the caller. It can be assigned a value and its value can be read. Typically, an `IN OUT` parameter is a string buffer or numeric accumulator, that is read inside the subprogram and then updated.

The actual parameter that corresponds to an `IN OUT` formal parameter must be a variable; it cannot be a constant or an expression.

If you exit a subprogram successfully, PL/SQL assigns values to the actual parameters. If you exit with an unhandled exception, PL/SQL does not assign values to the actual parameters.

Summary of Subprogram Parameter Modes

Table 8–1 summarizes all you need to know about the parameter modes.

Table 8–1 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 and 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 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
Actual parameter is passed by reference (a pointer to the value is passed in)	Actual parameter is passed by value (a copy of the value is passed out) unless `NOCOPY` is specified	Actual parameter is passed by value (a copy of the value is passed in and out) unless `NOCOPY` is specified

Using Default Values for Subprogram Parameters

By initializing `IN` parameters to default values, you can pass different numbers of actual parameters to a subprogram, accepting the default values for any parameters you omit. You can also add new formal parameters without having to change every call to the subprogram.

If a parameter is omitted, the default value of its corresponding formal parameter is used. You cannot skip a formal parameter by leaving out its actual parameter. To omit the first parameter and specify the second, use named notation.

You cannot assign a null to an uninitialized formal parameter by leaving out its actual parameter. You must pass the null explicitly, or you can specify a default value of `NULL` in the declaration.

Example 8–7 illustrates the use of default values for subprogram parameters.

Example 8–7 Procedure with Default Parameter Values

```
DECLARE
  emp_num NUMBER(6) := 120;
  bonus   NUMBER(6);
  merit   NUMBER(4);
  PROCEDURE raise_salary (emp_id IN NUMBER, amount IN NUMBER DEFAULT 100,
                         extra IN NUMBER DEFAULT 50) IS
    BEGIN
      UPDATE employees SET salary = salary + amount + extra
        WHERE employee_id = emp_id;
  END raise_salary;
BEGIN
  raise_salary(120); -- same as raise_salary(120, 100, 50)
  raise_salary(emp_num, extra => 25); -- same as raise_salary(120, 100, 25)
END;
/
```

Overloading Subprogram Names

PL/SQL lets you overload subprogram names and type methods. You can use the same name for several different subprograms as long as their formal parameters differ in number, order, or datatype family. For an example of an overloaded procedure in a package, see Example 9–3 on page 9-6.

Example 8–8 shows how you can define two subprograms with the same name. The procedures initialize different types of collections. Because the processing in these two procedures is the same, it is logical to give them the same name.

You can place the two overloaded `initialize` procedures in the same block, subprogram, package, or object type. PL/SQL determines which procedure to call by checking their formal parameters. The version of `initialize` that PL/SQL uses depends on whether you call the procedure with a `DateTabTyp` or `NumTabTyp` parameter.

Example 8–8 Overloading a Subprogram Name

```
DECLARE
   TYPE DateTabTyp IS TABLE OF DATE INDEX BY PLS_INTEGER;
   TYPE NumTabTyp IS TABLE OF NUMBER INDEX BY PLS_INTEGER;
   hiredate_tab DateTabTyp;
   sal_tab NumTabTyp;
   PROCEDURE initialize (tab OUT DateTabTyp, n INTEGER) IS
     BEGIN
        FOR i IN 1..n LOOP
          tab(i) := SYSDATE;
     END LOOP;
   END initialize;
   PROCEDURE initialize (tab OUT NumTabTyp, n INTEGER) IS
     BEGIN
       FOR i IN 1..n LOOP
         tab(i) := 0.0;
     END LOOP;
   END initialize;
BEGIN
   initialize(hiredate_tab, 50);  -- calls first (DateTabTyp) version
   initialize(sal_tab, 100);      -- calls second (NumTabTyp) version
END;
/
```

Guidelines for Overloading with Numeric Types

You can overload two subprograms if their formal parameters differ only in numeric datatype. This technique might be useful in writing mathematical application programming interfaces (APIs), where several versions of a function could use the same name, each accepting a different numeric type. For example, a function accepting `BINARY_FLOAT` might be faster, while a function accepting `BINARY_DOUBLE` might provide more precision.

To avoid problems or unexpected results passing parameters to such overloaded subprograms:

- Make sure to test that the expected version of a subprogram is called for each set of expected parameters. For example, if you have overloaded functions that accept `BINARY_FLOAT` and `BINARY_DOUBLE`, which is called if you pass a `VARCHAR2` literal such as '5.0'?

- Qualify numeric literals and use conversion functions to make clear what the intended parameter types are. For example, use literals such as 5.0f (for BINARY_FLOAT), 5.0d (for BINARY_DOUBLE), or conversion functions such as TO_BINARY_FLOAT(), TO_BINARY_DOUBLE(), and TO_NUMBER().

PL/SQL looks for matching numeric parameters starting with PLS_INTEGER or BINARY_INTEGER, then NUMBER, then BINARY_FLOAT, then BINARY_DOUBLE. The first overloaded subprogram that matches the supplied parameters is used. A VARCHAR2 value can match a NUMBER, BINARY_FLOAT, or BINARY_DOUBLE parameter.

For example, consider the SQRT function, which takes a single parameter. There are overloaded versions that accept a NUMBER, a BINARY_FLOAT, or a BINARY_DOUBLE parameter. If you pass a PLS_INTEGER parameter, the first matching overload (using the order given in the preceding paragraph) is the one with a NUMBER parameter, which is likely to be the slowest. To use one of the faster versions, use the TO_BINARY_FLOAT or TO_BINARY_DOUBLE functions to convert the parameter to the right datatype.

For another example, consider the ATAN2 function, which takes two parameters of the same type. If you pass two parameters of the same type, you can predict which overloaded version is used through the same rules as before. If you pass parameters of different types, for example one PLS_INTEGER and one BINARY_FLOAT, PL/SQL tries to find a match where both parameters use the higher type. In this case, that is the version of ATAN2 that takes two BINARY_FLOAT parameters; the PLS_INTEGER parameter is converted upwards.

The preference for converting upwards holds in more complicated situations. For example, you might have a complex function that takes two parameters of different types. One overloaded version might take a PLS_INTEGER and a BINARY_FLOAT parameter. Another overloaded version might take a NUMBER and a BINARY_DOUBLE parameter. What happens if you call this procedure name and pass two NUMBER parameters? PL/SQL looks upward first to find the overloaded version where the second parameter is BINARY_FLOAT. Because this parameter is a closer match than the BINARY_DOUBLE parameter in the other overload, PL/SQL then looks downward and converts the first NUMBER parameter to PLS_INTEGER.

Restrictions on Overloading

Only local or packaged subprograms, or type methods, can be overloaded. You cannot overload standalone subprograms.

You cannot overload two subprograms if their formal parameters differ only in name or parameter mode. For example, you cannot overload the following two procedures:

Example 8–9 Restrictions on Overloading PL/SQL Procedures

```
DECLARE
   PROCEDURE balance (acct_no IN INTEGER) IS
   BEGIN NULL; END;
   PROCEDURE balance (acct_no OUT INTEGER) IS
   BEGIN NULL; END;
BEGIN
  DBMS_OUTPUT.PUT_LINE('The following procedure call raises an error.');
-- balance(100); raises an error because the procedure declaration is not unique
END;
/
```

You cannot overload subprograms whose parameters differ only in subtype. For example, you cannot overload procedures where one accepts an `INTEGER` parameter and the other accepts a `REAL` parameter, even though `INTEGER` and `REAL` are both subtypes of `NUMBER` and so are in the same family.

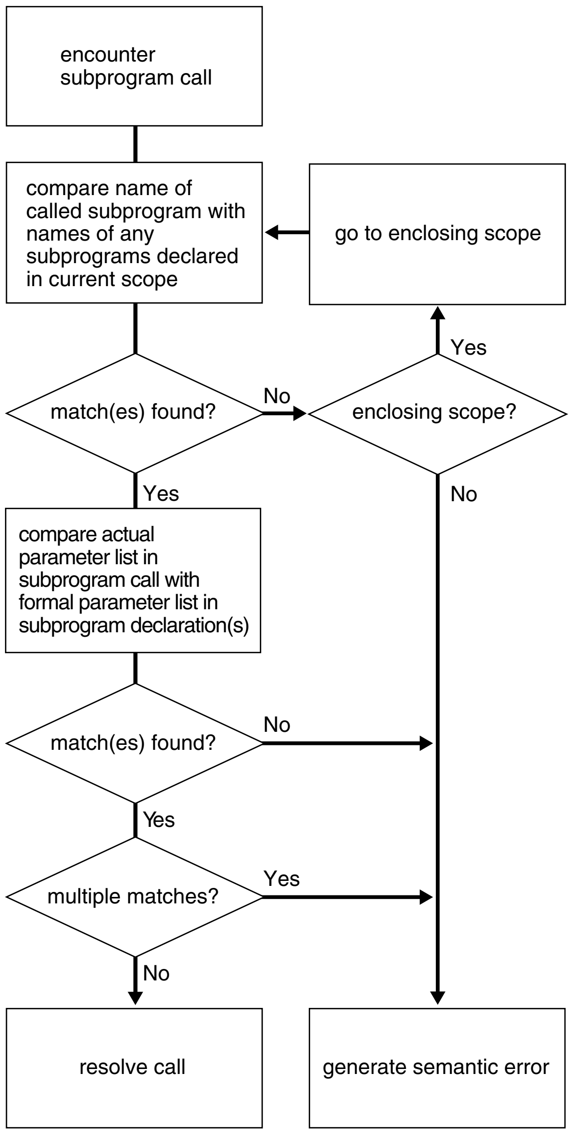
You cannot overload two functions that differ only in the datatype of the return value, even if the types are in different families. For example, you cannot overload two functions where one returns `BOOLEAN` and the other returns `INTEGER`.

How Subprogram Calls Are Resolved

Figure 8–1 shows how the PL/SQL compiler resolves subprogram calls. When the compiler encounters a procedure or function call, it tries to find a declaration that matches the call. The compiler searches first in the current scope and then, if necessary, in successive enclosing scopes. The compiler looks more closely when it finds one or more subprogram declarations in which the subprogram name matches the name of the called subprogram.

To resolve a call among possibly like-named subprograms at the same level of scope, the compiler must find an exact match between the actual and formal parameters. They must match in number, order, and datatype (unless some formal parameters were assigned default values). If no match is found or if multiple matches are found, the compiler generates a semantic error.

Figure 8–1 How the PL/SQL Compiler Resolves Calls


encounter subprogram call
compare name of called subprogram with names of any subprograms declared in current scope
go to enclosing scope
match(es) found?
No
Yes
enclosing scope?
Yes
No
compare actual parameter list in subprogram call with formal parameter list in subprogram declaration(s)
match(es) found?
No
Yes
multiple matches?
Yes
No
resolve call
generate semantic error

Example 8–10 calls the enclosing procedure `swap` from the function `balance`, generating an error because neither declaration of `swap` within the current scope matches the procedure call.

Example 8–10 Resolving PL/SQL Procedure Names

```
DECLARE
  PROCEDURE swap (n1 NUMBER, n2 NUMBER) IS
    num1 NUMBER;
    num2 NUMBER;
    FUNCTION balance (bal NUMBER) RETURN NUMBER IS
      x NUMBER := 10;
      PROCEDURE swap (d1 DATE, d2 DATE) IS BEGIN NULL; END;
      PROCEDURE swap (b1 BOOLEAN, b2 BOOLEAN) IS BEGIN NULL; END;
    BEGIN
      DBMS_OUTPUT.PUT_LINE('The following raises an error');
--      swap(num1, num2); wrong number or types of arguments in call to 'SWAP'
      RETURN x;
    END balance;
  BEGIN NULL;END swap;
BEGIN
  NULL;
END;
/
```

How Overloading Works with Inheritance

The overloading algorithm allows substituting a subtype value for a formal parameter that is a supertype. This capability is known as substitutability. If more than one instance of an overloaded procedure matches the procedure call, the following rules apply to determine which procedure is called:

If the only difference in the signatures of the overloaded procedures is that some parameters are object types from the same supertype-subtype hierarchy, the closest match is used. The closest match is one where all the parameters are at least as close as any other overloaded instance, as determined by the depth of inheritance between the subtype and supertype, and at least one parameter is closer.

A semantic error occurs when two overloaded instances match, and some argument types are closer in one overloaded procedure to the actual arguments than in any other instance.

A semantic error also occurs if some parameters are different in their position within the object type hierarchy, and other parameters are of different datatypes so that an implicit conversion would be necessary.

For example, create a type hierarchy with three levels and then declare two overloaded instances of a function, where the only difference in argument types is their position in this type hierarchy, as shown in Example 8–11. We declare a variable of type `final_t`, then call the overloaded function. The instance of the function that is executed is the one that accepts a `sub_t` parameter, because that type is closer to `final_t` in the hierarchy than `super_t` is.

Example 8–11 Resolving PL/SQL Functions With Inheritance

```
CREATE OR REPLACE TYPE super_t AS OBJECT
  (n NUMBER) NOT final;
/
CREATE OR REPLACE TYPE sub_t UNDER super_t
  (n2 NUMBER) NOT final;
/
CREATE OR REPLACE TYPE final_t UNDER sub_t
  (n3 NUMBER);
/
CREATE OR REPLACE PACKAGE p IS
   FUNCTION func (arg super_t) RETURN NUMBER;
   FUNCTION func (arg sub_t) RETURN NUMBER;
END;
/
CREATE OR REPLACE PACKAGE BODY p IS
   FUNCTION func (arg super_t) RETURN NUMBER IS BEGIN RETURN 1; END;
   FUNCTION func (arg sub_t) RETURN NUMBER IS BEGIN RETURN 2; END;
END;
/

DECLARE
  v final_t := final_t(1,2,3);
BEGIN
  DBMS_OUTPUT.PUT_LINE(p.func(v));  -- prints 2
```

```
END;
/
```

In Example 8–11, the choice of which instance to call is made at compile time. In Example 8–12, this choice is made dynamically. We declare `v` as an instance of `super_t`, but because we assign a value of `sub_t` to it, the appropriate instance of the function is called. This feature is known as dynamic dispatch.

Example 8–12 Resolving PL/SQL Functions With Inheritance Dynamically

```
CREATE TYPE super_t AS OBJECT
  (n NUMBER, MEMBER FUNCTION func RETURN NUMBER) NOT final;
/
CREATE TYPE BODY super_t AS
 MEMBER FUNCTION func RETURN NUMBER IS BEGIN RETURN 1; END; END;
/
CREATE OR REPLACE TYPE sub_t UNDER super_t
  (n2 NUMBER,
   OVERRIDING MEMBER FUNCTION func RETURN NUMBER) NOT final;
/
CREATE TYPE BODY sub_t AS
 OVERRIDING MEMBER FUNCTION func RETURN NUMBER IS BEGIN RETURN 2; END; END;
/
CREATE OR REPLACE TYPE final_t UNDER sub_t
  (n3 NUMBER);
/

DECLARE
  v super_t := final_t(1,2,3);
BEGIN
  DBMS_OUTPUT.PUT_LINE(v.func); -- prints 2
END;
/
```

Using Invoker's Rights Versus Definer's Rights (AUTHID Clause)

By default, stored procedures and SQL methods execute with the privileges of their owner, not their current user. Such definer's rights subprograms are bound to the schema in which they reside, allowing you to refer to objects in the same schema without qualifying their names. For example, if schemas `HR` and `OE` both have a table called `departments`, a procedure owned by `HR` can refer to `departments` rather than `HR.departments`. If user `OE` calls `HR`'s procedure, the procedure still accesses the `departments` table owned by `HR`.

If you compile the same procedure in both schemas, you can define the schema name as a variable in SQL*Plus and refer to the table like `&schema..departments`. The code is portable, but if you change it, you must recompile it in each schema.

A more maintainable way is to use the `AUTHID` clause, which makes stored procedures and SQL methods execute with the privileges and schema context of the calling user. You can create one instance of the procedure, and many users can call it to access their own data.

Such invoker's rights subprograms are not bound to a particular schema. The following version of procedure `create_dept` executes with the privileges of the calling user and inserts rows into that user's `departments` table:

Example 8–13 Specifying Invoker's Rights With a Procedure

```
CREATE OR REPLACE PROCEDURE create_dept (
   v_deptno NUMBER,
   v_dname  VARCHAR2,
   v_mgr    NUMBER,
   v_loc    NUMBER)
AUTHID CURRENT_USER AS
BEGIN
   INSERT INTO departments VALUES (v_deptno, v_dname, v_mgr, v_loc);
END;
/
CALL create_dept(44, 'Information Technology', 200, 1700);
```

Advantages of Invoker's Rights

Invoker's rights subprograms let you reuse code and centralize application logic. They are especially useful in applications that store data using identical tables in different schemas. All the schemas in one instance can call procedures owned by a central schema. You can even have schemas in different instances call centralized procedures using a database link.

Consider a company that uses a stored procedure to analyze sales. If the company has several schemas, each with a similar SALES table, normally it would also need several copies of the stored procedure, one in each schema.

To solve the problem, the company installs an invoker's rights version of the stored procedure in a central schema. Now, all the other schemas can call the same procedure, which queries the appropriate to SALES table in each case.

You can restrict access to sensitive data by calling from an invoker's rights subprogram to a definer's rights subprogram that queries or updates the table containing the sensitive data. Although multiple users can call the invoker's rights subprogram, they do not have direct access to the sensitive data.

Specifying the Privileges for a Subprogram with the AUTHID Clause

To implement invoker's rights, use the AUTHID clause, which specifies whether a subprogram executes with the privileges of its owner or its current user. It also specifies whether external references (that is, references to objects outside the subprogram) are resolved in the schema of the owner or the current user.

The AUTHID clause is allowed only in the header of a standalone subprogram, a package spec, or an object type spec. In the CREATE FUNCTION, CREATE PROCEDURE, CREATE PACKAGE, or CREATE TYPE statement, you can include either AUTHID CURRENT_USER or AUTHID DEFINER immediately before the IS or AS keyword that begins the declaration section.

DEFINER is the default option. In a package or object type, the AUTHID clause applies to all subprograms.

Most supplied PL/SQL packages (such as DBMS_LOB, DBMS_PIPE, DBMS_ROWID, DBMS_SQL, and UTL_REF) are invoker's rights packages.

Who Is the Current User During Subprogram Execution?

In a sequence of calls, whenever control is inside an invoker's rights subprogram, the current user is the session user. When a definer's rights subprogram is called, the owner of that subprogram becomes the current user. The current user might change as new subprograms are called or as subprograms exit.

To verify who the current user is at any time, you can check the `USER_USERS` data dictionary view. Inside an invoker's rights subprogram, the value from this view might be different from the value of the `USER` built-in function, which always returns the name of the session user.

How External References Are Resolved in Invoker's Rights Subprograms

If you specify `AUTHID CURRENT_USER`, the privileges of the current user are checked at run time, and external references are resolved in the schema of the current user. However, this applies only to external references in:

- `SELECT`, `INSERT`, `UPDATE`, and `DELETE` data manipulation statements
- The `LOCK TABLE` transaction control statement
- `OPEN` and `OPEN-FOR` cursor control statements
- `EXECUTE IMMEDIATE` and `OPEN-FOR-USING` dynamic SQL statements
- SQL statements parsed using `DBMS_SQL.PARSE()`

For all other statements, the privileges of the owner are checked at compile time, and external references are resolved in the schema of the owner. For example, the assignment statement in Example 8–14 refers to the packaged function `num_above_salary` in the `emp_actions` package in Example 1–13 on page 1-14. This external reference is resolved in the schema of the owner of procedure `above_salary`.

Example 8–14 Resolving External References in an Invoker's Rights Subprogram

```
CREATE PROCEDURE above_salary (emp_id IN NUMBER)
  AUTHID CURRENT_USER AS
  emps NUMBER;
BEGIN
  emps := emp_actions.num_above_salary(emp_id);
  DBMS_OUTPUT.PUT_LINE( 'Number of employees with higher salary: ' ||
                        TO_CHAR(emps));
END;
/
CALL above_salary(120);
```

The Need for Template Objects in Invoker's Rights Subprograms

The PL/SQL compiler must resolve all references to tables and other objects at compile time. The owner of an invoker's rights subprogram must have objects in the same schema with the right names and columns, even if they do not contain any data. At run time, the corresponding objects in the caller's schema must have matching definitions. Otherwise, you get an error or unexpected results, such as ignoring table columns that exist in the caller's schema but not in the schema that contains the subprogram.

Overriding Default Name Resolution in Invoker's Rights Subprograms

Occasionally, you might want an unqualified name to refer to some particular schema, not the schema of the caller. In the same schema as the invoker's rights subprogram, create a public synonym for the table, procedure, function, or other object using the `CREATE SYNONYM` statement:

```
CREATE PUBLIC SYNONYM emp FOR hr.employees;
```

When the invoker's rights subprogram refers to this name, it will match the synonym in its own schema, which resolves to the object in the specified schema. This technique does not work if the calling schema already has a schema object or private synonym with the same name. In that case, the invoker's rights subprogram must fully qualify the reference.

Granting Privileges on Invoker's Rights Subprograms

To call a subprogram directly, users must have the `EXECUTE` privilege on that subprogram. By granting the privilege, you allow a user to:

- Call the subprogram directly
- Compile functions and procedures that call the subprogram

For external references resolved in the current user's schema (such as those in DML statements), the current user must have the privileges needed to access schema objects referenced by the subprogram. For all other external references (such as function calls), the owner's privileges are checked at compile time, and no run-time check is done.

A definer's rights subprogram operates under the security domain of its owner, no matter who is executing it. The owner must have the privileges needed to access schema objects referenced by the subprogram.

You can write a program consisting of multiple subprograms, some with definer's rights and others with invoker's rights. Then, you can use the `EXECUTE` privilege to restrict program entry points. That way, users of an entry-point subprogram can execute the other subprograms indirectly but not directly.

Granting Privileges on an Invoker's Rights Subprogram: Example

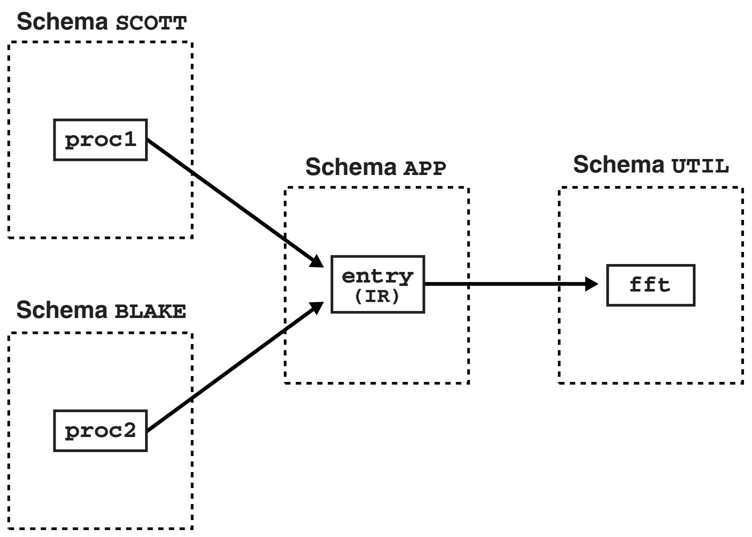
Suppose user `UTIL` grants the `EXECUTE` privilege on subprogram `FFT` to user `APP`:

```
GRANT EXECUTE ON util.fft TO app;
```

Now, user `APP` can compile functions and procedures that call subprogram `FFT`. At run time, no privilege checks on the calls are done. As Figure 8–2 shows, user `UTIL` need not grant the `EXECUTE` privilege to every user who might call `FFT` indirectly.

Since subprogram `util.fft` is called directly only from invoker's rights subprogram `app.entry`, user `util` must grant the `EXECUTE` privilege only to user `APP`. When `UTIL.FFT` is executed, its current user could be `APP`, `SCOTT`, or `BLAKE` even though `SCOTT` and `BLAKE` were not granted the `EXECUTE` privilege.

Figure 8–2 Indirect Calls to an Invoker's Rights Subprogram



Using Roles with Invoker's Rights Subprograms

The use of roles in a subprogram depends on whether it executes with definer's rights or invoker's rights. Within a definer's rights subprogram, all roles are disabled. Roles are not used for privilege checking, and you cannot set roles.

Within an invoker's rights subprogram, roles are enabled (unless the subprogram was called directly or indirectly by a definer's rights subprogram). Roles are used for privilege checking, and you can use native dynamic SQL to set roles for the session. However, you cannot use roles to grant privileges on template objects because roles apply at run time, not at compile time.

Using Views and Database Triggers with Invoker's Rights Subprograms

For invoker's rights subprograms executed within a view expression, the schema that created the view, not the schema that is querying the view, is considered to be the current user. This rule also applies to database triggers.

Using Database Links with Invoker's Rights Subprograms

You can create a database link to use invoker's rights:

```
CREATE DATABASE LINK link_name CONNECT TO CURRENT_USER
  USING connect_string;
```

A current-user link lets you connect to a remote database as another user, with that user's privileges. To connect, Oracle uses the username of the current user (who must be a global user). Suppose an invoker's rights subprogram owned by user `OE` references the following database link. If global user `HR` calls the subprogram, it connects to the Dallas database as user `HR`, who is the current user.

```
CREATE DATABASE LINK dallas CONNECT TO CURRENT_USER USING ...
```

If it were a definer's rights subprogram, the current user would be `OE`, and the subprogram would connect to the Dallas database as global user `OE`.

Using Object Types with Invoker's Rights Subprograms

To define object types for use in any schema, specify the AUTHID CURRENT_USER clause. For information on object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*.

Suppose user HR creates the following object type:

Example 8–15 Creating an Object Type With AUTHID CURRENT USER

```
CREATE TYPE person_typ AUTHID CURRENT_USER AS OBJECT (
  person_id   NUMBER,
  person_name VARCHAR2(30),
  person_job  VARCHAR2(10),
  STATIC PROCEDURE new_person_typ (
    person_id NUMBER, person_name VARCHAR2, person_job VARCHAR2,
    schema_name VARCHAR2, table_name VARCHAR2),
  MEMBER PROCEDURE change_job (SELF IN OUT NOCOPY person_typ, new_job VARCHAR2)
);
/
CREATE TYPE BODY person_typ AS
  STATIC PROCEDURE new_person_typ (
    person_id NUMBER, person_name VARCHAR2, person_job VARCHAR2,
    schema_name VARCHAR2, table_name VARCHAR2) IS
    sql_stmt VARCHAR2(200);
  BEGIN
    sql_stmt := 'INSERT INTO ' || schema_name || '.'
       || table_name || ' VALUES (HR.person_typ(:1, :2, :3))';
    EXECUTE IMMEDIATE sql_stmt USING person_id, person_name, person_job;
  END;
  MEMBER PROCEDURE change_job (SELF IN OUT NOCOPY person_typ, new_job VARCHAR2) IS
  BEGIN
    person_job := new_job;
  END;
END;
/
```

Then, user HR grants the EXECUTE privilege on object type person_typ to user OE:

```
GRANT EXECUTE ON person_typ TO OE;
```

Finally, user OE creates an object table to store objects of type person_typ, then calls procedure new_person_typ to populate the table:

```
CONNECT oe/oe;
CREATE TABLE person_tab OF hr.person_typ;

BEGIN
  hr.person_typ.new_person_typ(1001, 'Jane Smith', 'CLERK', 'oe', 'person_tab');
  hr.person_typ.new_person_typ(1002, 'Joe Perkins', 'SALES','oe', 'person_tab');
  hr.person_typ.new_person_typ(1003, 'Robert Lange', 'DEV','oe', 'person_tab');
END;
/
```

The calls succeed because the procedure executes with the privileges of its current user (OE), not its owner (HR).

For subtypes in an object type hierarchy, the following rules apply:

- If a subtype does not explicitly specify an AUTHID clause, it inherits the AUTHID of its supertype.

- If a subtype does specify an AUTHID clause, its AUTHID must match the AUTHID of its supertype. Also, if the AUTHID is DEFINER, both the supertype and subtype must have been created in the same schema.

Calling Invoker's Rights Instance Methods

An invoker's rights instance method executes with the privileges of the invoker, not the creator of the instance. Suppose that person_typ is an invoker's rights object type as created in Example 8–15, and that user HR creates p1, an object of type person_typ. If user OE calls instance method change_job to operate on object p1, the current user of the method is OE, not HR, as shown in Example 8–16.

Example 8–16 Calling an Invoker's Rights Instance Methods

```
-- oe creates a procedure that calls change_job
CREATE PROCEDURE reassign (p IN OUT NOCOPY hr.person_typ, new_job VARCHAR2) AS
BEGIN
   p.change_job(new_job); -- executes with the privileges of oe
END;
/
-- OE grants EXECUTE to HR on procedure reassign
GRANT EXECUTE ON reassign to HR;
CONNECT hr/hr

-- user hr passes a person_typ object to the procedure reassign
DECLARE
   p1 person_typ;
BEGIN
   p1 := person_typ(1004,  'June Washburn', 'SALES');
   oe.reassign(p1, 'CLERK'); -- current user is oe, not hr
END;
/
```

Using Recursion with PL/SQL

Recursion is a powerful technique for simplifying the design of algorithms. Basically, recursion means self-reference. In a recursive mathematical sequence, each term is derived by applying a formula to preceding terms. The Fibonacci sequence (0, 1, 1, 2, 3, 5, 8, 13, 21, ...), is an example. Each term in the sequence (after the second) is the sum of the two terms that immediately precede it.

In a recursive definition, something is defined as simpler versions of itself. Consider the definition of *n* factorial (*n!*), the product of all integers from 1 to *n*:

```
n! = n * (n - 1)!
```

What Is a Recursive Subprogram?

A recursive subprogram is one that calls itself. Each recursive call creates a new instance of any items declared in the subprogram, including parameters, variables, cursors, and exceptions. Likewise, new instances of SQL statements are created at each level in the recursive descent.

Be careful where you place a recursive call. If you place it inside a cursor FOR loop or between OPEN and CLOSE statements, another cursor is opened at each call, which might exceed the limit set by the Oracle initialization parameter OPEN_CURSORS.

There must be at least two paths through a recursive subprogram: one that leads to the recursive call and one that does not. At least one path must lead to a terminating condition. Otherwise, the recursion would go on until PL/SQL runs out of memory and raises the predefined exception `STORAGE_ERROR`.

Calling External Subprograms

Although PL/SQL is a powerful, flexible language, some tasks are more easily done in another language. Low-level languages such as C are very fast. Widely used languages such as Java have reusable libraries for common design patterns.

You can use PL/SQL call specs to invoke external subprograms written in other languages, making their capabilities and libraries available from PL/SQL. For example, you can call Java stored procedures from any PL/SQL block, subprogram, or package. For more information about Java stored procedures, see *Oracle Database Java Developer's Guide*.

If the following Java class is stored in the database, it can be called as shown in Example 8–17.

```
import java.sql.*;
import oracle.jdbc.driver.*;
public class Adjuster {
  public static void raiseSalary (int empNo, float percent)
  throws SQLException {
    Connection conn = new OracleDriver().defaultConnection();
    String sql = "UPDATE employees SET salary = salary * ?
                    WHERE employee_id = ?";
    try {
      PreparedStatement pstmt = conn.prepareStatement(sql);
      pstmt.setFloat(1, (1 + percent / 100));
      pstmt.setInt(2, empNo);
      pstmt.executeUpdate();
      pstmt.close();
    } catch (SQLException e)
          {System.err.println(e.getMessage());}
    }
}
```

The class `Adjuster` has one method, which raises the salary of an employee by a given percentage. Because `raiseSalary` is a `void` method, you publish it as a procedure using the call specification shown inExample 8–17 and then can call the procedure `raise_salary` from an anonymous PL/SQL block.

Example 8–17 Calling an External Procedure From PL/SQL

```
CREATE OR REPLACE PROCEDURE raise_salary (empid NUMBER, pct NUMBER)
AS LANGUAGE JAVA
NAME 'Adjuster.raiseSalary(int, float)';
/

DECLARE
   emp_id  NUMBER := 120;
   percent NUMBER := 10;
BEGIN
   -- get values for emp_id and percent
   raise_salary(emp_id, percent);  -- call external subprogram
END;
```

```
/
```

Java call specs cannot be declared as nested procedures, but can be specified in object type specifications, object type bodies, PL/SQL package specifications, PL/SQL package bodies, and as top level PL/SQL procedures and functions.

Example 8–18 shows a call to a Java function from a PL/SQL procedure.

Example 8–18 Calling a Java Function From PL/SQL

```
-- the following nested Java call spec is not valid, throws PLS-00999
--   CREATE PROCEDURE sleep (milli_seconds in number) IS
--     PROCEDURE java_sleep (milli_seconds IN NUMBER) AS ...

-- first, create the Java call spec, then call from a PL/SQL procedure
CREATE PROCEDURE java_sleep (milli_seconds IN NUMBER)
  AS LANGUAGE JAVA NAME 'java.lang.Thread.sleep(long)';
/
CREATE PROCEDURE sleep (milli_seconds in number) IS
-- the following nested PROCEDURE spec is not legal
--  PROCEDURE java_sleep (milli_seconds IN NUMBER)
--    AS LANGUAGE JAVA NAME 'java.lang.Thread.sleep(long)';
BEGIN
  DBMS_OUTPUT.PUT_LINE(DBMS_UTILITY.get_time());
  java_sleep (milli_seconds);
  DBMS_OUTPUT.PUT_LINE(DBMS_UTILITY.get_time());
END;
/
```

External C subprograms are used to interface with embedded systems, solve engineering problems, analyze data, or control real-time devices and processes. External C subprograms extend the functionality of the database server, and move computation-bound programs from client to server, where they execute faster. For more information about external C subprograms, see *Oracle Database Application Developer's Guide - Fundamentals*.

Controlling Side Effects of PL/SQL Subprograms

To be callable from SQL statements, a stored function (and any subprograms called by that function) must obey certain purity rules, which are meant to control side effects:

- When called from a SELECT statement or a parallelized INSERT, UPDATE, or DELETE statement, the function cannot modify any database tables.
- When called from an INSERT, UPDATE, or DELETE statement, the function cannot query or modify any database tables modified by that statement.
- When called from a SELECT, INSERT, UPDATE, or DELETE statement, the function cannot execute SQL transaction control statements (such as COMMIT), session control statements (such as SET ROLE), or system control statements (such as ALTER SYSTEM). Also, it cannot execute DDL statements (such as CREATE) because they are followed by an automatic commit.

If any SQL statement inside the function body violates a rule, you get an error at run time (when the statement is parsed).

To check for violations of the rules, you can use the pragma (compiler directive) RESTRICT_REFERENCES. The pragma asserts that a function does not read or write database tables or package variables. For example, the following pragma asserts that packaged function `credit_ok` writes no database state (`WNDS`) and reads no package state (`RNPS`):

```
CREATE PACKAGE loans AS
   FUNCTION credit_ok RETURN BOOLEAN;
   PRAGMA RESTRICT_REFERENCES (credit_ok, WNDS, RNPS);
END loans;
/
```

A static `INSERT`, `UPDATE`, or `DELETE` statement always violates `WNDS`. It also violates `RNDS` (reads no database state) if it reads any columns. A dynamic `INSERT`, `UPDATE`, or `DELETE` statement always violates `WNDS` and `RNDS`.

For syntax details, see "RESTRICT_REFERENCES Pragma" on page 13-98. For more information about the purity rules, see *Oracle Database Application Developer's Guide - Fundamentals*.

Understanding Subprogram Parameter Aliasing

To optimize a subprogram call, the PL/SQL compiler can choose between two methods of parameter passing. With the *by-value* method, the value of an actual parameter is passed to the subprogram. With the *by-reference* method, only a pointer to the value is passed; the actual and formal parameters reference the same item.

The `NOCOPY` compiler hint increases the possibility of aliasing (that is, having two different names refer to the same memory location). This can occur when a global variable appears as an actual parameter in a subprogram call and then is referenced within the subprogram. The result is indeterminate because it depends on the method of parameter passing chosen by the compiler.

In Example 8–19, procedure `ADD_ENTRY` refers to varray `LEXICON` both as a parameter and as a global variable. When `ADD_ENTRY` is called, the identifiers `WORD_LIST` and `LEXICON` point to the same varray.

Example 8–19   Aliasing from Passing Global Variable with NOCOPY Hint

```
DECLARE
   TYPE Definition IS RECORD (
      word    VARCHAR2(20),
      meaning VARCHAR2(200));
   TYPE Dictionary IS VARRAY(2000) OF Definition;
   lexicon Dictionary := Dictionary();
   PROCEDURE add_entry (word_list IN OUT NOCOPY Dictionary) IS
   BEGIN
     word_list(1).word := 'aardvark';
     lexicon(1).word := 'aardwolf';
   END;
BEGIN
   lexicon.EXTEND;
   add_entry(lexicon);
   DBMS_OUTPUT.PUT_LINE(lexicon(1).word);
END;
/
```

The program prints `aardwolf` if the compiler obeys the `NOCOPY` hint. The assignment to `WORD_LIST` is done immediately through a pointer, then is overwritten by the assignment to `LEXICON`.

The program prints `aardvark` if the `NOCOPY` hint is omitted, or if the compiler does not obey the hint. The assignment to `WORD_LIST` uses an internal copy of the varray, which is copied back to the actual parameter (overwriting the contents of LEXICON) when the procedure ends.

Aliasing can also occur when the same actual parameter appears more than once in a subprogram call. In Example 8–20, n2 is an IN OUT parameter, so the value of the actual parameter is not updated until the procedure exits. That is why the first PUT_LINE prints 10 (the initial value of n) and the third PUT_LINE prints 20. However, n3 is a NOCOPY parameter, so the value of the actual parameter is updated immediately. That is why the second PUT_LINE prints 30.

Example 8–20 Aliasing Passing Same Parameter Multiple Times

```
DECLARE
   n NUMBER := 10;
   PROCEDURE do_something (
      n1 IN NUMBER,
      n2 IN OUT NUMBER,
      n3 IN OUT NOCOPY NUMBER) IS
   BEGIN
      n2 := 20;
      DBMS_OUTPUT.put_line(n1);  -- prints 10
      n3 := 30;
      DBMS_OUTPUT.put_line(n1);  -- prints 30
   END;
BEGIN
   do_something(n, n, n);
   DBMS_OUTPUT.put_line(n);  -- prints 20
END;
/
```

Because they are pointers, cursor variables also increase the possibility of aliasing. In Example 8–21, after the assignment, emp_cv2 is an alias of emp_cv1; both point to the same query work area. The first fetch from emp_cv2 fetches the third row, not the first, because the first two rows were already fetched from emp_cv1. The second fetch from emp_cv2 fails because emp_cv1 is closed.

Example 8–21 Aliasing from Assigning Cursor Variables to Same Work Area

```
DECLARE
  TYPE EmpCurTyp IS REF CURSOR;
  c1 EmpCurTyp;
  c2 EmpCurTyp;
  PROCEDURE get_emp_data (emp_cv1 IN OUT EmpCurTyp, emp_cv2 IN OUT EmpCurTyp) IS
    emp_rec employees%ROWTYPE;
  BEGIN
    OPEN emp_cv1 FOR SELECT * FROM employees;
    emp_cv2 := emp_cv1;
    FETCH emp_cv1 INTO emp_rec;  -- fetches first row
    FETCH emp_cv1 INTO emp_rec;  -- fetches second row
    FETCH emp_cv2 INTO emp_rec;  -- fetches third row
    CLOSE emp_cv1;
    DBMS_OUTPUT.put_line('The following raises an invalid cursor');
--  FETCH emp_cv2 INTO emp_rec; raises invalid cursor when get_emp_data is called
  END;
BEGIN
  get_emp_data(c1, c2);
END;
/
```

9 Using PL/SQL Packages

This chapter shows how to bundle related PL/SQL code and data into a package. The package might include a set of procedures that forms an API, or a pool of type definitions and variable declarations. The package is compiled and stored in the database, where its contents can be shared by many applications.

This chapter contains these topics:

What Is a PL/SQL Package?

A package is a schema object that groups logically related PL/SQL types, variables, and subprograms. Packages usually have two parts, a specification (spec) and a body; sometimes the body is unnecessary. The specification is the interface to the package. It declares the types, variables, constants, exceptions, cursors, and subprograms that can be referenced from outside the package. The body defines the queries for the cursors and the code for the subprograms.

You can think of the spec as an interface and of the body as a *black box*. You can debug, enhance, or replace a package body without changing the package spec.

To create package specs, use the SQL statement `CREATE PACKAGE`. A `CREATE PACKAGE BODY` statement defines the package body. For information on the `CREATE PACKAGE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE PACKAGE BODY` SQL statement, see *Oracle Database SQL Reference*.

The spec holds public declarations, which are visible to stored procedures and other code outside the package. You must declare subprograms at the end of the spec after all other items (except pragmas that name a specific function; such pragmas must follow the function spec).

The body holds implementation details and private declarations, which are hidden from code outside the package. Following the declarative part of the package body is the optional initialization part, which holds statements that initialize package variables and do any other one-time setup steps.

The `AUTHID` clause determines whether all the packaged subprograms execute with the privileges of their definer (the default) or invoker, and whether their unqualified references to schema objects are resolved in the schema of the definer or invoker. For more information, see "Using Invoker's Rights Versus Definer's Rights (AUTHID Clause)" on page 8-15.

A call spec lets you map a package subprogram to a Java method or external C function. The call spec maps the Java or C name, parameter types, and return type to their SQL counterparts. To learn how to write Java call specs, see *Oracle Database Java Developer's Guide*. To learn how to write C call specs, see *Oracle Database Application Developer's Guide - Fundamentals*.

For information about PL/SQL packages provided with the Oracle database, see *Oracle Database PL/SQL Packages and Types Reference*.

What Goes In a PL/SQL Package?

The following is contained in a PL/SQL package:

- `Get` and `Set` methods for the package variables, if you want to avoid letting other procedures read and write them directly.
- Cursor declarations with the text of SQL queries. Reusing exactly the same query text in multiple locations is faster than retyping the same query each time with slight differences. It is also easier to maintain if you need to change a query that is used in many places.
- Declarations for exceptions. Typically, you need to be able to reference these from different procedures, so that you can handle exceptions within called subprograms.
- Declarations for procedures and functions that call each other. You do not need to worry about compilation order for packaged procedures and functions, making them more convenient than standalone stored procedures and functions when they call back and forth to each other.
- Declarations for overloaded procedures and functions. You can create multiple variations of a procedure or function, using the same names but different sets of parameters.
- Variables that you want to remain available between procedure calls in the same session. You can treat variables in a package like global variables.
- Type declarations for PL/SQL collection types. To pass a collection as a parameter between stored procedures or functions, you must declare the type in a package so that both the calling and called subprogram can refer to it.

For additional information, see "Package Declaration" on page 13-85. For an examples of a PL/SQL packages, see Example 1–13, "Creating a Package and Package Body" on page 1-14 and Example 9–3 on page 9-6. Only the declarations in the package spec are visible and accessible to applications. Implementation details in the package body are hidden and inaccessible. You can change the body (implementation) without having to recompile calling programs.

Advantages of PL/SQL Packages

Packages have a long history in software engineering, offering important features for reliable, maintainable, reusable code, often in team development efforts for large systems.

Modularity

Packages let you encapsulate logically related types, items, and subprograms in a named PL/SQL module. Each package is easy to understand, and the interfaces between packages are simple, clear, and well defined. This aids application development.

Easier Application Design

When designing an application, all you need initially is the interface information in the package specs. You can code and compile a spec without its body. Then, stored subprograms that reference the package can be compiled as well. You need not define the package bodies fully until you are ready to complete the application.

Information Hiding

With packages, you can specify which types, items, and subprograms are public (visible and accessible) or private (hidden and inaccessible). For example, if a package contains four subprograms, three might be public and one private. The package hides the implementation of the private subprogram so that only the package (not your application) is affected if the implementation changes. This simplifies maintenance and enhancement. Also, by hiding implementation details from users, you protect the integrity of the package.

Added Functionality

Packaged public variables and cursors persist for the duration of a session. They can be shared by all subprograms that execute in the environment. They let you maintain data across transactions without storing it in the database.

Better Performance

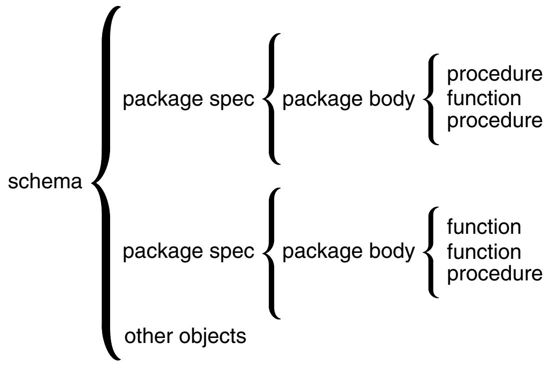
When you call a packaged subprogram for the first time, the whole package is loaded into memory. Later calls to related subprograms in the package require no disk I/O.

Packages stop cascading dependencies and avoid unnecessary recompiling. For example, if you change the body of a packaged function, Oracle does not recompile other subprograms that call the function; these subprograms only depend on the parameters and return value that are declared in the spec, so they are only recompiled if the spec changes.

Understanding The Package Specification

The package specification contains public declarations. The declared items are accessible from anywhere in the package and to any other subprograms in the same schema. Figure 9–1 illustrates the scoping.

Figure 9–1 Package Scope



The spec lists the package resources available to applications. All the information your application needs to use the resources is in the spec. For example, the following declaration shows that the function named `factorial` takes one argument of type `INTEGER` and returns a value of type `INTEGER`:

```
FUNCTION factorial (n INTEGER) RETURN INTEGER; -- returns n!
```

That is all the information you need to call the function. You need not consider its underlying implementation (whether it is iterative or recursive for example).

If a spec declares only types, constants, variables, exceptions, and call specs, the package body is unnecessary. Only subprograms and cursors have an underlying implementation. In Example 9–1, the package needs no body because it declares types, exceptions, and variables, but no subprograms or cursors. Such packages let you define global variables, usable by stored procedures and functions and triggers, that persist throughout a session.

Example 9–1 A Simple Package Specification Without a Body

```
CREATE PACKAGE trans_data AS  -- bodiless package
   TYPE TimeRec IS RECORD (
      minutes SMALLINT,
      hours   SMALLINT);
   TYPE TransRec IS RECORD (
      category VARCHAR2(10),
      account  INT,
      amount   REAL,
      time_of  TimeRec);
   minimum_balance    CONSTANT REAL := 10.00;
   number_processed   INT;
   insufficient_funds EXCEPTION;
END trans_data;
/
```

Referencing Package Contents

To reference the types, items, subprograms, and call specs declared within a package spec, use dot notation:

```
package_name.type_name
package_name.item_name
package_name.subprogram_name
package_name.call_spec_name
```

You can reference package contents from database triggers, stored subprograms, 3GL application programs, and various Oracle tools. For example, you can call package procedures as shown in Example 1–14, "Calling a Procedure in a Package" on page 1-15 or Example 9–3 on page 9-6.

The following example calls the `hire_employee` procedure from an anonymous block in a Pro*C program. The actual parameters `emp_id`, `emp_lname`, and `emp_fname` are host variables.

```
EXEC SQL EXECUTE
 BEGIN
  emp_actions.hire_employee(:emp_id,:emp_lname,:emp_fname, ...);
```

Restrictions

You cannot reference remote packaged variables, either directly or indirectly. For example, you cannot call the a procedure through a database link if the procedure refers to a packaged variable.

Inside a package, you cannot reference host variables.

Understanding The Package Body

The package body contains the implementation of every cursor and subprogram declared in the package spec. Subprograms defined in a package body are accessible outside the package only if their specs also appear in the package spec. If a subprogram spec is not included in the package spec, that subprogram can only be called by other subprograms in the same package. A package body must be in the same schema as the package spec.

To match subprogram specs and bodies, PL/SQL does a token-by-token comparison of their headers. Except for white space, the headers must match word for word. Otherwise, PL/SQL raises an exception, as Example 9–2 shows.

Example 9–2 Matching Package Specifications and Bodies

```
CREATE PACKAGE emp_bonus AS
   PROCEDURE calc_bonus (date_hired employees.hire_date%TYPE);
END emp_bonus;
/
CREATE PACKAGE BODY emp_bonus AS
-- the following parameter declaration raises an exception
-- because 'DATE' does not match employees.hire_date%TYPE
-- PROCEDURE calc_bonus (date_hired DATE) IS
-- the following is correct because there is an exact match
   PROCEDURE calc_bonus (date_hired employees.hire_date%TYPE) IS
   BEGIN
     DBMS_OUTPUT.PUT_LINE('Employees hired on ' || date_hired || ' get bonus.');
   END;
END emp_bonus;
/
```

The package body can also contain private declarations, which define types and items necessary for the internal workings of the package. The scope of these declarations is local to the package body. Therefore, the declared types and items are inaccessible except from within the package body. Unlike a package spec, the declarative part of a package body can contain subprogram bodies.

Following the declarative part of a package body is the optional initialization part, which typically holds statements that initialize some of the variables previously declared in the package.

The initialization part of a package plays a minor role because, unlike subprograms, a package cannot be called or passed parameters. As a result, the initialization part of a package is run only once, the first time you reference the package.

Remember, if a package spec declares only types, constants, variables, exceptions, and call specs, the package body is unnecessary. However, the body can still be used to initialize items declared in the package spec.

Some Examples of Package Features

Consider the following package, named `emp_admin`. The package specification declares the following types, items, and subprograms:

- Type `EmpRecTyp`
- Cursor `desc_salary`
- Exception `invalid_salary`
- Functions `hire_employee` and `nth_highest_salary`
- Procedures `fire_employee` and `raise_salary`

After writing the package, you can develop applications that reference its types, call its subprograms, use its cursor, and raise its exception. When you create the package, it is stored in an Oracle database for use by any application that has execute privilege on the package.

Example 9–3 Creating the emp_admin Package

```
-- create the audit table to track changes
CREATE TABLE emp_audit(date_of_action DATE, user_id VARCHAR2(20),
                       package_name VARCHAR2(30));

CREATE OR REPLACE PACKAGE emp_admin AS
-- Declare externally visible types, cursor, exception
   TYPE EmpRecTyp IS RECORD (emp_id NUMBER, sal NUMBER);
   CURSOR desc_salary RETURN EmpRecTyp;
   invalid_salary EXCEPTION;
-- Declare externally callable subprograms
   FUNCTION hire_employee (last_name VARCHAR2, first_name VARCHAR2,
     email VARCHAR2, phone_number VARCHAR2, job_id VARCHAR2, salary NUMBER,
     commission_pct NUMBER, manager_id NUMBER, department_id NUMBER)
     RETURN NUMBER;
   PROCEDURE fire_employee (emp_id NUMBER); -- overloaded subprogram
   PROCEDURE fire_employee (emp_email VARCHAR2); -- overloaded subprogram
   PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER);
   FUNCTION nth_highest_salary (n NUMBER) RETURN EmpRecTyp;
END emp_admin;
/
CREATE OR REPLACE PACKAGE BODY emp_admin AS
   number_hired NUMBER;  -- visible only in this package
-- Fully define cursor specified in package
   CURSOR desc_salary RETURN EmpRecTyp IS
      SELECT employee_id, salary FROM employees ORDER BY salary DESC;
-- Fully define subprograms specified in package
   FUNCTION hire_employee (last_name VARCHAR2, first_name VARCHAR2,
     email VARCHAR2, phone_number VARCHAR2, job_id VARCHAR2, salary NUMBER,
     commission_pct NUMBER, manager_id NUMBER, department_id NUMBER)
     RETURN NUMBER IS
     new_emp_id NUMBER;
   BEGIN
      SELECT employees_seq.NEXTVAL INTO new_emp_id FROM dual;
      INSERT INTO employees VALUES (new_emp_id, last_name, first_name, email,
        phone_number, SYSDATE, job_id, salary, commission_pct, manager_id,
        department_id);
      number_hired := number_hired + 1;
      DBMS_OUTPUT.PUT_LINE('The number of employees hired is '
                           || TO_CHAR(number_hired) );
      RETURN new_emp_id;
   END hire_employee;
   PROCEDURE fire_employee (emp_id NUMBER) IS
   BEGIN
      DELETE FROM employees WHERE employee_id = emp_id;
   END fire_employee;
   PROCEDURE fire_employee (emp_email VARCHAR2) IS
   BEGIN
      DELETE FROM employees WHERE email = emp_email;
   END fire_employee;
  -- Define local function, available only inside package
   FUNCTION sal_ok (jobid VARCHAR2, sal NUMBER) RETURN BOOLEAN IS
      min_sal NUMBER;
      max_sal NUMBER;
   BEGIN
      SELECT MIN(salary), MAX(salary) INTO min_sal, max_sal FROM employees
         WHERE job_id = jobid;
      RETURN (sal >= min_sal) AND (sal <= max_sal);
   END sal_ok;
   PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER) IS
      sal NUMBER(8,2);
      jobid VARCHAR2(10);
   BEGIN
      SELECT job_id, salary INTO jobid, sal FROM employees
             WHERE employee_id = emp_id;
      IF sal_ok(jobid, sal + amount) THEN
         UPDATE employees SET salary = salary + amount WHERE employee_id = emp_id;
      ELSE
         RAISE invalid_salary;
      END IF;
   EXCEPTION  -- exception-handling part starts here
     WHEN invalid_salary THEN
       DBMS_OUTPUT.PUT_LINE('The salary is out of the specified range.');
   END raise_salary;
   FUNCTION nth_highest_salary (n NUMBER) RETURN EmpRecTyp IS
      emp_rec EmpRecTyp;
   BEGIN
      OPEN desc_salary;
      FOR i IN 1..n LOOP
         FETCH desc_salary INTO emp_rec;
      END LOOP;
      CLOSE desc_salary;
      RETURN emp_rec;
   END nth_highest_salary;
BEGIN  -- initialization part starts here
   INSERT INTO emp_audit VALUES (SYSDATE, USER, 'EMP_ADMIN');
   number_hired := 0;
END emp_admin;
/
```

```
-- calling the package procedures
DECLARE
  new_emp_id NUMBER(6);
BEGIN
  new_emp_id := emp_admin.hire_employee('Belden', 'Enrique', 'EBELDEN',
                  '555.111.2222', 'ST_CLERK', 2500, .1, 101, 110);
  DBMS_OUTPUT.PUT_LINE('The new employee id is ' || TO_CHAR(new_emp_id) );
  EMP_ADMIN.raise_salary(new_emp_id, 100);
  DBMS_OUTPUT.PUT_LINE('The 10th highest salary is '||
    TO_CHAR(emp_admin.nth_highest_salary(10).sal) || ', belonging to employee: '
    || TO_CHAR(emp_admin.nth_highest_salary(10).emp_id) );
  emp_admin.fire_employee(new_emp_id);
-- you could also delete the newly added employee as follows:
--  emp_admin.fire_employee('EBELDEN');
END;
/
```

Remember, the initialization part of a package is run just once, the first time you reference the package. In the last example, only one row is inserted into the database table `emp_audit`, and the variable `number_hired` is initialized only once.

Every time the procedure `hire_employee` is called, the variable `number_hired` is updated. However, the count kept by `number_hired` is session specific. That is, the count reflects the number of new employees processed by one user, not the number processed by all users.

PL/SQL allows two or more packaged subprograms to have the same name. This option is useful when you want a subprogram to accept similar sets of parameters that have different datatypes. For example, the `emp_admin` package in Example 9–3 defines two procedures named `fire_employee`. The first procedure accepts a number, while the second procedure accepts string. Each procedure handles the data appropriately. For the rules that apply to overloaded subprograms, see "Overloading Subprogram Names" on page 8-10.

Private Versus Public Items in Packages

In the package `emp_admin`, the package body declares a variable named `number_hired`, which is initialized to zero. Items declared in the body are restricted to use within the package. PL/SQL code outside the package cannot reference the variable `number_hired`. Such items are called private.

Items declared in the spec of `emp_admin`, such as the exception `invalid_salary`, are visible outside the package. Any PL/SQL code can reference the exception `invalid_salary`. Such items are called public.

To maintain items throughout a session or across transactions, place them in the declarative part of the package body. For example, the value of `number_hired` is kept between calls to `hire_employee` within the same session. The value is lost when the session ends.

To make the items public, place them in the package specification. For example, `emp_rec` declared in the spec of the package is available for general use.

How Package STANDARD Defines the PL/SQL Environment

A package named `STANDARD` defines the PL/SQL environment. The package spec globally declares types, exceptions, and subprograms, which are available automatically to PL/SQL programs. For example, package `STANDARD` declares function `ABS`, which returns the absolute value of its argument, as follows:

```
FUNCTION ABS (n NUMBER) RETURN NUMBER;
```

The contents of package `STANDARD` are directly visible to applications. You do not need to qualify references to its contents by prefixing the package name. For example, you might call `ABS` from a database trigger, stored subprogram, Oracle tool, or 3GL application, as follows:

```
abs_diff := ABS(x - y);
```

If you declare your own version of `ABS`, your local declaration overrides the global declaration. You can still call the built-in function by specifying its full name:

```
abs_diff := STANDARD.ABS(x - y);
```

Most built-in functions are overloaded. For example, package `STANDARD` contains the following declarations:

```
FUNCTION TO_CHAR (right DATE) RETURN VARCHAR2;
FUNCTION TO_CHAR (left NUMBER) RETURN VARCHAR2;
FUNCTION TO_CHAR (left DATE, right VARCHAR2) RETURN VARCHAR2;
FUNCTION TO_CHAR (left NUMBER, right VARCHAR2) RETURN VARCHAR2;
```

PL/SQL resolves a call to `TO_CHAR` by matching the number and datatypes of the formal and actual parameters.

Overview of Product-Specific Packages

Oracle and various Oracle tools are supplied with product-specific packages that define application programming interfaces (APIs) you can call from PL/SQL, SQL, Java, or other programming environments. Here we mention a few of the more widely used ones. For more information, see *Oracle Database PL/SQL Packages and Types Reference*.

About the DBMS_ALERT Package

Package `DBMS_ALERT` lets you use database triggers to alert an application when specific database values change. The alerts are transaction based and asynchronous (that is, they operate independently of any timing mechanism). For example, a company might use this package to update the value of its investment portfolio as new stock and bond quotes arrive.

About the DBMS_OUTPUT Package

Package `DBMS_OUTPUT` enables you to display output from PL/SQL blocks, subprograms, packages, and triggers. The package is especially useful for displaying PL/SQL debugging information. The procedure `PUT_LINE` outputs information to a buffer that can be read by another trigger, procedure, or package. You display the information by calling the procedure `GET_LINE` or by setting `SERVEROUTPUT ON` in SQL*Plus. Example 9–4 shows how to display output from a PL/SQL block.

Example 9–4 Using PUT_LINE in the DBMS_OUTPUT Package

```
REM set server output to ON to display output from DBMS_OUTPUT
SET SERVEROUTPUT ON
BEGIN
  DBMS_OUTPUT.PUT_LINE('These are the tables that ' || USER || ' owns:');
  FOR item IN (SELECT table_name FROM user_tables)
    LOOP
      DBMS_OUTPUT.PUT_LINE(item.table_name);
```

```
   END LOOP;
END;
/
```

About the DBMS_PIPE Package

Package DBMS_PIPE allows different sessions to communicate over named pipes. (A *pipe* is an area of memory used by one process to pass information to another.) You can use the procedures PACK_MESSAGE and SEND_MESSAGE to pack a message into a pipe, then send it to another session in the same instance or to a waiting application such as a UNIX program.

At the other end of the pipe, you can use the procedures RECEIVE_MESSAGE and UNPACK_MESSAGE to receive and unpack (read) the message. Named pipes are useful in many ways. For example, you can write a C program to collect data, then send it through pipes to stored procedures in an Oracle database.

About the HTF and HTP Packages

Packages HTF and HTP allow your PL/SQL programs to generate HTML tags.

About the UTL_FILE Package

Package UTL_FILE lets PL/SQL programs read and write operating system (OS) text files. It provides a restricted version of standard OS stream file I/O, including open, put, get, and close operations.

When you want to read or write a text file, you call the function FOPEN, which returns a file handle for use in subsequent procedure calls. For example, the procedure PUT_LINE writes a text string and line terminator to an open file, and the procedure GET_LINE reads a line of text from an open file into an output buffer.

About the UTL_HTTP Package

Package UTL_HTTP allows your PL/SQL programs to make hypertext transfer protocol (HTTP) callouts. It can retrieve data from the Internet or call Oracle Web Server cartridges. The package has two entry points, each of which accepts a URL (uniform resource locator) string, contacts the specified site, and returns the requested data, which is usually in hypertext markup language (HTML) format.

About the UTL_SMTP Package

Package UTL_SMTP allows your PL/SQL programs to send electronic mails (emails) over Simple Mail Transfer Protocol (SMTP). The package provides interfaces to the SMTP commands for an email client to dispatch emails to a SMTP server.

Guidelines for Writing Packages

When writing packages, keep them general so they can be reused in future applications. Become familiar with the Oracle-supplied packages, and avoid writing packages that duplicate features already provided by Oracle.

Design and define package specs before the package bodies. Place in a spec only those things that must be visible to calling programs. That way, other developers cannot build unsafe dependencies on your implementation details.

To reduce the need for recompiling when code is changed, place as few items as possible in a package spec. Changes to a package body do not require recompiling calling procedures. Changes to a package spec require Oracle to recompile every stored subprogram that references the package.

Separating Cursor Specs and Bodies with Packages

You can separate a cursor specification (spec for short) from its body for placement in a package. That way, you can change the cursor body without having to change the cursor spec. For information on the cursor syntax, see "Cursor Declaration" on page 13-33.

In Example 9–5, you use the %ROWTYPE attribute to provide a record type that represents a row in the database table employees:

Example 9–5 Separating Cursor Specifications With Packages

```
CREATE PACKAGE emp_stuff AS
   CURSOR c1 RETURN employees%ROWTYPE;  -- declare cursor spec
END emp_stuff;
/
CREATE PACKAGE BODY emp_stuff AS
   CURSOR c1 RETURN employees%ROWTYPE IS
      SELECT * FROM employees WHERE salary > 2500;  -- define cursor body
END emp_stuff;
/
```

The cursor spec has no SELECT statement because the RETURN clause specifies the datatype of the return value. However, the cursor body must have a SELECT statement and the same RETURN clause as the cursor spec. Also, the number and datatypes of items in the SELECT list and the RETURN clause must match.

Packaged cursors increase flexibility. For example, you can change the cursor body in the last example, without having to change the cursor spec.

From a PL/SQL block or subprogram, you use dot notation to reference a packaged cursor, as the following example shows:

```
DECLARE
   emp_rec employees%ROWTYPE;
BEGIN
   OPEN emp_stuff.c1;
   LOOP
      FETCH emp_stuff.c1 INTO emp_rec;
-- do processing here ...
      EXIT WHEN emp_stuff.c1%NOTFOUND;
   END LOOP;
   CLOSE emp_stuff.c1;
END;
/
```

The scope of a packaged cursor is not limited to a PL/SQL block. When you open a packaged cursor, it remains open until you close it or you disconnect from the session.

10 Handling PL/SQL Errors

Run-time errors arise from design faults, coding mistakes, hardware failures, and many other sources. Although you cannot anticipate all possible errors, you can plan to handle certain kinds of errors meaningful to your PL/SQL program.

With many programming languages, unless you disable error checking, a run-time error such as stack overflow or division by zero stops normal processing and returns control to the operating system. With PL/SQL, a mechanism called exception handling lets you bulletproof your program so that it can continue operating in the presence of errors.

This chapter contains these topics:

Overview of PL/SQL Runtime Error Handling

In PL/SQL, an error condition is called an exception. Exceptions can be internally defined (by the runtime system) or user defined. Examples of internally defined exceptions include `division by zero` and `out of memory`. Some common internal exceptions have predefined names, such as `ZERO_DIVIDE` and `STORAGE_ERROR`. The other internal exceptions can be given names.

You can define exceptions of your own in the declarative part of any PL/SQL block, subprogram, or package. For example, you might define an exception named `insufficient_funds` to flag overdrawn bank accounts. Unlike internal exceptions, user-defined exceptions must be given names.

When an error occurs, an exception is raised. That is, normal execution stops and control transfers to the exception-handling part of your PL/SQL block or subprogram. Internal exceptions are raised implicitly (automatically) by the run-time system. User-defined exceptions must be raised explicitly by `RAISE` statements, which can also raise predefined exceptions.

To handle raised exceptions, you write separate routines called exception handlers. After an exception handler runs, the current block stops executing and the enclosing block resumes with the next statement. If there is no enclosing block, control returns to the host environment. For information on managing errors when using `BULK COLLECT`, see "Handling FORALL Exceptions with the %BULK_EXCEPTIONS Attribute" on page 11-14.

Example 10–1 calculates a price-to-earnings ratio for a company. If the company has zero earnings, the division operation raises the predefined exception `ZERO_DIVIDE`, the execution of the block is interrupted, and control is transferred to the exception handlers. The optional `OTHERS` handler catches all exceptions that the block does not name specifically.

Example 10–1 Runtime Error Handling

```
DECLARE
   stock_price NUMBER := 9.73;
   net_earnings NUMBER := 0;
   pe_ratio NUMBER;
BEGIN
-- Calculation might cause division-by-zero error.
   pe_ratio := stock_price / net_earnings;
   DBMS_OUTPUT.PUT_LINE('Price/earnings ratio = ' || pe_ratio);
EXCEPTION  -- exception handlers begin
-- Only one of the WHEN blocks is executed.
   WHEN ZERO_DIVIDE THEN  -- handles 'division by zero' error
      DBMS_OUTPUT.PUT_LINE('Company must have had zero earnings.');
      pe_ratio := NULL;
   WHEN OTHERS THEN  -- handles all other errors
      DBMS_OUTPUT.PUT_LINE('Some other kind of error occurred.');
      pe_ratio := NULL;
END;  -- exception handlers and block end here
/
```

The last example illustrates exception handling. With some better error checking, we could have avoided the exception entirely, by substituting a null for the answer if the denominator was zero, as shown in the following example.

```
DECLARE
   stock_price NUMBER := 9.73;
   net_earnings NUMBER := 0;
   pe_ratio NUMBER;
BEGIN
   pe_ratio :=
      CASE net_earnings
         WHEN 0 THEN NULL
         ELSE stock_price / net_earnings
      end;
END;
/
```

Guidelines for Avoiding and Handling PL/SQL Errors and Exceptions

Because reliability is crucial for database programs, use both error checking and exception handling to ensure your program can handle all possibilities:

- Add exception handlers whenever there is any possibility of an error occurring. Errors are especially likely during arithmetic calculations, string manipulation, and database operations. Errors could also occur at other times, for example if a hardware failure with disk storage or memory causes a problem that has nothing to do with your code; but your code still needs to take corrective action.

- Add error-checking code whenever you can predict that an error might occur if your code gets bad input data. Expect that at some time, your code will be passed incorrect or null parameters, that your queries will return no rows or more rows than you expect.
- Make your programs robust enough to work even if the database is not in the state you expect. For example, perhaps a table you query will have columns added or deleted, or their types changed. You can avoid such problems by declaring individual variables with `%TYPE` qualifiers, and declaring records to hold query results with `%ROWTYPE` qualifiers.
- Handle named exceptions whenever possible, instead of using WHEN OTHERS in exception handlers. Learn the names and causes of the predefined exceptions. If your database operations might cause particular ORA- errors, associate names with these errors so you can write handlers for them. (You will learn how to do that later in this chapter.)
- Test your code with different combinations of bad data to see what potential errors arise.
- Write out debugging information in your exception handlers. You might store such information in a separate table. If so, do it by making a call to a procedure declared with the `PRAGMA AUTONOMOUS_TRANSACTION`, so that you can commit your debugging information, even if you roll back the work that the main procedure was doing.
- Carefully consider whether each exception handler should commit the transaction, roll it back, or let it continue. Remember, no matter how severe the error is, you want to leave the database in a consistent state and avoid storing any bad data.

Advantages of PL/SQL Exceptions

Using exceptions for error handling has several advantages. With exceptions, you can reliably handle potential errors from many statements with a single exception handler:

Example 10–2 Managing Multiple Errors With a Single Exception Handler

```
DECLARE
   emp_column       VARCHAR2(30) := 'last_name';
   table_name       VARCHAR2(30) := 'emp';
   temp_var         VARCHAR2(30);
BEGIN
  temp_var := emp_column;
  SELECT COLUMN_NAME INTO temp_var FROM USER_TAB_COLS
    WHERE TABLE_NAME = 'EMPLOYEES' AND COLUMN_NAME = UPPER(emp_column);
-- processing here
  temp_var := table_name;
  SELECT OBJECT_NAME INTO temp_var FROM USER_OBJECTS
    WHERE OBJECT_NAME = UPPER(table_name) AND OBJECT_TYPE = 'TABLE';
-- processing here
EXCEPTION
   WHEN NO_DATA_FOUND THEN  -- catches all 'no data found' errors
     DBMS_OUTPUT.PUT_LINE ('No Data found for SELECT on ' || temp_var);
END;
/
```

Instead of checking for an error at every point it might occur, just add an exception handler to your PL/SQL block. If the exception is ever raised in that block (or any sub-block), you can be sure it will be handled.

Sometimes the error is not immediately obvious, and could not be detected until later when you perform calculations using bad data. Again, a single exception handler can trap all division-by-zero errors, bad array subscripts, and so on.

If you need to check for errors at a specific spot, you can enclose a single statement or a group of statements inside its own `BEGIN-END` block with its own exception handler. You can make the checking as general or as precise as you like.

Isolating error-handling routines makes the rest of the program easier to read and understand.

Summary of Predefined PL/SQL Exceptions

An internal exception is raised automatically if your PL/SQL program violates an Oracle rule or exceeds a system-dependent limit. PL/SQL predefines some common Oracle errors as exceptions. For example, PL/SQL raises the predefined exception `NO_DATA_FOUND` if a `SELECT INTO` statement returns no rows.

You can use the pragma `EXCEPTION_INIT` to associate exception names with other Oracle error codes that you can anticipate. To handle unexpected Oracle errors, you can use the `OTHERS` handler. Within this handler, you can call the functions `SQLCODE` and `SQLERRM` to return the Oracle error code and message text. Once you know the error code, you can use it with pragma `EXCEPTION_INIT` and write a handler specifically for that error.

PL/SQL declares predefined exceptions globally in package `STANDARD`. You need not declare them yourself. You can write handlers for predefined exceptions using the names in the following table:

Exception	**ORA Error**	**SQLCODE**	**Raise When ...**
`ACCESS_INTO_NULL`	`06530`	`-6530`	A program attempts to assign values to the attributes of an uninitialized object
`CASE_NOT_FOUND`	`06592`	`-6592`	None of the choices in the `WHEN` clauses of a `CASE` statement is selected, and there is no `ELSE` clause.
`COLLECTION_IS_NULL`	`06531`	`-6531`	A program attempts to apply collection methods other than `EXISTS` to an uninitialized nested table or varray, or the program attempts to assign values to the elements of an uninitialized nested table or varray.
`CURSOR_ALREADY_OPEN`	`06511`	`-6511`	A program attempts to open an already open cursor. A cursor must be closed before it can be reopened. A cursor `FOR` loop automatically opens the cursor to which it refers, so your program cannot open that cursor inside the loop.
`DUP_VAL_ON_INDEX`	`00001`	`-1`	A program attempts to store duplicate values in a column that is constrained by a unique index.
`INVALID_CURSOR`	`01001`	`-1001`	A program attempts a cursor operation that is not allowed, such as closing an unopened cursor.
`INVALID_NUMBER`	`01722`	`-1722`	n a SQL statement, the conversion of a character string into a number fails because the string does not represent a valid number. (In procedural statements, `VALUE_ERROR` is raised.) This exception is also raised when the `LIMIT`-clause expression in a bulk `FETCH` statement does not evaluate to a positive number.

Exception	ORA Error	SQLCODE	Raise When ...
LOGIN_DENIED	01017	-1017	A program attempts to log on to Oracle with an invalid username or password.
NO_DATA_FOUND	01403	+100	A SELECT INTO statement returns no rows, or your program references a deleted element in a nested table or an uninitialized element in an index-by table. Because this exception is used internally by some SQL functions to signal completion, you should not rely on this exception being propagated if you raise it within a function that is called as part of a query.
NOT_LOGGED_ON	01012	-1012	A program issues a database call without being connected to Oracle.
PROGRAM_ERROR	06501	-6501	PL/SQL has an internal problem.
ROWTYPE_MISMATCH	06504	-6504	The host cursor variable and PL/SQL cursor variable involved in an assignment have incompatible return types. When an open host cursor variable is passed to a stored subprogram, the return types of the actual and formal parameters must be compatible.
SELF_IS_NULL	30625	-30625	A program attempts to call a MEMBER method, but the instance of the object type has not been initialized. The built-in parameter SELF points to the object, and is always the first parameter passed to a MEMBER method.
STORAGE_ERROR	06500	-6500	PL/SQL runs out of memory or memory has been corrupted.
SUBSCRIPT_BEYOND_COUNT	06533	-6533	A program references a nested table or varray element using an index number larger than the number of elements in the collection.
SUBSCRIPT_OUTSIDE_LIMIT	06532	-6532	A program references a nested table or varray element using an index number (-1 for example) that is outside the legal range.
SYS_INVALID_ROWID	01410	-1410	The conversion of a character string into a universal rowid fails because the character string does not represent a valid rowid.
TIMEOUT_ON_RESOURCE	00051	-51	A time out occurs while Oracle is waiting for a resource.
TOO_MANY_ROWS	01422	-1422	A SELECT INTO statement returns more than one row.
VALUE_ERROR	06502	-6502	An arithmetic, conversion, truncation, or size-constraint error occurs. For example, when your program selects a column value into a character variable, if the value is longer than the declared length of the variable, PL/SQL aborts the assignment and raises VALUE_ERROR. In procedural statements, VALUE_ERROR is raised if the conversion of a character string into a number fails. (In SQL statements, INVALID_NUMBER is raised.)
ZERO_DIVIDE	01476	-1476	A program attempts to divide a number by zero.

Defining Your Own PL/SQL Exceptions

PL/SQL lets you define exceptions of your own. Unlike predefined exceptions, user-defined exceptions must be declared and must be raised explicitly by RAISE statements.

Declaring PL/SQL Exceptions

Exceptions can be declared only in the declarative part of a PL/SQL block, subprogram, or package. You declare an exception by introducing its name, followed by the keyword EXCEPTION. In the following example, you declare an exception named past_due:

```
DECLARE
   past_due EXCEPTION;
```

Exception and variable declarations are similar. But remember, an exception is an error condition, not a data item. Unlike variables, exceptions cannot appear in assignment statements or SQL statements. However, the same scope rules apply to variables and exceptions.

Scope Rules for PL/SQL Exceptions

You cannot declare an exception twice in the same block. You can, however, declare the same exception in two different blocks.

Exceptions declared in a block are considered local to that block and global to all its sub-blocks. Because a block can reference only local or global exceptions, enclosing blocks cannot reference exceptions declared in a sub-block.

If you redeclare a global exception in a sub-block, the local declaration prevails. The sub-block cannot reference the global exception, unless the exception is declared in a labeled block and you qualify its name with the block label:

```
block_label.exception_name
```

Example 10–3 illustrates the scope rules:

Example 10–3 Scope of PL/SQL Exceptions

```
DECLARE
   past_due EXCEPTION;
   acct_num NUMBER;
BEGIN
   DECLARE  ---------- sub-block begins
      past_due EXCEPTION;  -- this declaration prevails
      acct_num NUMBER;
     due_date DATE := SYSDATE - 1;
     todays_date DATE := SYSDATE;
   BEGIN
      IF due_date < todays_date THEN
         RAISE past_due;  -- this is not handled
      END IF;
   END;  ------------- sub-block ends
EXCEPTION
  WHEN past_due THEN  -- does not handle raised exception
    DBMS_OUTPUT.PUT_LINE('Handling PAST_DUE exception.');
  WHEN OTHERS THEN
    DBMS_OUTPUT.PUT_LINE('Could not recognize PAST_DUE_EXCEPTION in this scope.');
END;
/
```

The enclosing block does not handle the raised exception because the declaration of past_due in the sub-block prevails. Though they share the same name, the two past_due exceptions are different, just as the two acct_num variables share the same name but are different variables. Thus, the RAISE statement and the WHEN clause refer to different exceptions. To have the enclosing block handle the raised exception, you must remove its declaration from the sub-block or define an `OTHERS` handler.

Associating a PL/SQL Exception with a Number: Pragma EXCEPTION_INIT

To handle error conditions (typically `ORA-` messages) that have no predefined name, you must use the `OTHERS` handler or the pragma `EXCEPTION_INIT`. A pragma is a compiler directive that is processed at compile time, not at run time.

In PL/SQL, the pragma `EXCEPTION_INIT` tells the compiler to associate an exception name with an Oracle error number. That lets you refer to any internal exception by name and to write a specific handler for it. When you see an error stack, or sequence of error messages, the one on top is the one that you can trap and handle.

You code the pragma `EXCEPTION_INIT` in the declarative part of a PL/SQL block, subprogram, or package using the syntax

```
PRAGMA EXCEPTION_INIT(exception_name, -Oracle_error_number);
```

where `exception_name` is the name of a previously declared exception and the number is a negative value corresponding to an `ORA-` error number. The pragma must appear somewhere after the exception declaration in the same declarative section, as shown in Example 10–4.

Example 10–4   Using PRAGMA EXCEPTION_INIT

```
DECLARE
   deadlock_detected EXCEPTION;
   PRAGMA EXCEPTION_INIT(deadlock_detected, -60);
BEGIN
   NULL; -- Some operation that causes an ORA-00060 error
EXCEPTION
   WHEN deadlock_detected THEN
      NULL; -- handle the error
END;
/
```

Defining Your Own Error Messages: Procedure RAISE_APPLICATION_ERROR

The procedure `RAISE_APPLICATION_ERROR` lets you issue user-defined `ORA-` error messages from stored subprograms. That way, you can report errors to your application and avoid returning unhandled exceptions.

To call `RAISE_APPLICATION_ERROR`, use the syntax

```
raise_application_error(
      error_number, message[, {TRUE | FALSE}]);
```

where `error_number` is a negative integer in the range -20000 .. -20999 and `message` is a character string up to 2048 bytes long. If the optional third parameter is `TRUE`, the error is placed on the stack of previous errors. If the parameter is `FALSE` (the default), the error replaces all previous errors. `RAISE_APPLICATION_ERROR` is part of package `DBMS_STANDARD`, and as with package `STANDARD`, you do not need to qualify references to it.

An application can call `raise_application_error` only from an executing stored subprogram (or method). When called, `raise_application_error` ends the subprogram and returns a user-defined error number and message to the application. The error number and message can be trapped like any Oracle error.

In Example 10–5, you call raise_application_error if an error condition of your choosing happens (in this case, if the current schema owns less than 1000 tables):

Example 10–5 Raising an Application Error With raise_application_error

```
DECLARE
   num_tables NUMBER;
BEGIN
   SELECT COUNT(*) INTO num_tables FROM USER_TABLES;
   IF num_tables < 1000 THEN
      /* Issue your own error code (ORA-20101) with your own error message.
         Note that you do not need to qualify raise_application_error with
         DBMS_STANDARD */
      raise_application_error(-20101, 'Expecting at least 1000 tables');
   ELSE
      NULL; -- Do the rest of the processing (for the non-error case).
   END IF;
END;
/
```

The calling application gets a PL/SQL exception, which it can process using the error-reporting functions SQLCODE and SQLERRM in an OTHERS handler. Also, it can use the pragma EXCEPTION_INIT to map specific error numbers returned by raise_application_error to exceptions of its own, as the following Pro*C example shows:

```
EXEC SQL EXECUTE
  /* Execute embedded PL/SQL block using host
    variables v_emp_id and v_amount, which were
    assigned values in the host environment. */
  DECLARE
    null_salary EXCEPTION;
    /* Map error number returned by raise_application_error
      to user-defined exception. */
    PRAGMA EXCEPTION_INIT(null_salary, -20101);
  BEGIN
    raise_salary(:v_emp_id, :v_amount);
  EXCEPTION
    WHEN null_salary THEN
      INSERT INTO emp_audit VALUES (:v_emp_id, ...);
  END;
END-EXEC;
```

This technique allows the calling application to handle error conditions in specific exception handlers.

Redeclaring Predefined Exceptions

Remember, PL/SQL declares predefined exceptions globally in package STANDARD, so you need not declare them yourself. Redeclaring predefined exceptions is error prone because your local declaration overrides the global declaration. For example, if you declare an exception named invalid_number and then PL/SQL raises the predefined exception INVALID_NUMBER internally, a handler written for INVALID_NUMBER will not catch the internal exception. In such cases, you must use dot notation to specify the predefined exception, as follows:

```
EXCEPTION
  WHEN invalid_number OR STANDARD.INVALID_NUMBER THEN
```

```
      -- handle the error
END;
```

How PL/SQL Exceptions Are Raised

Internal exceptions are raised implicitly by the run-time system, as are user-defined exceptions that you have associated with an Oracle error number using `EXCEPTION_INIT`. However, other user-defined exceptions must be raised explicitly by `RAISE` statements.

Raising Exceptions with the RAISE Statement

PL/SQL blocks and subprograms should raise an exception only when an error makes it undesirable or impossible to finish processing. You can place `RAISE` statements for a given exception anywhere within the scope of that exception. In Example 10–6, you alert your PL/SQL block to a user-defined exception named `out_of_stock`.

Example 10–6 Using RAISE to Force a User-Defined Exception

```
DECLARE
   out_of_stock   EXCEPTION;
   number_on_hand NUMBER := 0;
BEGIN
   IF number_on_hand < 1 THEN
      RAISE out_of_stock; -- raise an exception that we defined
   END IF;
EXCEPTION
   WHEN out_of_stock THEN
      -- handle the error
      DBMS_OUTPUT.PUT_LINE('Encountered out-of-stock error.');
END;
/
```

You can also raise a predefined exception explicitly. That way, an exception handler written for the predefined exception can process other errors, as Example 10–7 shows:

Example 10–7 Using RAISE to Force a Pre-Defined Exception

```
DECLARE
   acct_type INTEGER := 7;
BEGIN
   IF acct_type NOT IN (1, 2, 3) THEN
      RAISE INVALID_NUMBER;  -- raise predefined exception
   END IF;
EXCEPTION
   WHEN INVALID_NUMBER THEN
      DBMS_OUTPUT.PUT_LINE('HANDLING INVALID INPUT BY ROLLING BACK.');
      ROLLBACK;
END;
/
```

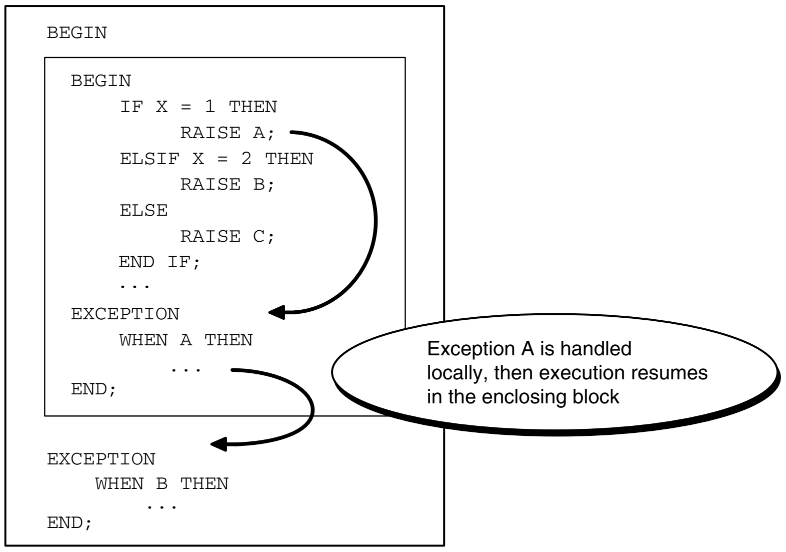
How PL/SQL Exceptions Propagate

When an exception is raised, if PL/SQL cannot find a handler for it in the current block or subprogram, the exception propagates. That is, the exception reproduces itself in successive enclosing blocks until a handler is found or there are no more blocks to search. If no handler is found, PL/SQL returns an unhandled exception error to the host environment.

Exceptions cannot propagate across remote procedure calls done through database links. A PL/SQL block cannot catch an exception raised by a remote subprogram. For a workaround, see "Defining Your Own Error Messages: Procedure RAISE_APPLICATION_ERROR" on page 10-7.

Figure 10–1, Figure 10–2, and Figure 10–3 illustrate the basic propagation rules.

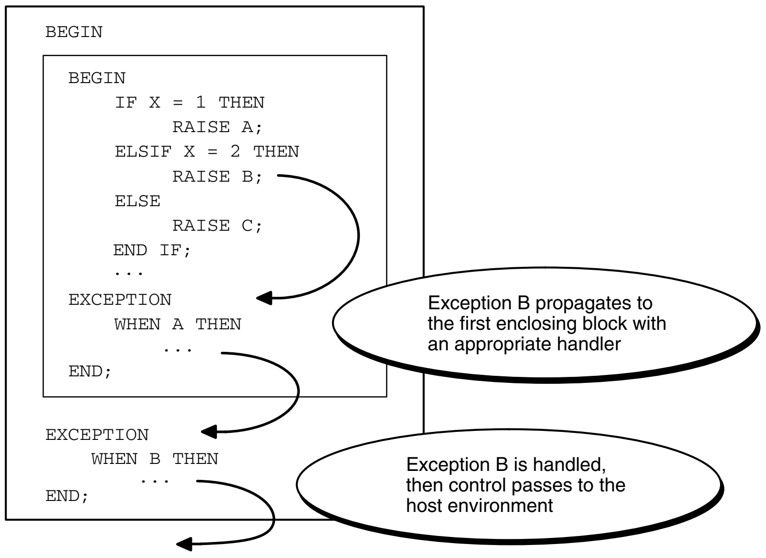
Figure 10–1 Propagation Rules: Example 1



```
BEGIN
  BEGIN
      IF X = 1 THEN
           RAISE A;
      ELSIF X = 2 THEN
           RAISE B;
      ELSE
           RAISE C;
      END IF;
      ...
  EXCEPTION
      WHEN A THEN
          ...
  END;
EXCEPTION
    WHEN B THEN
        ...
END;
```

Exception A is handled locally, then execution resumes in the enclosing block

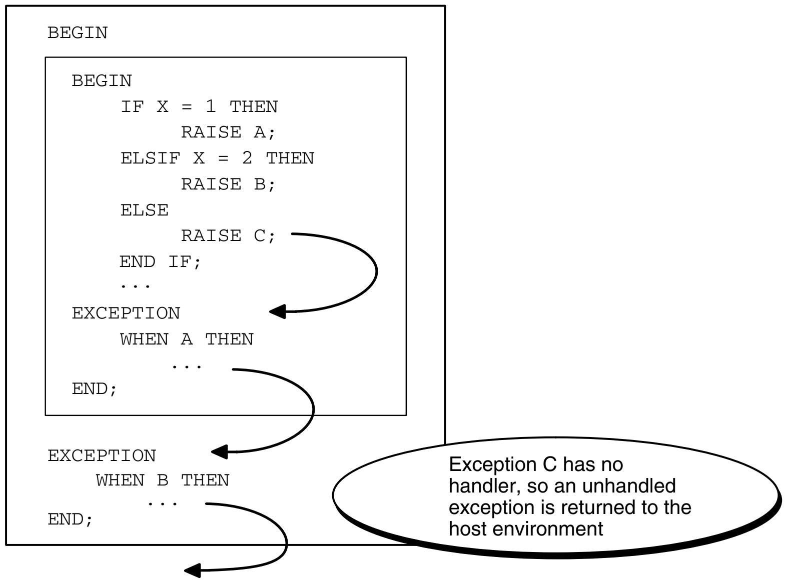
Figure 10–2 Propagation Rules: Example 2



```
BEGIN
  BEGIN
      IF X = 1 THEN
           RAISE A;
      ELSIF X = 2 THEN
           RAISE B;
      ELSE
           RAISE C;
      END IF;
      ...
  EXCEPTION
      WHEN A THEN
          ...
  END;
EXCEPTION
    WHEN B THEN
        ...
END;
```

Exception B propagates to the first enclosing block with an appropriate handler
Exception B is handled, then control passes to the host environment

Figure 10–3 Propagation Rules: Example 3



An exception can propagate beyond its scope, that is, beyond the block in which it was declared, as shown in Example 10–8.

Example 10–8 Scope of an Exception

```
BEGIN
   DECLARE  ---------- sub-block begins
     past_due EXCEPTION;
     due_date DATE := trunc(SYSDATE) - 1;
     todays_date DATE := trunc(SYSDATE);
   BEGIN
     IF due_date < todays_date THEN
        RAISE past_due;
     END IF;
   END;  ------------- sub-block ends
EXCEPTION
   WHEN OTHERS THEN
      ROLLBACK;
END;
/
```

Because the block that declares the exception `past_due` has no handler for it, the exception propagates to the enclosing block. But the enclosing block cannot reference the name `PAST_DUE`, because the scope where it was declared no longer exists. Once the exception name is lost, only an `OTHERS` handler can catch the exception. If there is no handler for a user-defined exception, the calling application gets this error:

```
ORA-06510: PL/SQL: unhandled user-defined exception
```

Reraising a PL/SQL Exception

Sometimes, you want to reraise an exception, that is, handle it locally, then pass it to an enclosing block. For example, you might want to roll back a transaction in the current block, then log the error in an enclosing block.

To reraise an exception, use a `RAISE` statement without an exception name, which is allowed only in an exception handler:

Example 10–9 Reraising a PL/SQL Exception

```
DECLARE
  salary_too_high  EXCEPTION;
  current_salary NUMBER := 20000;
  max_salary NUMBER := 10000;
  erroneous_salary NUMBER;
BEGIN
  BEGIN  ---------- sub-block begins
    IF current_salary > max_salary THEN
      RAISE salary_too_high;  -- raise the exception
    END IF;
  EXCEPTION
    WHEN salary_too_high THEN
      -- first step in handling the error
      DBMS_OUTPUT.PUT_LINE('Salary ' || erroneous_salary || ' is out of range.');
      DBMS_OUTPUT.PUT_LINE('Maximum salary is ' || max_salary || '.');
      RAISE;  -- reraise the current exception
  END;  ------------ sub-block ends
EXCEPTION
  WHEN salary_too_high THEN
    -- handle the error more thoroughly
    erroneous_salary := current_salary;
    current_salary := max_salary;
    DBMS_OUTPUT.PUT_LINE('Revising salary from ' || erroneous_salary ||
       ' to ' || current_salary || '.');
END;
/
```

Handling Raised PL/SQL Exceptions

When an exception is raised, normal execution of your PL/SQL block or subprogram stops and control transfers to its exception-handling part, which is formatted as follows:

```
EXCEPTION
  WHEN exception1 THEN -- handler for exception1
    sequence_of_statements1
  WHEN exception2 THEN -- another handler for exception2
    sequence_of_statements2
  ...
  WHEN OTHERS THEN -- optional handler for all other errors
    sequence_of_statements3
END;
```

To catch raised exceptions, you write exception handlers. Each handler consists of a `WHEN` clause, which specifies an exception, followed by a sequence of statements to be executed when that exception is raised. These statements complete execution of the block or subprogram; control does not return to where the exception was raised. In other words, you cannot resume processing where you left off.

The optional `OTHERS` exception handler, which is always the last handler in a block or subprogram, acts as the handler for all exceptions not named specifically. Thus, a block or subprogram can have only one `OTHERS` handler. Use of the `OTHERS` handler guarantees that no exception will go unhandled.

If you want two or more exceptions to execute the same sequence of statements, list the exception names in the `WHEN` clause, separating them by the keyword `OR`, as follows:

```
EXCEPTION
  WHEN over_limit OR under_limit OR VALUE_ERROR THEN
    -- handle the error
```

If any of the exceptions in the list is raised, the associated sequence of statements is executed. The keyword `OTHERS` cannot appear in the list of exception names; it must appear by itself. You can have any number of exception handlers, and each handler can associate a list of exceptions with a sequence of statements. However, an exception name can appear only once in the exception-handling part of a PL/SQL block or subprogram.

The usual scoping rules for PL/SQL variables apply, so you can reference local and global variables in an exception handler. However, when an exception is raised inside a cursor `FOR` loop, the cursor is closed implicitly before the handler is invoked. Therefore, the values of explicit cursor attributes are *not* available in the handler.

Exceptions Raised in Declarations

Exceptions can be raised in declarations by faulty initialization expressions. For example, the following declaration raises an exception because the constant `credit_limit` cannot store numbers larger than 999:

Example 10–10 Raising an Exception in a Declaration

```
DECLARE
   credit_limit CONSTANT NUMBER(3) := 5000;  -- raises an error
BEGIN
   NULL;
EXCEPTION
   WHEN OTHERS THEN
      -- Cannot catch the exception. This handler is never called.
      DBMS_OUTPUT.PUT_LINE('Can''t handle an exception in a declaration.');
END;
/
```

Handlers in the current block cannot catch the raised exception because an exception raised in a declaration propagates immediately to the enclosing block.

Handling Exceptions Raised in Handlers

When an exception occurs within an exception handler, that same handler cannot catch the exception. An exception raised inside a handler propagates immediately to the enclosing block, which is searched to find a handler for this new exception. From there on, the exception propagates normally. For example:

```
EXCEPTION
  WHEN INVALID_NUMBER THEN
    INSERT INTO ... -- might raise DUP_VAL_ON_INDEX
  WHEN DUP_VAL_ON_INDEX THEN ... -- cannot catch the exception
END;
```

Branching to or from an Exception Handler

A `GOTO` statement can branch from an exception handler into an enclosing block.

A `GOTO` statement cannot branch into an exception handler, or from an exception handler into the current block.

Retrieving the Error Code and Error Message: SQLCODE and SQLERRM

In an exception handler, you can use the built-in functions `SQLCODE` and `SQLERRM` to find out which error occurred and to get the associated error message. For internal exceptions, `SQLCODE` returns the number of the Oracle error. The number that `SQLCODE` returns is negative unless the Oracle error is `no data found`, in which case `SQLCODE` returns +100. `SQLERRM` returns the corresponding error message. The message begins with the Oracle error code.

For user-defined exceptions, `SQLCODE` returns +1 and `SQLERRM` returns the message `User-Defined Exception` unless you used the pragma `EXCEPTION_INIT` to associate the exception name with an Oracle error number, in which case `SQLCODE` returns that error number and `SQLERRM` returns the corresponding error message. The maximum length of an Oracle error message is 512 characters including the error code, nested messages, and message inserts such as table and column names.

If no exception has been raised, `SQLCODE` returns zero and `SQLERRM` returns the message: `ORA-0000: normal, successful completion`.

You can pass an error number to `SQLERRM`, in which case `SQLERRM` returns the message associated with that error number. Make sure you pass negative error numbers to `SQLERRM`.

Passing a positive number to `SQLERRM` always returns the message `user-defined exception` unless you pass `+100`, in which case `SQLERRM` returns the message `no data found`. Passing a zero to `SQLERRM` always returns the message `normal, successful completion`.

You cannot use `SQLCODE` or `SQLERRM` directly in a SQL statement. Instead, you must assign their values to local variables, then use the variables in the SQL statement, as shown in Example 10–11.

Example 10–11 Displaying SQLCODE and SQLERRM

```
CREATE TABLE errors (code NUMBER, message VARCHAR2(64), happened TIMESTAMP);
DECLARE
   name employees.last_name%TYPE;
   v_code NUMBER;
   v_errm VARCHAR2(64);
BEGIN
   SELECT last_name INTO name FROM employees WHERE employee_id = -1;
   EXCEPTION
      WHEN OTHERS THEN
         v_code := SQLCODE;
         v_errm := SUBSTR(SQLERRM, 1 , 64);
         DBMS_OUTPUT.PUT_LINE('Error code ' || v_code || ': ' || v_errm);
-- Normally we would call another procedure, declared with PRAGMA
-- AUTONOMOUS_TRANSACTION, to insert information about errors.
         INSERT INTO errors VALUES (v_code, v_errm, SYSTIMESTAMP);
END;
/
```

The string function `SUBSTR` ensures that a `VALUE_ERROR` exception (for truncation) is not raised when you assign the value of `SQLERRM` to `err_msg`. The functions `SQLCODE` and `SQLERRM` are especially useful in the `OTHERS` exception handler because they tell you which internal exception was raised.

When using pragma `RESTRICT_REFERENCES` to assert the purity of a stored function, you cannot specify the constraints `WNPS` and `RNPS` if the function calls `SQLCODE` or `SQLERRM`.

Catching Unhandled Exceptions

Remember, if it cannot find a handler for a raised exception, PL/SQL returns an unhandled exception error to the host environment, which determines the outcome. For example, in the Oracle Precompilers environment, any database changes made by a failed SQL statement or PL/SQL block are rolled back.

Unhandled exceptions can also affect subprograms. If you exit a subprogram successfully, PL/SQL assigns values to `OUT` parameters. However, if you exit with an unhandled exception, PL/SQL does not assign values to `OUT` parameters (unless they are `NOCOPY` parameters). Also, if a stored subprogram fails with an unhandled exception, PL/SQL does not roll back database work done by the subprogram.

You can avoid unhandled exceptions by coding an `OTHERS` handler at the topmost level of every PL/SQL program.

Tips for Handling PL/SQL Errors

In this section, you learn techniques that increase flexibility.

Continuing after an Exception Is Raised

An exception handler lets you recover from an otherwise fatal error before exiting a block. But when the handler completes, the block is terminated. You cannot return to the current block from an exception handler. In the following example, if the `SELECT INTO` statement raises `ZERO_DIVIDE`, you cannot resume with the `INSERT` statement:

```
CREATE TABLE employees_temp AS
  SELECT employee_id, salary, commission_pct FROM employees;

DECLARE
  sal_calc NUMBER(8,2);
BEGIN
  INSERT INTO employees_temp VALUES (301, 2500, 0);
  SELECT salary / commission_pct INTO sal_calc FROM employees_temp
    WHERE employee_id = 301;
  INSERT INTO employees_temp VALUES (302, sal_calc/100, .1);
EXCEPTION
  WHEN ZERO_DIVIDE THEN
    NULL;
END;
/
```

You can still handle an exception for a statement, then continue with the next statement. Place the statement in its own sub-block with its own exception handlers. If an error occurs in the sub-block, a local handler can catch the exception. When the sub-block ends, the enclosing block continues to execute at the point where the sub-block ends, as shown in Example 10–12.

Example 10–12 Continuing After an Exception

```
DECLARE
  sal_calc NUMBER(8,2);
BEGIN
  INSERT INTO employees_temp VALUES (303, 2500, 0);
  BEGIN -- sub-block begins
    SELECT salary / commission_pct INTO sal_calc FROM employees_temp
      WHERE employee_id = 301;
    EXCEPTION
      WHEN ZERO_DIVIDE THEN
      sal_calc := 2500;
  END; -- sub-block ends
  INSERT INTO employees_temp VALUES (304, sal_calc/100, .1);
EXCEPTION
  WHEN ZERO_DIVIDE THEN
    NULL;
END;
/
```

In this example, if the `SELECT INTO` statement raises a `ZERO_DIVIDE` exception, the local handler catches it and sets `sal_calc` to 2500. Execution of the handler is complete, so the sub-block terminates, and execution continues with the `INSERT` statement. See also Example 5–38, "Collection Exceptions" on page 5-27.

You can also perform a sequence of DML operations where some might fail, and process the exceptions only after the entire operation is complete, as described in "Handling FORALL Exceptions with the %BULK_EXCEPTIONS Attribute" on page 11-14.

Retrying a Transaction

After an exception is raised, rather than abandon your transaction, you might want to retry it. The technique is:

1. Encase the transaction in a sub-block.
2. Place the sub-block inside a loop that repeats the transaction.
3. Before starting the transaction, mark a savepoint. If the transaction succeeds, commit, then exit from the loop. If the transaction fails, control transfers to the exception handler, where you roll back to the savepoint undoing any changes, then try to fix the problem.

In Example 10–13, the `INSERT` statement might raise an exception because of a duplicate value in a unique column. In that case, we change the value that needs to be unique and continue with the next loop iteration. If the INSERT succeeds, we exit from the loop immediately. With this technique, you should use a `FOR` or `WHILE` loop to limit the number of attempts.

Example 10–13 Retrying a Transaction After an Exception

```
CREATE TABLE results ( res_name VARCHAR(20), res_answer VARCHAR2(3) );
CREATE UNIQUE INDEX res_name_ix ON results (res_name);
INSERT INTO results VALUES ('SMYTHE', 'YES');
INSERT INTO results VALUES ('JONES', 'NO');

DECLARE
   name     VARCHAR2(20) := 'SMYTHE';
   answer   VARCHAR2(3) := 'NO';
   suffix   NUMBER := 1;
BEGIN
   FOR i IN 1..5 LOOP  -- try 5 times
      BEGIN  -- sub-block begins
         SAVEPOINT start_transaction;  -- mark a savepoint
         /* Remove rows from a table of survey results. */
         DELETE FROM results WHERE res_answer = 'NO';
         /* Add a survey respondent's name and answers. */
         INSERT INTO results VALUES (name, answer);
 -- raises DUP_VAL_ON_INDEX if two respondents have the same name
         COMMIT;
         EXIT;
      EXCEPTION
         WHEN DUP_VAL_ON_INDEX THEN
            ROLLBACK TO start_transaction;  -- undo changes
            suffix := suffix + 1;           -- try to fix problem
            name := name || TO_CHAR(suffix);
      END;  -- sub-block ends
   END LOOP;
END;
/
```

Using Locator Variables to Identify Exception Locations

Using one exception handler for a sequence of statements, such as `INSERT`, `DELETE`, or `UPDATE` statements, can mask the statement that caused an error. If you need to know which statement failed, you can use a `locator variable`:

Example 10–14 Using a Locator Variable to Identify the Location of an Exception

```
CREATE OR REPLACE PROCEDURE loc_var AS
   stmt_no NUMBER;
   name    VARCHAR2(100);
BEGIN
   stmt_no := 1;  -- designates 1st SELECT statement
   SELECT table_name INTO name FROM user_tables WHERE table_name LIKE 'ABC%';
   stmt_no := 2;  -- designates 2nd SELECT statement
   SELECT table_name INTO name FROM user_tables WHERE table_name LIKE 'XYZ%';
EXCEPTION
   WHEN NO_DATA_FOUND THEN
      DBMS_OUTPUT.PUT_LINE('Table name not found in query ' || stmt_no);
END;
/
CALL loc_var();
```

Overview of PL/SQL Compile-Time Warnings

To make your programs more robust and avoid problems at run time, you can turn on checking for certain warning conditions. These conditions are not serious enough to produce an error and keep you from compiling a subprogram. They might point out something in the subprogram that produces an undefined result or might create a performance problem.

To work with PL/SQL warning messages, you use the `PLSQL_WARNINGS` initialization parameter, the `DBMS_WARNING` package, and the `USER/DBA/ALL_PLSQL_OBJECT_SETTINGS` views.

PL/SQL Warning Categories

PL/SQL warning messages are divided into categories, so that you can suppress or display groups of similar warnings during compilation. The categories are:

- `SEVERE`: Messages for conditions that might cause unexpected behavior or wrong results, such as aliasing problems with parameters.
- `PERFORMANCE`: Messages for conditions that might cause performance problems, such as passing a `VARCHAR2` value to a `NUMBER` column in an `INSERT` statement.

- `INFORMATIONAL`: Messages for conditions that do not have an effect on performance or correctness, but that you might want to change to make the code more maintainable, such as unreachable code that can never be executed.

The keyword `All` is a shorthand way to refer to all warning messages.

You can also treat particular messages as errors instead of warnings. For example, if you know that the warning message `PLW-05003` represents a serious problem in your code, including `'ERROR:05003'` in the `PLSQL_WARNINGS` setting makes that condition trigger an error message (`PLS_05003`) instead of a warning message. An error message causes the compilation to fail.

Controlling PL/SQL Warning Messages

To let the database issue warning messages during PL/SQL compilation, you set the initialization parameter `PLSQL_WARNINGS`. You can enable and disable entire categories of warnings (`ALL`, `SEVERE`, `INFORMATIONAL`, `PERFORMANCE`), enable and disable specific message numbers, and make the database treat certain warnings as compilation errors so that those conditions must be corrected.

This parameter can be set at the system level or the session level. You can also set it for a single compilation by including it as part of the `ALTER PROCEDURE` ... `COMPILE` statement. You might turn on all warnings during development, turn off all warnings when deploying for production, or turn on some warnings when working on a particular subprogram where you are concerned with some aspect, such as unnecessary code or performance.

Example 10–15 Controlling the Display of PL/SQL Warnings

```
-- To focus on one aspect
ALTER SESSION SET PLSQL_WARNINGS='ENABLE:PERFORMANCE';
-- Recompile with extra checking
ALTER PROCEDURE loc_var COMPILE PLSQL_WARNINGS='ENABLE:PERFORMANCE'
  REUSE SETTINGS;
-- To turn off all warnings
ALTER SESSION SET PLSQL_WARNINGS='DISABLE:ALL';
-- Display 'severe' warnings, don't want 'performance' warnings, and
-- want PLW-06002 warnings to produce errors that halt compilation
ALTER SESSION SET PLSQL_WARNINGS='ENABLE:SEVERE', 'DISABLE:PERFORMANCE',
                                 'ERROR:06002';
-- For debugging during development
ALTER SESSION SET PLSQL_WARNINGS='ENABLE:ALL';
```

Warning messages can be issued during compilation of PL/SQL subprograms; anonymous blocks do not produce any warnings.

The settings for the `PLSQL_WARNINGS` parameter are stored along with each compiled subprogram. If you recompile the subprogram with a `CREATE OR REPLACE` statement, the current settings for that session are used. If you recompile the subprogram with an `ALTER` ... `COMPILE` statement, the current session setting might be used, or the original setting that was stored with the subprogram, depending on whether you include the `REUSE SETTINGS` clause in the statement. For more information, see `ALTER FUNCTION`, `ALTER PACKAGE`, and `ALTER PROCEDURE` in *Oracle Database SQL Reference*.

To see any warnings generated during compilation, you use the SQL*Plus `SHOW ERRORS` command or query the `USER_ERRORS` data dictionary view. PL/SQL warning messages all use the prefix `PLW`.

Using the DBMS_WARNING Package

If you are writing a development environment that compiles PL/SQL subprograms, you can control PL/SQL warning messages by calling subprograms in the `DBMS_WARNING` package. You might also use this package when compiling a complex application, made up of several nested SQL*Plus scripts, where different warning settings apply to different subprograms. You can save the current state of the `PLSQL_WARNINGS` parameter with one call to the package, change the parameter to compile a particular set of subprograms, then restore the original parameter value.

For example, Example 10–16 is a procedure with unnecessary code that could be removed. It could represent a mistake, or it could be intentionally hidden by a debug flag, so you might or might not want a warning message for it.

Example 10–16   Using the DBMS_WARNING Package to Display Warnings

```
-- When warnings disabled, the following procedure compiles with no warnings
CREATE OR REPLACE PROCEDURE unreachable_code AS
  x CONSTANT BOOLEAN := TRUE;
BEGIN
  IF x THEN
    DBMS_OUTPUT.PUT_LINE('TRUE');
  ELSE
    DBMS_OUTPUT.PUT_LINE('FALSE');
  END IF;
END unreachable_code;
/
-- enable all warning messages for this session
CALL DBMS_WARNING.set_warning_setting_string('ENABLE:ALL' ,'SESSION');
-- Check the current warning setting
SELECT DBMS_WARNING.get_warning_setting_string() FROM DUAL;

-- Recompile the procedure and a warning about unreachable code displays
ALTER PROCEDURE unreachable_code COMPILE;
SHOW ERRORS;
```

In Example 10–16, you could have used the following `ALTER PROCEDURE` without the call to `DBMS_WARNINGS.set_warning_setting_string`:

```
ALTER PROCEDURE unreachable_code COMPILE
     PLSQL_WARNINGS = 'ENABLE:ALL' REUSE SETTINGS;
```

For more information, see `ALTER PROCEDURE` in *Oracle Database SQL Reference*, `DBMS_WARNING` package in *Oracle Database PL/SQL Packages and Types Reference*, and PLW- messages in *Oracle Database Error Messages*

11

Tuning PL/SQL Applications for Performance

This chapter shows you how to write efficient PL/SQL code, and speed up existing code.

This chapter contains these topics:

See Also:

- Information about PL/SQL performance tuning at:

  `http://www.oracle.com/technology/tech/pl_sql/htdocs/new_in_10gr1.htm`
- Additional information related to tuning PL/SQL applications on the Oracle Technology Network (OTN), at:

  `http://www.oracle.com/technology/tech/pl_sql/`
- Information for a specific topic on OTN, such as "PL/SQL best practices", by entering the appropriate phrase in the search field on the OTN main page at:

  `http://www.oracle.com/technology/`
- Changes to the PL/SQL compiler for Oracle 10*g*:

  "Improved Performance" on page xxvi

Initialization Parameters for PL/SQL Compilation

There are several Oracle initialization parameters that are used in the compilation of PL/SQL units. These designated PL/SQL compiler parameters include

PLSQL_CCFLAGS, PLSQL_CODE_TYPE, PLSQL_DEBUG, PLSQL_NATIVE_LIBRARY_DIR, PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT, PLSQL_OPTIMIZE_LEVEL, PLSQL_WARNINGS, and NLS_LENGTH_SEMANTICS. For information about these initialization parameters, see *Oracle Database Reference*.

The values at the time of compilation of the PLSQL_CCFLAGS, PLSQL_CODE_TYPE, PLSQL_DEBUG, PLSQL_OPTIMIZE_LEVEL, PLSQL_WARNINGS, and NLS_LENGTH_SEMANTICS initialization parameters are stored with the unit's metadata. You can view information about the settings of these parameters with the ALL_PLSQL_OBJECT_SETTINGS view. For information, see *Oracle Database Reference*.

You can specify REUSE SETTINGS with the SQL ALTER statement to preserve the values stored in a unit's metadata. For information of the use of the PL/SQL compiler parameters with the ALTER statement, see the ALTER FUNCTION, ALTER PACKAGE, ALTER PROCEDURE, and ALTER SESSION statements in the *Oracle Database SQL Reference*.

How PL/SQL Optimizes Your Programs

In Oracle releases prior to 10*g*, the PL/SQL compiler translated your code to machine code without applying many changes for performance. Now, PL/SQL uses an optimizing compiler that can rearrange code for better performance.

You do not need to do anything to get the benefits of this new optimizer. It is enabled by default. In rare cases, if the overhead of the optimizer makes compilation of very large applications take too long, you might lower the optimization by setting the initialization parameter PLSQL_OPTIMIZE_LEVEL=1 instead of its default value 2. In even rarer cases, you might see a change in exception behavior, either an exception that is not raised at all, or one that is raised earlier than expected. Setting PLSQL_OPTIMIZE_LEVEL=0 prevents the code from being rearranged at all. For information on the PLSQL_OPTIMIZE_LEVEL initialization parameter, see *Oracle Database Reference*.

You can view information about the optimization level and other PLSQL compiler settings for your environment with the ALL_PLSQL_OBJECT_SETTINGS view. For information, see *Oracle Database Reference*.

When to Tune PL/SQL Code

The information in this chapter is especially valuable if you are responsible for:

- Programs that do a lot of mathematical calculations. You will want to investigate the datatypes PLS_INTEGER, BINARY_FLOAT, and BINARY_DOUBLE.
- Functions that are called from PL/SQL queries, where the functions might be executed millions of times. You will want to look at all performance features to make the function as efficient as possible, and perhaps a function-based index to precompute the results for each row and save on query time.
- Programs that spend a lot of time processing INSERT, UPDATE, or DELETE statements, or looping through query results. You will want to investigate the FORALL statement for issuing DML, and the BULK COLLECT INTO and RETURNING BULK COLLECT INTO clauses for queries.
- Older code that does not take advantage of recent PL/SQL language features. With the many performance improvements in Oracle Database 10*g*, any code from earlier releases is a candidate for tuning.

- Any program that spends a lot of time doing PL/SQL processing, as opposed to issuing DDL statements like `CREATE TABLE` that are just passed directly to SQL. You will want to investigate native compilation. Because many built-in database features use PL/SQL, you can apply this tuning feature to an entire database to improve performance in many areas, not just your own code.

Before starting any tuning effort, benchmark the current system and measure how long particular subprograms take. PL/SQL in Oracle Database 10*g* includes many automatic optimizations, so you might see performance improvements without doing any tuning.

Guidelines for Avoiding PL/SQL Performance Problems

When a PL/SQL-based application performs poorly, it is often due to badly written SQL statements, poor programming practices, inattention to PL/SQL basics, or misuse of shared memory.

Avoiding CPU Overhead in PL/SQL Code

This sections discusses how you can avoid excessive CPU overhead in the PL/SQL code.

Make SQL Statements as Efficient as Possible

PL/SQL programs look relatively simple because most of the work is done by SQL statements. Slow SQL statements are the main reason for slow execution.

If SQL statements are slowing down your program:

- Make sure you have appropriate indexes. There are different kinds of indexes for different situations. Your index strategy might be different depending on the sizes of various tables in a query, the distribution of data in each query, and the columns used in the `WHERE` clauses.
- Make sure you have up-to-date statistics on all the tables, using the subprograms in the `DBMS_STATS` package.
- Analyze the execution plans and performance of the SQL statements, using:
  - `EXPLAIN PLAN` statement
  - SQL Trace facility with `TKPROF` utility
- Rewrite the SQL statements if necessary. For example, query hints can avoid problems such as unnecessary full-table scans.

For more information about these methods, see *Oracle Database Performance Tuning Guide*.

Some PL/SQL features also help improve the performance of SQL statements:

- If you are running SQL statements inside a PL/SQL loop, look at the `FORALL` statement as a way to replace loops of `INSERT`, `UPDATE`, and `DELETE` statements.
- If you are looping through the result set of a query, look at the `BULK COLLECT` clause of the `SELECT INTO` statement as a way to bring the entire result set into memory in a single operation.

Make Function Calls as Efficient as Possible

Badly written subprograms (for example, a slow sort or search function) can harm performance. Avoid unnecessary calls to subprograms, and optimize their code:

- If a function is called within a SQL query, you can cache the function value for each row by creating a function-based index on the table in the query. The `CREATE INDEX` statement might take a while, but queries can be much faster.
- If a column is passed to a function within an SQL query, the query cannot use regular indexes on that column, and the function might be called for every row in a (potentially very large) table. Consider nesting the query so that the inner query filters the results to a small number of rows, and the outer query calls the function only a few times as shown in Example 11–1.

Example 11–1 Nesting a Query to Improve Performance

```
BEGIN
-- Inefficient, calls function for every row
   FOR item IN (SELECT DISTINCT(SQRT(department_id)) col_alias FROM employees)
   LOOP
      DBMS_OUTPUT.PUT_LINE(item.col_alias);
   END LOOP;
-- Efficient, only calls function once for each distinct value.
   FOR item IN
   ( SELECT SQRT(department_id) col_alias FROM
     ( SELECT DISTINCT department_id FROM employees)
   )
   LOOP
      DBMS_OUTPUT.PUT_LINE(item.col_alias);
   END LOOP;
END;
/
```

If you use `OUT` or `IN OUT` parameters, PL/SQL adds some performance overhead to ensure correct behavior in case of exceptions (assigning a value to the `OUT` parameter, then exiting the subprogram because of an unhandled exception, so that the `OUT` parameter keeps its original value).

If your program does not depend on `OUT` parameters keeping their values in such situations, you can add the `NOCOPY` keyword to the parameter declarations, so the parameters are declared `OUT NOCOPY` or `IN OUT NOCOPY`.

This technique can give significant speedup if you are passing back large amounts of data in `OUT` parameters, such as collections, big `VARCHAR2` values, or LOBs.

This technique also applies to member methods of object types. If these methods modify attributes of the object type, all the attributes are copied when the method ends. To avoid this overhead, you can explicitly declare the first parameter of the member method as `SELF IN OUT NOCOPY`, instead of relying on PL/SQL's implicit declaration `SELF IN OUT`. For information about design considerations for object methods, see *Oracle Database Application Developer's Guide - Object-Relational Features*.

Make Loops as Efficient as Possible

Because PL/SQL applications are often built around loops, it is important to optimize the loop itself and the code inside the loop:

- To issue a series of DML statements, replace loop constructs with `FORALL` statements.
- To loop through a result set and store the values, use the `BULK COLLECT` clause on the query to bring the query results into memory in one operation.
- If you have to loop through a result set more than once, or issue other queries as you loop through a result set, you can probably enhance the original query to give

you exactly the results you want. Some query operators to explore include UNION, INTERSECT, MINUS, and CONNECT BY.

- You can also nest one query inside another (known as a subselect) to do the filtering and sorting in multiple stages. For example, instead of calling a PL/SQL function in the inner WHERE clause (which might call the function once for each row of the table), you can filter the result set to a small set of rows in the inner query, and call the function in the outer query.

Do Not Duplicate Built-in String Functions

PL/SQL provides many highly optimized string functions such as REPLACE, TRANSLATE, SUBSTR, INSTR, RPAD, and LTRIM. The built-in functions use low-level code that is more efficient than regular PL/SQL.

If you use PL/SQL string functions to search for regular expressions, consider using the built-in regular expression functions, such as REGEXP_SUBSTR.

- You can search for regular expressions using the SQL operator REGEXP_LIKE. See Example 6–10 on page 6-10.
- You can test or manipulate strings using the built-in functions REGEXP_INSTR, REGEXP_REPLACE, and REGEXP_SUBSTR.

Oracle's regular expression features use characters like '.', '*', '^', and '$' that you might be familiar with from UNIX or Perl programming. For multi-language programming, there are also extensions such as '[:lower:]' to match a lowercase letter, instead of '[a-z]' which does not match lowercase accented letters.

> **See Also:** Oracle By Example - Using Regular Expressions on the Oracle Technology Network (OTN):
>
> http://www.oracle.com/technology/obe/obe10gdb/develop/regexp/regexp.htm

Reorder Conditional Tests to Put the Least Expensive First

PL/SQL stops evaluating a logical expression as soon as the result can be determined. This functionality is known as short-circuit evaluation. See "Short-Circuit Evaluation" on page 2-21.

When evaluating multiple conditions separated by AND or OR, put the least expensive ones first. For example, check the values of PL/SQL variables before testing function return values, because PL/SQL might be able to skip calling the functions.

Minimize Datatype Conversions

At run time, PL/SQL converts between different datatypes automatically. For example, assigning a PLS_INTEGER variable to a NUMBER variable results in a conversion because their internal representations are different.

Whenever possible, choose datatypes carefully to minimize implicit conversions. Use literals of the appropriate types, such as character literals in character expressions and decimal numbers in number expressions.

Minimizing conversions might mean changing the types of your variables, or even working backward and designing your tables with different datatypes. Or, you might convert data once, such as from an INTEGER column to a PLS_INTEGER variable, and use the PL/SQL type consistently after that. Note that the conversion from an INTEGER to a PLS_INTEGER datatype could actually improve performance because of the use of more efficient hardware arithmetic. See "Use PLS_INTEGER for Integer Arithmetic" on page 11-6.

Use PLS_INTEGER for Integer Arithmetic

When you need to declare a local integer variable, use the datatype `PLS_INTEGER`, which is the most efficient integer type. `PLS_INTEGER` values require less storage than `INTEGER` or `NUMBER` values, and `PLS_INTEGER` operations use hardware arithmetic. Note that the `BINARY_INTEGER` datatype is identical to `PLS_INTEGER`.

The datatype `NUMBER` and its subtypes are represented in a special internal format, designed for portability and arbitrary scale and precision, not performance. Even the subtype `INTEGER` is treated as a floating-point number with nothing after the decimal point. Operations on `NUMBER` or `INTEGER` variables require calls to library routines.

Avoid constrained subtypes such as `INTEGER`, `NATURAL`, `NATURALN`, `POSITIVE`, `POSITIVEN`, and `SIGNTYPE` in performance-critical code. Variables of these types require extra checking at run time, each time they are used in a calculation.

Use BINARY_FLOAT and BINARY_DOUBLE for Floating-Point Arithmetic

The datatype `NUMBER` and its subtypes are represented in a special internal format, designed for portability and arbitrary scale and precision, not performance. Operations on `NUMBER` or `INTEGER` variables require calls to library routines.

The `BINARY_FLOAT` and `BINARY_DOUBLE` types can use native hardware arithmetic instructions, and are more efficient for number-crunching applications such as scientific processing. They also require less space in the database.

These types do not always represent fractional values precisely, and handle rounding differently than the `NUMBER` types. These types are less suitable for financial code where accuracy is critical.

Avoiding Memory Overhead in PL/SQL Code

This sections discusses how you can avoid excessive memory overhead in the PL/SQL code.

Be Generous When Declaring Sizes for VARCHAR2 Variables

You might need to allocate large `VARCHAR2` variables when you are not sure how big an expression result will be. You can actually conserve memory by declaring `VARCHAR2` variables with large sizes, such as 32000, rather than estimating just a little on the high side, such as by specifying 256 or 1000. PL/SQL has an optimization that makes it easy to avoid overflow problems and still conserve memory. Specify a size of more than 4000 characters for the `VARCHAR2` variable; PL/SQL waits until you assign the variable, then only allocates as much storage as needed.

Group Related Subprograms into Packages

When you call a packaged subprogram for the first time, the whole package is loaded into the shared memory pool. Subsequent calls to related subprograms in the package require no disk I/O, and your code executes faster. If the package is aged out of memory, it must be reloaded if you reference it again.

You can improve performance by sizing the shared memory pool correctly. Make sure it is large enough to hold all frequently used packages but not so large that memory is wasted.

Pin Packages in the Shared Memory Pool

You can pin frequently accessed packages in the shared memory pool, using the supplied package `DBMS_SHARED_POOL`. When a package is pinned, it is not aged out by the least recently used (LRU) algorithm that Oracle normally uses. The package remains in memory no matter how full the pool gets or how frequently you access the package.

For more information on the `DBMS_SHARED_POOL` package, see *Oracle Database PL/SQL Packages and Types Reference*.

Improve Your Code to Avoid Compiler Warnings

The PL/SQL compiler issues warnings about things that do not make a program incorrect, but might lead to poor performance. If you receive such a warning, and the performance of this code is important, follow the suggestions in the warning and change the code to be more efficient.

Profiling and Tracing PL/SQL Programs

As you develop larger and larger PL/SQL applications, it becomes more difficult to isolate performance problems. PL/SQL provides a Profiler API to profile run-time behavior and to help you identify performance bottlenecks. PL/SQL also provides a Trace API for tracing the execution of programs on the server. You can use Trace to trace the execution by subprogram or exception.

Using The Profiler API: Package DBMS_PROFILER

The Profiler API is implemented as PL/SQL package `DBMS_PROFILER`, which provides services for gathering and saving run-time statistics. The information is stored in database tables, which you can query later. For example, you can learn how much time was spent executing each PL/SQL line and subprogram.

To use the Profiler, you start the profiling session, run your application long enough to get adequate code coverage, flush the collected data to the database, then stop the profiling session.

The Profiler traces the execution of your program, computing the time spent at each line and in each subprogram. You can use the collected data to improve performance. For instance, you might focus on subprograms that run slowly. For information about the `DBMS_PROFILER` subprograms, see *Oracle Database PL/SQL Packages and Types Reference*.

After you have collected data with the Profiler, you can do the following:

- Analyze the Collected Performance Data

  Determine why more time was spent executing certain code segments or accessing certain data structures. Find the problem areas by querying the performance data. Focus on the subprograms and packages that use up the most execution time, inspecting possible performance bottlenecks such as SQL statements, loops, and recursive functions.

- Use Trace Data to Improve Performance

  Use the results of your analysis to rework slow algorithms. For example, due to an exponential growth in data, you might need to replace a linear search with a binary search. Also, look for inefficiencies caused by inappropriate data structures, and, if necessary, replace those data structures.

Using The Trace API: Package DBMS_TRACE

With large, complex applications, it becomes difficult to keep track of calls between subprograms. By tracing your code with the Trace API, you can see the order in which subprograms execute. The Trace API is implemented as PL/SQL package `DBMS_TRACE`, which provides services for tracing execution by subprogram or exception.

To use Trace, you start the tracing session, run your application, then stop the tracing session. As the program executes, trace data is collected and stored in database tables.

For information about the `DBMS_TRACE` subprograms, see *Oracle Database PL/SQL Packages and Types Reference*.

Controlling the Trace

Tracing large applications can produce huge amounts of data that are difficult to manage. Before starting Trace, you can optionally limit the volume of data collected by selecting specific subprograms for trace data collection.

In addition, you can choose a tracing level. For example, you can choose to trace all subprograms and exceptions, or you can choose to trace selected subprograms and exceptions.

Reducing Loop Overhead for DML Statements and Queries with Bulk SQL

PL/SQL sends SQL statements such as DML and queries to the SQL engine for execution, and SQL returns the result data to PL/SQL. You can minimize the performance overhead of this communication between PL/SQL and SQL by using the PL/SQL language features known collectively as bulk SQL. The `FORALL` statement sends `INSERT`, `UPDATE`, or `DELETE` statements in batches, rather than one at a time. The `BULK COLLECT` clause brings back batches of results from SQL. If the DML statement affects four or more database rows, the use of bulk SQL can improve performance considerably.

The assigning of values to PL/SQL variables in SQL statements is called binding. PL/SQL binding operations fall into three categories:

- `in-bind`: When a PL/SQL variable or host variable is stored in the database by an `INSERT` or `UPDATE` statement.
- `out-bind`: When a database value is assigned to a PL/SQL variable or a host variable by the `RETURNING` clause of an `INSERT`, `UPDATE`, or `DELETE` statement.
- `define`: When a database value is assigned to a PL/SQL variable or a host variable by a `SELECT` or `FETCH` statement.

Bulk SQL uses PL/SQL collections, such as varrays or nested tables, to pass large amounts of data back and forth in a single operation. This process is known as bulk binding. If the collection has 20 elements, bulk binding lets you perform the equivalent of 20 `SELECT`, `INSERT`, `UPDATE`, or `DELETE` statements using a single operation. Queries can pass back any number of results, without requiring a `FETCH` statement for each row.

To speed up `INSERT`, `UPDATE`, and `DELETE` statements, enclose the SQL statement within a PL/SQL `FORALL` statement instead of a loop construct.

To speed up `SELECT` statements, include the `BULK COLLECT INTO` clause in the `SELECT` statement instead of using `INTO`.

For full details of the syntax and restrictions for these statements, see "FORALL Statement" on page 13-56 and "SELECT INTO Statement" on page 13-107.

Using the FORALL Statement

The keyword FORALL lets you run multiple DML statements very efficiently. It can only repeat a single DML statement, unlike a general-purpose FOR loop. For full syntax and restrictions, see "FORALL Statement" on page 13-56.

The SQL statement can reference more than one collection, but FORALL only improves performance where the index value is used as a subscript.

Usually, the bounds specify a range of consecutive index numbers. If the index numbers are not consecutive, such as after you delete collection elements, you can use the INDICES OF or VALUES OF clause to iterate over just those index values that really exist.

The INDICES OF clause iterates over all of the index values in the specified collection, or only those between a lower and upper bound.

The VALUES OF clause refers to a collection that is indexed by BINARY_INTEGER or PLS_INTEGER and whose elements are of type BINARY_INTEGER or PLS_INTEGER. The FORALL statement iterates over the index values specified by the elements of this collection.

The FORALL statement in Example 11–2 sends all three DELETE statements to the SQL engine at once.

Example 11–2 Issuing DELETE Statements in a Loop

```
CREATE TABLE employees_temp AS SELECT * FROM employees;
DECLARE
   TYPE NumList IS VARRAY(20) OF NUMBER;
   depts NumList := NumList(10, 30, 70);  -- department numbers
BEGIN
   FORALL i IN depts.FIRST..depts.LAST
      DELETE FROM employees_temp WHERE department_id = depts(i);
   COMMIT;
END;
/
```

Example 11–3 loads some data into PL/SQL collections. Then it inserts the collection elements into a database table twice: first using a FOR loop, then using a FORALL statement. The FORALL version is much faster.

Example 11–3 Issuing INSERT Statements in a Loop

```
CREATE TABLE parts1 (pnum INTEGER, pname VARCHAR2(15));
CREATE TABLE parts2 (pnum INTEGER, pname VARCHAR2(15));
DECLARE
  TYPE NumTab IS TABLE OF parts1.pnum%TYPE INDEX BY PLS_INTEGER;
  TYPE NameTab IS TABLE OF parts1.pname%TYPE INDEX BY PLS_INTEGER;
  pnums  NumTab;
  pnames NameTab;
  iterations CONSTANT PLS_INTEGER := 500;
  t1 INTEGER;
  t2 INTEGER;
  t3 INTEGER;
BEGIN
  FOR j IN 1..iterations LOOP  -- load index-by tables
     pnums(j) := j;
```

```
      pnames(j) := 'Part No. ' || TO_CHAR(j);
   END LOOP;
   t1 := DBMS_UTILITY.get_time;
   FOR i IN 1..iterations LOOP  -- use FOR loop
      INSERT INTO parts1 VALUES (pnums(i), pnames(i));
   END LOOP;
   t2 := DBMS_UTILITY.get_time;
   FORALL i IN 1..iterations  -- use FORALL statement
      INSERT INTO parts2 VALUES (pnums(i), pnames(i));
   t3 := DBMS_UTILITY.get_time;
   DBMS_OUTPUT.PUT_LINE('Execution Time (secs)');
   DBMS_OUTPUT.PUT_LINE('---------------------');
   DBMS_OUTPUT.PUT_LINE('FOR loop: ' || TO_CHAR((t2 - t1)/100));
   DBMS_OUTPUT.PUT_LINE('FORALL:   ' || TO_CHAR((t3 - t2)/100));
   COMMIT;
END;
/
```

Executing this block should show that the loop using FORALL is much faster.

The bounds of the FORALL loop can apply to part of a collection, not necessarily all the elements, as shown in Example 11–4.

Example 11–4 Using FORALL with Part of a Collection

```
CREATE TABLE employees_temp AS SELECT * FROM employees;
DECLARE
   TYPE NumList IS VARRAY(10) OF NUMBER;
   depts NumList := NumList(5,10,20,30,50,55,57,60,70,75);
BEGIN
   FORALL j IN 4..7  -- use only part of varray
      DELETE FROM employees_temp WHERE department_id = depts(j);
   COMMIT;
END;
/
```

You might need to delete some elements from a collection before using the collection in a FORALL statement. The INDICES OF clause processes sparse collections by iterating through only the remaining elements.

You might also want to leave the original collection alone, but process only some elements, process the elements in a different order, or process some elements more than once. Instead of copying the entire elements into new collections, which might use up substantial amounts of memory, the VALUES OF clause lets you set up simple collections whose elements serve as pointers to elements in the original collection.

Example 11–5 creates a collection holding some arbitrary data, a set of table names. Deleting some of the elements makes it a sparse collection that would not work in a default FORALL statement. The program uses a FORALL statement with the INDICES OF clause to insert the data into a table. It then sets up two more collections, pointing to certain elements from the original collection. The program stores each set of names in a different database table using FORALL statements with the VALUES OF clause.

Example 11–5 Using FORALL with Non-Consecutive Index Values

```
-- Create empty tables to hold order details
CREATE TABLE valid_orders (cust_name VARCHAR2(32), amount NUMBER(10,2));
CREATE TABLE big_orders AS SELECT * FROM valid_orders WHERE 1 = 0;
CREATE TABLE rejected_orders AS SELECT * FROM valid_orders WHERE 1 = 0;
DECLARE
```

```
-- Make collections to hold a set of customer names and order amounts.
   SUBTYPE cust_name IS valid_orders.cust_name%TYPE;
   TYPE cust_typ IS TABLe OF cust_name;
   cust_tab cust_typ;
   SUBTYPE order_amount IS valid_orders.amount%TYPE;
   TYPE amount_typ IS TABLE OF NUMBER;
   amount_tab amount_typ;
-- Make other collections to point into the CUST_TAB collection.
   TYPE index_pointer_t IS TABLE OF PLS_INTEGER;
   big_order_tab index_pointer_t := index_pointer_t();
   rejected_order_tab index_pointer_t := index_pointer_t();
   PROCEDURE setup_data IS BEGIN
 -- Set up sample order data, including some invalid orders and some 'big' orders.
     cust_tab := cust_typ('Company1','Company2','Company3','Company4','Company5');
     amount_tab := amount_typ(5000.01, 0, 150.25, 4000.00, NULL);
   END;
BEGIN
   setup_data();
   DBMS_OUTPUT.PUT_LINE('--- Original order data ---');
   FOR i IN 1..cust_tab.LAST LOOP
     DBMS_OUTPUT.PUT_LINE('Customer #' || i || ', ' || cust_tab(i) || ': $' ||
                          amount_tab(i));
   END LOOP;
-- Delete invalid orders (where amount is null or 0).
   FOR i IN 1..cust_tab.LAST LOOP
     IF amount_tab(i) is null or amount_tab(i) = 0 THEN
        cust_tab.delete(i);
        amount_tab.delete(i);
     END IF;
   END LOOP;
   DBMS_OUTPUT.PUT_LINE('--- Data with invalid orders deleted ---');
   FOR i IN 1..cust_tab.LAST LOOP
     IF cust_tab.EXISTS(i) THEN
       DBMS_OUTPUT.PUT_LINE('Customer #' || i || ', ' || cust_tab(i) || ': $' ||
                            amount_tab(i));
      END IF;
   END LOOP;
-- Because the subscripts of the collections are not consecutive, use
-- FORALL...INDICES OF to iterate through the actual subscripts,
-- rather than 1..COUNT
   FORALL i IN INDICES OF cust_tab
     INSERT INTO valid_orders(cust_name, amount)
        VALUES(cust_tab(i), amount_tab(i));
-- Now process the order data differently
-- Extract 2 subsets and store each subset in a different table
   setup_data(); -- Initialize the CUST_TAB and AMOUNT_TAB collections again.
   FOR i IN cust_tab.FIRST .. cust_tab.LAST LOOP
     IF amount_tab(i) IS NULL OR amount_tab(i) = 0 THEN
       rejected_order_tab.EXTEND; -- Add a new element to this collection
-- Record the subscript from the original collection
       rejected_order_tab(rejected_order_tab.LAST) := i;
     END IF;
     IF amount_tab(i) > 2000 THEN
        big_order_tab.EXTEND; -- Add a new element to this collection
-- Record the subscript from the original collection
        big_order_tab(big_order_tab.LAST) := i;
     END IF;
   END LOOP;
-- Now it's easy to run one DML statement on one subset of elements,
-- and another DML statement on a different subset.
```

```
   FORALL i IN VALUES OF rejected_order_tab
     INSERT INTO rejected_orders VALUES (cust_tab(i), amount_tab(i));
   FORALL i IN VALUES OF big_order_tab
     INSERT INTO big_orders VALUES (cust_tab(i), amount_tab(i));
   COMMIT;
END;
/
-- Verify that the correct order details were stored
SELECT cust_name "Customer", amount "Valid order amount" FROM valid_orders;
SELECT cust_name "Customer", amount "Big order amount" FROM big_orders;
SELECT cust_name "Customer", amount "Rejected order amount" FROM rejected_orders;
```

How FORALL Affects Rollbacks

In a FORALL statement, if any execution of the SQL statement raises an unhandled exception, all database changes made during previous executions are rolled back. However, if a raised exception is caught and handled, changes are rolled back to an implicit savepoint marked before each execution of the SQL statement. Changes made during previous executions are not rolled back. For example, suppose you create a database table that stores department numbers and job titles, as shown in Example 11–6. Then, you change the job titles so that they are longer. The second UPDATE fails because the new value is too long for the column. Because we handle the exception, the first UPDATE is not rolled back and we can commit that change.

Example 11–6 Using Rollbacks With FORALL

```
CREATE TABLE emp_temp (deptno NUMBER(2), job VARCHAR2(18));
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   depts NumList := NumList(10, 20, 30);
BEGIN
  INSERT INTO emp_temp VALUES(10, 'Clerk');
-- Lengthening this job title causes an exception
  INSERT INTO emp_temp VALUES(20, 'Bookkeeper');
  INSERT INTO emp_temp VALUES(30, 'Analyst');
  COMMIT;
  FORALL j IN depts.FIRST..depts.LAST -- Run 3 UPDATE statements.
    UPDATE emp_temp SET job = job || ' (Senior)' WHERE deptno = depts(j);
-- raises a "value too large" exception
EXCEPTION
  WHEN OTHERS THEN
    DBMS_OUTPUT.PUT_LINE('Problem in the FORALL statement.');
    COMMIT; -- Commit results of successful updates.
END;
/
```

Counting Rows Affected by FORALL with the %BULK_ROWCOUNT Attribute

The cursor attributes SQL%FOUND, SQL%ISOPEN, SQL%NOTFOUND, and SQL%ROWCOUNT, return useful information about the most recently executed DML statement. For additional description of cursor attributes, see "Implicit Cursors" on page 6-6.

The SQL cursor has one composite attribute, %BULK_ROWCOUNT, for use with the FORALL statement. This attribute works like an associative array: SQL%BULK_ROWCOUNT(i) stores the number of rows processed by the ith execution of an INSERT, UPDATE or DELETE statement. For example:

Example 11–7 Using %BULK_ROWCOUNT With the FORALL Statement

```
CREATE TABLE emp_temp AS SELECT * FROM employees;
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   depts NumList := NumList(30, 50, 60);
BEGIN
   FORALL j IN depts.FIRST..depts.LAST
      DELETE FROM emp_temp WHERE department_id = depts(j);
-- How many rows were affected by each DELETE statement?
   FOR i IN depts.FIRST..depts.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Iteration #' || i || ' deleted ' ||
         SQL%BULK_ROWCOUNT(i) || ' rows.');
   END LOOP;
END;
/
```

The `FORALL` statement and `%BULK_ROWCOUNT` attribute use the same subscripts. For example, if `FORALL` uses the range `5..10`, so does `%BULK_ROWCOUNT`. If the `FORALL` statement uses the `INDICES OF` clause to process a sparse collection, `%BULK_ROWCOUNT` has corresponding sparse subscripts. If the `FORALL` statement uses the `VALUES OF` clause to process a subset of elements, `%BULK_ROWCOUNT` has subscripts corresponding to the values of the elements in the index collection. If the index collection contains duplicate elements, so that some DML statements are issued multiple times using the same subscript, then the corresponding elements of `%BULK_ROWCOUNT` represent the sum of all rows affected by the DML statement using that subscript. For examples on how to interpret `%BULK_ROWCOUNT` when using the `INDICES OF` and `VALUES OF` clauses, see the PL/SQL sample programs at `http://www.oracle.com/technology/sample_code/tech/pl_sql/`.

`%BULK_ROWCOUNT` is usually equal to 1 for inserts, because a typical insert operation affects only a single row. For the `INSERT ... SELECT` construct, `%BULK_ROWCOUNT` might be greater than 1. For example, the `FORALL` statement in Example 11–8 inserts an arbitrary number of rows for each iteration. After each iteration, `%BULK_ROWCOUNT` returns the number of items inserted.

Example 11–8 Counting Rows Affected by FORALL With %BULK_ROWCOUNT

```
CREATE TABLE emp_by_dept AS SELECT employee_id, department_id
   FROM employees WHERE 1 = 0;
DECLARE
  TYPE dept_tab IS TABLE OF departments.department_id%TYPE;
  deptnums dept_tab;
BEGIN
  SELECT department_id BULK COLLECT INTO deptnums FROM departments;
  FORALL i IN 1..deptnums.COUNT
     INSERT INTO emp_by_dept
        SELECT employee_id, department_id FROM employees
           WHERE department_id = deptnums(i);
  FOR i IN 1..deptnums.COUNT LOOP
-- Count how many rows were inserted for each department; that is,
-- how many employees are in each department.
   DBMS_OUTPUT.PUT_LINE('Dept '||deptnums(i)||': inserted '||
                        SQL%BULK_ROWCOUNT(i)||' records');
  END LOOP;
  DBMS_OUTPUT.PUT_LINE('Total records inserted: ' || SQL%ROWCOUNT);
END;
/
```

You can also use the scalar attributes %FOUND, %NOTFOUND, and %ROWCOUNT after running a FORALL statement. For example, %ROWCOUNT returns the total number of rows processed by all executions of the SQL statement.

%FOUND and %NOTFOUND refer only to the last execution of the SQL statement. You can use %BULK_ROWCOUNT to infer their values for individual executions. For example, when %BULK_ROWCOUNT(i) is zero, %FOUND and %NOTFOUND are FALSE and TRUE, respectively.

Handling FORALL Exceptions with the %BULK_EXCEPTIONS Attribute

PL/SQL provides a mechanism to handle exceptions raised during the execution of a FORALL statement. This mechanism enables a bulk-bind operation to save information about exceptions and continue processing.

To have a bulk bind complete despite errors, add the keywords SAVE EXCEPTIONS to your FORALL statement after the bounds, before the DML statement. You should also provide an exception handler to track the exceptions that occurred during the bulk operation.

Example 11–9 shows how you can perform a number of DML operations, without stopping if some operations encounter errors. In the example, EXCEPTION_INIT is used to associate the dml_errors exception with the ORA-24381 error. The ORA-24381 error is raised if any exceptions are caught and saved after a bulk operation.

All exceptions raised during the execution are saved in the cursor attribute %BULK_EXCEPTIONS, which stores a collection of records. Each record has two fields:

- %BULK_EXCEPTIONS(i).ERROR_INDEX holds the iteration of the FORALL statement during which the exception was raised.
- %BULK_EXCEPTIONS(i).ERROR_CODE holds the corresponding Oracle error code.

The values stored by %BULK_EXCEPTIONS always refer to the most recently executed FORALL statement. The number of exceptions is saved in %BULK_EXCEPTIONS.COUNT. Its subscripts range from 1 to COUNT.

The individual error messages, or any substitution arguments, are not saved, but the error message text can looked up using ERROR_CODE with SQLERRM as shown in Example 11–9.

You might need to work backward to determine which collection element was used in the iteration that caused an exception. For example, if you use the INDICES OF clause to process a sparse collection, you must step through the elements one by one to find the one corresponding to %BULK_EXCEPTIONS(i).ERROR_INDEX. If you use the VALUES OF clause to process a subset of elements, you must find the element in the index collection whose subscript matches %BULK_EXCEPTIONS(i).ERROR_INDEX, and then use that element's value as the subscript to find the erroneous element in the original collection. For examples showing how to find the erroneous elements when using the INDICES OF and VALUES OF clauses, see the PL/SQL sample programs at http://www.oracle.com/technology/tech/pl_sql/.

If you omit the keywords SAVE EXCEPTIONS, execution of the FORALL statement stops when an exception is raised. In that case, SQL%BULK_EXCEPTIONS.COUNT returns 1, and SQL%BULK_EXCEPTIONS contains just one record. If no exception is raised during execution, SQL%BULK_EXCEPTIONS.COUNT returns 0.

Example 11–9 Bulk Operation That Continues Despite Exceptions

```
-- create a temporary table for this example
CREATE TABLE emp_temp AS SELECT * FROM employees;

DECLARE
   TYPE empid_tab IS TABLE OF employees.employee_id%TYPE;
   emp_sr empid_tab;
-- create an exception handler for ORA-24381
   errors NUMBER;
   dml_errors EXCEPTION;
   PRAGMA EXCEPTION_INIT(dml_errors, -24381);
BEGIN
   SELECT employee_id BULK COLLECT INTO emp_sr FROM emp_temp
         WHERE hire_date < '30-DEC-94';
-- add '_SR' to the job_id of the most senior employees
     FORALL i IN emp_sr.FIRST..emp_sr.LAST SAVE EXCEPTIONS
       UPDATE emp_temp SET job_id = job_id || '_SR'
          WHERE emp_sr(i) = emp_temp.employee_id;
-- If any errors occurred during the FORALL SAVE EXCEPTIONS,
-- a single exception is raised when the statement completes.

EXCEPTION
  WHEN dml_errors THEN -- Now we figure out what failed and why.
   errors := SQL%BULK_EXCEPTIONS.COUNT;
   DBMS_OUTPUT.PUT_LINE('Number of statements that failed: ' || errors);
   FOR i IN 1..errors LOOP
      DBMS_OUTPUT.PUT_LINE('Error #' || i || ' occurred during '||
         'iteration #' || SQL%BULK_EXCEPTIONS(i).ERROR_INDEX);
          DBMS_OUTPUT.PUT_LINE('Error message is ' ||
          SQLERRM(-SQL%BULK_EXCEPTIONS(i).ERROR_CODE));
   END LOOP;
END;
/
DROP TABLE emp_temp;
```

The output from the example is similar to:

```
Number of statements that failed: 2
Error #1 occurred during iteration #7
Error message is ORA-12899: value too large for column
Error #2 occurred during iteration #13
Error message is ORA-12899: value too large for column
```

In Example 11–9, PL/SQL raises predefined exceptions because updated values were too large to insert into the `job_id` column. After the `FORALL` statement, `SQL%BULK_EXCEPTIONS.COUNT` returned 2, and the contents of `SQL%BULK_EXCEPTIONS` were (7,12899) and (13,12899).

To get the Oracle error message (which includes the code), the value of `SQL%BULK_EXCEPTIONS(i).ERROR_CODE` was negated and then passed to the error-reporting function `SQLERRM`, which expects a negative number.

Retrieving Query Results into Collections with the BULK COLLECT Clause

Using the keywords `BULK COLLECT` with a query is a very efficient way to retrieve the result set. Instead of looping through each row, you store the results in one or more collections, in a single operation. You can use these keywords in the `SELECT INTO` and `FETCH INTO` statements, and the `RETURNING INTO` clause.

With the BULK COLLECT clause, all the variables in the INTO list must be collections. The table columns can hold scalar or composite values, including object types. Example 11–10 loads two entire database columns into nested tables:

Example 11–10 Retrieving Query Results With BULK COLLECT

```
DECLARE
   TYPE NumTab IS TABLE OF employees.employee_id%TYPE;
   TYPE NameTab IS TABLE OF employees.last_name%TYPE;
   enums NumTab;   -- No need to initialize the collections.
   names NameTab;  -- Values will be filled in by the SELECT INTO.
   PROCEDURE print_results IS
   BEGIN
     IF enums.COUNT = 0 THEN
       DBMS_OUTPUT.PUT_LINE('No results!');
     ELSE
       DBMS_OUTPUT.PUT_LINE('Results:');
       FOR i IN enums.FIRST .. enums.LAST
       LOOP
         DBMS_OUTPUT.PUT_LINE('  Employee #' || enums(i) || ': ' || names(i));
       END LOOP;
     END IF;
   END;
BEGIN
 -- Retrieve data for employees with Ids greater than 1000
   SELECT employee_id, last_name
     BULK COLLECT INTO enums, names FROM employees WHERE employee_id > 1000;
-- The data has all been brought into memory by BULK COLLECT
-- No need to FETCH each row from the result set
   print_results();
 -- Retrieve approximately 20% of all rows
   SELECT employee_id, last_name
      BULK COLLECT INTO enums, names FROM employees SAMPLE (20);
   print_results();
END;
/
```

The collections are initialized automatically. Nested tables and associative arrays are extended to hold as many elements as needed. If you use varrays, all the return values must fit in the varray's declared size. Elements are inserted starting at index 1, overwriting any existing elements.

Because the processing of the BULK COLLECT INTO clause is similar to a FETCH loop, it does not raise a NO_DATA_FOUND exception if no rows match the query. You must check whether the resulting nested table or varray is null, or if the resulting associative array has no elements, as shown in Example 11–10.

To prevent the resulting collections from expanding without limit, you can use the LIMIT clause to or pseudocolumn ROWNUM to limit the number of rows processed. You can also use the SAMPLE clause to retrieve a random sample of rows.

Example 11–11 Using the Pseudocolumn ROWNUM to Limit Query Results

```
DECLARE
   TYPE SalList IS TABLE OF employees.salary%TYPE;
   sals SalList;
BEGIN
-- Limit the number of rows to 50
   SELECT salary BULK COLLECT INTO sals FROM employees
      WHERE ROWNUM <= 50;
```

```
-- Retrieve 10% (approximately) of the rows in the table
   SELECT salary BULK COLLECT INTO sals FROM employees SAMPLE (10);
END;
/
```

You can process very large result sets by fetching a specified number of rows at a time from a cursor, as shown in the following sections.

Examples of Bulk-Fetching from a Cursor

You can fetch from a cursor into one or more collections as shown in Example 11–12.

Example 11–12   Bulk-Fetching from a Cursor Into One or More Collections

```
DECLARE
  TYPE NameList IS TABLE OF employees.last_name%TYPE;
  TYPE SalList IS TABLE OF employees.salary%TYPE;
  CURSOR c1 IS SELECT last_name, salary FROM employees WHERE salary > 10000;
  names NameList;
  sals  SalList;
  TYPE RecList IS TABLE OF c1%ROWTYPE;
  recs RecList;
  v_limit PLS_INTEGER := 10;
  PROCEDURE print_results IS
  BEGIN
    IF names IS NULL OR names.COUNT = 0 THEN  -- check if collections are empty
       DBMS_OUTPUT.PUT_LINE('No results!');
    ELSE
      DBMS_OUTPUT.PUT_LINE('Results: ');
      FOR i IN names.FIRST .. names.LAST
      LOOP
        DBMS_OUTPUT.PUT_LINE('  Employee ' || names(i) || ': $' || sals(i));
      END LOOP;
    END IF;
  END;
BEGIN
  DBMS_OUTPUT.PUT_LINE('--- Processing all results at once ---');
  OPEN c1;
  FETCH c1 BULK COLLECT INTO names, sals;
  CLOSE c1;
  print_results();
  DBMS_OUTPUT.PUT_LINE('--- Processing ' || v_limit || ' rows at a time ---');
  OPEN c1;
  LOOP
    FETCH c1 BULK COLLECT INTO names, sals LIMIT v_limit;
    EXIT WHEN names.COUNT = 0;
    print_results();
  END LOOP;
  CLOSE c1;
  DBMS_OUTPUT.PUT_LINE('--- Fetching records rather than columns ---');
  OPEN c1;
  FETCH c1 BULK COLLECT INTO recs;
  FOR i IN recs.FIRST .. recs.LAST
  LOOP
-- Now all the columns from the result set come from a single record
    DBMS_OUTPUT.PUT_LINE('  Employee ' || recs(i).last_name || ': $'
         || recs(i).salary);
  END LOOP;
END;
/
```

Example 11–13 shows how you can fetch from a cursor into a collection of records.

Example 11–13 Bulk-Fetching from a Cursor Into a Collection of Records

```
DECLARE
  TYPE DeptRecTab IS TABLE OF departments%ROWTYPE;
  dept_recs DeptRecTab;
  CURSOR c1 IS
    SELECT department_id, department_name, manager_id, location_id
      FROM departments WHERE department_id > 70;
BEGIN
  OPEN c1;
  FETCH c1 BULK COLLECT INTO dept_recs;
END;
/
```

Limiting the Rows for a Bulk FETCH Operation with the LIMIT Clause

The optional `LIMIT` clause, allowed only in bulk `FETCH` statements, limits the number of rows fetched from the database. In Example 11–14, with each iteration of the loop, the `FETCH` statement fetches ten rows (or less) into index-by table `empids`. The previous values are overwritten. Note the use of `empids.COUNT` to determine when to exit the loop.

Example 11–14 Using LIMIT to Control the Number of Rows In a BULK COLLECT

```
DECLARE
   TYPE numtab IS TABLE OF NUMBER INDEX BY PLS_INTEGER;
   CURSOR c1 IS SELECT employee_id FROM employees WHERE department_id = 80;
   empids    numtab;
   rows      PLS_INTEGER := 10;
BEGIN
  OPEN c1;
  LOOP -- the following statement fetches 10 rows or less in each iteration
    FETCH c1 BULK COLLECT INTO empids LIMIT rows;
    EXIT WHEN empids.COUNT = 0;
--  EXIT WHEN c1%NOTFOUND; -- incorrect, can omit some data
    DBMS_OUTPUT.PUT_LINE('------- Results from Each Bulk Fetch --------');
    FOR i IN 1..empids.COUNT LOOP
      DBMS_OUTPUT.PUT_LINE( 'Employee Id: ' || empids(i));
    END LOOP;
  END LOOP;
  CLOSE c1;
END;
/
```

Retrieving DML Results into a Collection with the RETURNING INTO Clause

You can use the `BULK COLLECT` clause in the `RETURNING INTO` clause of an `INSERT`, `UPDATE`, or `DELETE` statement:

Example 11–15 Using BULK COLLECT With the RETURNING INTO Clause

```
CREATE TABLE emp_temp AS SELECT * FROM employees;
DECLARE
   TYPE NumList IS TABLE OF employees.employee_id%TYPE;
   enums NumList;
   TYPE NameList IS TABLE OF employees.last_name%TYPE;
   names NameList;
BEGIN
```

```
   DELETE FROM emp_temp WHERE department_id = 30
      RETURNING employee_id, last_name BULK COLLECT INTO enums, names;
   DBMS_OUTPUT.PUT_LINE('Deleted ' || SQL%ROWCOUNT || ' rows:');
   FOR i IN enums.FIRST .. enums.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Employee #' || enums(i) || ': ' || names(i));
   END LOOP;
END;
/
```

Using FORALL and BULK COLLECT Together

You can combine the BULK COLLECT clause with a FORALL statement. The output collections are built up as the FORALL statement iterates.

In Example 11–16, the employee_id value of each deleted row is stored in the collection e_ids. The collection depts has 3 elements, so the FORALL statement iterates 3 times. If each DELETE issued by the FORALL statement deletes 5 rows, then the collection e_ids, which stores values from the deleted rows, has 15 elements when the statement completes:

Example 11–16 Using FORALL With BULK COLLECT

```
CREATE TABLE emp_temp AS SELECT * FROM employees;
DECLARE
   TYPE NumList IS TABLE OF NUMBER;
   depts NumList := NumList(10,20,30);
   TYPE enum_t IS TABLE OF employees.employee_id%TYPE;
   TYPE dept_t IS TABLE OF employees.department_id%TYPE;
   e_ids enum_t;
   d_ids dept_t;
BEGIN
  FORALL j IN depts.FIRST..depts.LAST
    DELETE FROM emp_temp WHERE department_id = depts(j)
       RETURNING employee_id, department_id BULK COLLECT INTO e_ids, d_ids;
  DBMS_OUTPUT.PUT_LINE('Deleted ' || SQL%ROWCOUNT || ' rows:');
  FOR i IN e_ids.FIRST .. e_ids.LAST
  LOOP
    DBMS_OUTPUT.PUT_LINE('Employee #' || e_ids(i) || ' from dept #' || d_ids(i));
  END LOOP;
END;
/
```

The column values returned by each execution are added to the values returned previously. If you use a FOR loop instead of the FORALL statement, the set of returned values is overwritten by each DELETE statement.

You cannot use the SELECT ... BULK COLLECT statement in a FORALL statement.

Using Host Arrays with Bulk Binds

Client-side programs can use anonymous PL/SQL blocks to bulk-bind input and output host arrays. This is the most efficient way to pass collections to and from the database server.

Host arrays are declared in a host environment such as an OCI or a Pro*C program and must be prefixed with a colon to distinguish them from PL/SQL collections. In the following example, an input host array is used in a DELETE statement. At run time, the anonymous PL/SQL block is sent to the database server for execution.

```
DECLARE
  ...
BEGIN
  -- assume that values were assigned to the host array
  -- and host variables in the host environment
  FORALL i IN :lower..:upper
    DELETE FROM employees WHERE department_id = :depts(i);
  COMMIT;
END;
/
```

Writing Computation-Intensive Programs in PL/SQL

The `BINARY_FLOAT` and `BINARY_DOUBLE` datatypes make it practical to write PL/SQL programs to do number-crunching, for scientific applications involving floating-point calculations. These datatypes behave much like the native floating-point types on many hardware systems, with semantics derived from the IEEE-754 floating-point standard.

The way these datatypes represent decimal data make them less suitable for financial applications, where precise representation of fractional amounts is more important than pure performance.

The `PLS_INTEGER` and `BINARY_INTEGER` datatypes are PL/SQL-only datatypes that are more efficient than the SQL datatypes `NUMBER` or `INTEGER` for integer arithmetic. You can use `PLS_INTEGER` or `BINARY_INTEGER` to write pure PL/SQL code for integer arithmetic, or convert `NUMBER` or `INTEGER` values to `PLS_INTEGER` or `BINARY_INTEGER` for manipulation by PL/SQL. Note that the `BINARY_INTEGER` datatype is identical to `PLS_INTEGER`. For additional considerations, see "Change to the BINARY_INTEGER Datatype" on page xxvii.

Within a package, you can write overloaded versions of procedures and functions that accept different numeric parameters. The math routines can be optimized for each kind of parameter (`BINARY_FLOAT`, `BINARY_DOUBLE`, `NUMBER`, `PLS_INTEGER`), avoiding unnecessary conversions.

The built-in math functions such as `SQRT`, `SIN`, `COS`, and so on already have fast overloaded versions that accept `BINARY_FLOAT` and `BINARY_DOUBLE` parameters. You can speed up math-intensive code by passing variables of these types to such functions, and by calling the `TO_BINARY_FLOAT` or `TO_BINARY_DOUBLE` functions when passing expressions to such functions.

Tuning Dynamic SQL with EXECUTE IMMEDIATE and Cursor Variables

Some programs (a general-purpose report writer for example) must build and process a variety of SQL statements, where the exact text of the statement is unknown until run time. Such statements probably change from execution to execution. They are called dynamic SQL statements.

Formerly, to execute dynamic SQL statements, you had to use the supplied package `DBMS_SQL`. Now, within PL/SQL, you can execute any kind of dynamic SQL statement using an interface called native dynamic SQL. The main PL/SQL features involved are the `EXECUTE IMMEDIATE` statement and cursor variables (also known as `REF CURSOR`s).

Native dynamic SQL code is more compact and much faster than calling the `DBMS_SQL` package. The following example declares a cursor variable, then associates it with a dynamic `SELECT` statement:

```
DECLARE
   TYPE EmpCurTyp IS REF CURSOR;
   emp_cv   EmpCurTyp;
   v_ename VARCHAR2(15);
   v_sal   NUMBER := 1000;
   table_name VARCHAR2(30) := 'employees';
BEGIN
   OPEN emp_cv FOR 'SELECT last_name, salary FROM ' || table_name ||
      ' WHERE salary > :s' USING v_sal;
   CLOSE emp_cv;
END;
/
```

For more information, see Chapter 7, "Performing SQL Operations with Native Dynamic SQL".

Tuning PL/SQL Procedure Calls with the NOCOPY Compiler Hint

By default, `OUT` and `IN OUT` parameters are passed by value. The values of any `IN OUT` parameters are copied before the subprogram is executed. During subprogram execution, temporary variables hold the output parameter values. If the subprogram exits normally, these values are copied to the actual parameters. If the subprogram exits with an unhandled exception, the original parameters are unchanged.

When the parameters represent large data structures such as collections, records, and instances of object types, this copying slows down execution and uses up memory. In particular, this overhead applies to each call to an object method: temporary copies are made of all the attributes, so that any changes made by the method are only applied if the method exits normally.

To avoid this overhead, you can specify the `NOCOPY` hint, which allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference. If the subprogram exits normally, the behavior is the same as normal. If the subprogram exits early with an exception, the values of `OUT` and `IN  OUT` parameters (or object attributes) might still change. To use this technique, ensure that the subprogram handles all exceptions.

The following example asks the compiler to pass `IN OUT` parameter `v_staff` by reference, to avoid copying the varray on entry to and exit from the subprogram:

```
DECLARE
  TYPE Staff IS VARRAY(200) OF Employee;
  PROCEDURE reorganize (v_staff IN OUT NOCOPY Staff) IS ...
```

Example 11–17 loads 25,000 records into a local nested table, which is passed to two local procedures that do nothing. A call to the procedure that uses `NOCOPY` takes much less time.

Example 11–17   Using NOCOPY With Parameters

```
DECLARE
   TYPE EmpTabTyp IS TABLE OF employees%ROWTYPE;
   emp_tab EmpTabTyp := EmpTabTyp(NULL);  -- initialize
   t1 NUMBER;
   t2 NUMBER;
   t3 NUMBER;
   PROCEDURE get_time (t OUT NUMBER) IS
     BEGIN t := DBMS_UTILITY.get_time; END;
   PROCEDURE do_nothing1 (tab IN OUT EmpTabTyp) IS
     BEGIN NULL; END;
   PROCEDURE do_nothing2 (tab IN OUT NOCOPY EmpTabTyp) IS
     BEGIN NULL; END;
BEGIN
   SELECT * INTO emp_tab(1) FROM employees WHERE employee_id = 100;
   emp_tab.EXTEND(49999, 1);  -- copy element 1 into 2..50000
   get_time(t1);
   do_nothing1(emp_tab);  -- pass IN OUT parameter
   get_time(t2);
   do_nothing2(emp_tab);  -- pass IN OUT NOCOPY parameter
   get_time(t3);
   DBMS_OUTPUT.PUT_LINE('Call Duration (secs)');
   DBMS_OUTPUT.PUT_LINE('--------------------');
   DBMS_OUTPUT.PUT_LINE('Just IN OUT: ' || TO_CHAR((t2 - t1)/100.0));
   DBMS_OUTPUT.PUT_LINE('With NOCOPY: ' || TO_CHAR((t3 - t2))/100.0);
END;
/
```

Restrictions on NOCOPY

The use of NOCOPY increases the likelihood of parameter aliasing. For more information, see "Understanding Subprogram Parameter Aliasing" on page 8-24.

Remember, NOCOPY is a hint, not a directive. In the following cases, the PL/SQL compiler ignores the NOCOPY hint and uses the by-value parameter-passing method; no error is generated:

- The actual parameter is an element of an associative array. This restriction does not apply if the parameter is an entire associative array.
- The actual parameter is constrained, such as by scale or NOT NULL. This restriction does not apply to size-constrained character strings. This restriction does not extend to constrained elements or attributes of composite types.
- The actual and formal parameters are records, one or both records were declared using %ROWTYPE or %TYPE, and constraints on corresponding fields in the records differ.
- The actual and formal parameters are records, the actual parameter was declared (implicitly) as the index of a cursor FOR loop, and constraints on corresponding fields in the records differ.
- Passing the actual parameter requires an implicit datatype conversion.
- The subprogram is called through a database link or as an external procedure.

Compiling PL/SQL Code 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 process.

You can use native compilation with both the supplied Oracle packages, and procedures you write yourself. Procedures compiled this way work in all server environments, such as the shared server configuration (formerly known as multi-threaded server) and Oracle Real Application Clusters.

See Also:

- Best practices and additional information on setting up PL/SQL native compilation on the Oracle Technology Network (OTN):

  `http://www.oracle.com/technology/tech/pl_sql/`
- Additional information about native compilation, such as Note 269012.1, on Oracle Metalink:

  `http://metalink.oracle.com`

Before You Begin

If you are a first-time user of native PL/SQL compilation, try it first with a test database, before proceeding to a production environment.

Always back up your database before configuring the database for PL/SQL native compilation. If you find that the performance benefit is outweighed by extra compilation time, it might be faster to restore from a backup than to recompile everything in interpreted mode.

Some of the setup steps require DBA authority. You must change the values of some initialization parameters, and create a new directory on the database server, preferably near the data files for the instance. The database server also needs a C compiler; on a cluster, the compiler is needed on each node. Even if you can test out these steps yourself on a development machine, you will generally need to consult with a DBA and enlist their help to use native compilation on a production server.

Note: The pre-requirements for using native compiled PL/SQL code are documented for each platform in the individual Oracle database installation guides. Check the software requirements section for the certified compilers for native compilation on your platform to ensure that you use a certified compiler.

Determining Whether to Use PL/SQL Native Compilation

PL/SQL native compilation provides the greatest performance gains for computation-intensive procedural operations. Examples of such operations are data warehouse applications, and applications with extensive server-side transformations of data for display. In such cases, expect speed increases of up to 30%.

Because this technique cannot do much to speed up SQL statements called from PL/SQL, it is most effective for compute-intensive PL/SQL procedures that do not spend most of their time executing SQL. You can test to see how much performance gain you can get by enabling PL/SQL native compilation.

It takes longer to compile program units with native compilation than to use the default interpreted mode. You might turn off native compilation during the busiest parts of the development cycle, where code is being frequently recompiled.

If you have determined that there will be significant performance gains in database operations using PL/SQL native compilation, Oracle Corporation recommends that you compile the entire database using the `NATIVE` setting. Compiling all the PL/SQL code in the database means you see the speedup in your own code, and in calls to all the built-in PL/SQL packages.

If interpreted compilation is required for your environment, you can compile all the PL/SQL units to `INTERPRETED`. For example, if you import an entire database that includes NATIVE PL/SQL units into an environment where a C compiler is unavailable.

To convert an entire database to NATIVE or INTERPRETED compilation, see "Modifying the Entire Database for PL/SQL Native or Interpreted Compilation" on page 11-29.

How PL/SQL Native Compilation Works

If you do not use native compilation, each PL/SQL program unit is compiled into an intermediate form, machine-readable code (m-code). The m-code is stored in the database dictionary and interpreted at run time. With PL/SQL native compilation, the PL/SQL statements are turned into C code that bypasses all the runtime interpretation, giving faster runtime performance.

PLSQL_ initialization parameters set up the environment for PL/SQL native compilation, as described in "Setting up Initialization Parameters for PL/SQL Native Compilation" on page 11-25.

PL/SQL uses the command file $ORACLE_HOME/plsql/spnc_commands, and the supported operating system C compiler and linker, to compile and link the resulting C code into shared libraries. See "The spnc_commands File" on page 11-25.

The shared libraries are stored inside the data dictionary, so that they can be backed up automatically and are protected from being deleted. These shared library files are copied to the file system and are loaded and run when the PL/SQL subprogram is invoked. If the files are deleted from the file system while the database is shut down, or if you change the directory that holds the libraries, they are extracted again automatically.

Although PL/SQL program units that just call SQL statements might see little or no speedup, natively compiled PL/SQL is always at least as fast as the corresponding interpreted code. The compiled code makes the same library calls as the interpreted code would, so its behavior is exactly the same.

Dependencies, Invalidation and Revalidation

After the procedures are compiled and turned into shared libraries, they are automatically linked into the Oracle process. You do not need to restart the database, or move the shared libraries to a different location. You can call back and forth between stored procedures, whether they are all interpreted, all compiled for native execution, or a mixture of both.

Recompilation is automatic with invalidated PL/SQL modules. For example, if an object on which a natively compiled PL/SQL subprogram depends changes, the subprogram is invalidated. The next time the same subprogram is called, the database recompiles the subprogram automatically. Because the PLSQL_CODE_TYPE setting is stored inside the library unit for each subprogram, the automatic recompilation uses this stored setting for code type.

The stored settings are only used when recompiling as part of revalidation. If a PL/SQL subprogram is explicitly compiled through the SQL commands CREATE OR REPLACE or ALTER...COMPILE, the current session setting is used. See also "Initialization Parameters for PL/SQL Compilation" on page 11-1.

The generated shared libraries are stored in the database, in the SYSTEM tablespace. The first time a natively compiled procedure is executed, the corresponding shared library is copied from the database to the directory specified by the initialization parameter PLSQL_NATIVE_LIBRARY_DIR.

Real Application Clusters and PL/SQL Native Compilation

Because any node might need to compile a PL/SQL subprogram, each node in the cluster needs a C compiler and correct settings and paths in the `$ORACLE_HOME/plsql/spnc_commands` file.

When you use PLSQL native compilation in a Real Application Clusters (RAC) environment, the original copies of the shared library files are stored in the databases, and these files are automatically propagated to all nodes in the cluster. You do not need to do any copying of libraries for this feature to work.

Check that all nodes of a RAC cluster use the same settings for the initialization parameters that control PL/SQL native compilation. Make sure the path specified in `PLSQL_NATIVE_LIBRARY_DIR` where the shared libraries are placed is created identically on all nodes that are part of the cluster.

Limitations of Native Compilation

The following are some limitations of native compilation:

- Debugging tools for PL/SQL do not handle procedures compiled for native execution.
- When many procedures and packages (typically, over 15000) are compiled for native execution, the large number of shared objects in a single directory might affect system performance. See "Setting Up PL/SQL Native Library Subdirectories" on page 11-27 for a workaround.

The spnc_commands File

The `spnc_commands` file, in the `$ORACLE_HOME/plsql` directory, contains the templates for the commands to compile and link each program. Some special names such as `%(src)` are predefined, and are replaced by the corresponding filename. The variable `$(ORACLE_HOME)` is replaced by the location of the Oracle home directory. Comment lines start with a `#` character. The file contains comments that explain all the special notation.

The `spnc_commands` file contains a predefined path for the default C compiler, depending on the particular operating system. A specific compiler is supported on each operating system. Only one compiler can be used to compile the PL/SQL modules; do not compile PL/SQL modules in a database with different compilers.

You can view `spnc_commands` file to confirm that the command templates are correct. You should not need to change this file unless the system administrator has installed the C compiler in another location or you want to use a different supported C compiler. Additional information can be found in the Oracle database installation guide for your platform and by searching for `spnc_commands` on Oracle Metalink at `http://metalink.oracle.com`.

Setting up Initialization Parameters for PL/SQL Native Compilation

This section describes the initialization parameters that are used to set PL/SQL native compilation.

- `PLSQL_NATIVE_LIBRARY_DIR`
- `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT`
- `PLSQL_CODE_TYPE`

To check the settings of these parameters, enter the following in SQL*Plus:

```
SHOW PARAMETERS PLSQL
```

See also "Initialization Parameters for PL/SQL Compilation" on page 11-1.

PLSQL_NATIVE_LIBRARY_DIR Initialization Parameter

This is a required system-level only parameter that specifies the full path and directory name of the location of the shared libraries that contain natively compiled PL/SQL code. The value must be explicit and point to an existing, accessible directory; the path cannot contain a variable such as `ORACLE_HOME`. Use the `ALTER SYSTEM` command or update the initialization file to set the parameter value.

For example, if the path to the PL/SQL native library directory is `/oracle/oradata/db1/natlib`, then the setting in the initialization file is:

```
PLSQL_NATIVE_LIBRARY_DIR='/oracle/oradata/db1/natlib'
```

In accordance with optimal flexible architecture (OFA) rules, Oracle Corporation recommends that you create the shared library directory as a subdirectory where the data files are located. For security reasons, only the users `oracle` and `root` should have write privileges for this directory.

If using a Real Applications Cluster environment, see "Real Application Clusters and PL/SQL Native Compilation" on page 11-25. For details about the `PLSQL_NATIVE_LIBRARY_DIR` initialization parameter, see *Oracle Database Reference*.

PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT Initialization Parameter

This is an optional system-level only parameter that specifies the number of subdirectories in the directory that is specified by the parameter `PLSQL_NATIVE_LIBRARY_DIR`. Use the `ALTER SYSTEM` command or update the initialization file to set the parameter value.

For example, if you want to set the parameter for 1,000 subdirectories, then the setting in the initialization parameter file is:

```
PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT=1000;
```

Set this parameter if the number of natively compiled program units is very large. See "Setting Up PL/SQL Native Library Subdirectories" on page 11-27.

For details about the `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` initialization parameter, see *Oracle Database Reference*.

PLSQL_CODE_TYPE Initialization Parameter

The `PLSQL_CODE_TYPE` initialization parameter determines whether PL/SQL code is natively compiled or interpreted. The default setting is `INTERPRETED`. To enable PL/SQL native compilation, set the value of `PLSQL_CODE_TYPE` to `NATIVE`.

The parameter can be set at the system, session level, or for a specific PL/SQL module. Use the `ALTER SYSTEM` command, `ALTER SESSION` command, or update the initialization file to set the parameter value. If you compile the whole database as `NATIVE`, Oracle Corporation recommends that you set `PLSQL_CODE_TYPE` at the system level.

The following SQL*Plus syntax sets the parameter at the session level:

```
ALTER SESSION SET PLSQL_CODE_TYPE='NATIVE';
ALTER SESSION SET PLSQL_CODE_TYPE='INTERPRETED';
```

You can also use the `PLSQL_CODE_TYPE = NATIVE` clause with the `ALTER .. COMPILE` statement for a specific PL/SQL module, as shown in Example 11–18 on page 11-28.

This affects only the specified module without changing the initialization parameter for the entire session. Note that a package specification and its body do not need to be compiled with the same setting for native compilation.

For details about the `PLSQL_CODE_TYPE` initialization parameter, see *Oracle Database Reference*.

Setting Up PL/SQL Native Library Subdirectories

By default, PL/SQL program units are kept in one directory. However, if the number of program units is very large, then the operating system might have difficulty handling a large of files in one directory. To avoid this problem, Oracle Corporation recommends that you spread the PL/SQL program units in subdirectories under the directory specified by the `PLSQL_NATIVE_LIBRARY_DIR` initialization parameter.

If you have an existing database that you will migrate to the new installation, or if you have set up a test database, use the following SQL query to determine how many PL/SQL program units you are using:

```
SELECT COUNT (*) from DBA_PLSQL_OBJECT_SETTINGS
```

If you are going to exclude any units, such as packages, use the previous query with:

```
    WHERE TYPE NOT IN ('TYPE', 'PACKAGE')
```

If you need to set up PL/SQL native library subdirectories, first create subdirectories sequentially in the form of d0, d1, d2, d3...dx, where x is the total number of directories. Oracle Corporation recommends that you use a script for this task. For example, you might run a PL/SQL block like the following, save its output to a file, then run that file as a shell script:

```
SPOOL make_dirs
BEGIN
  FOR j IN 0..1000 -- change to the number of directories needed
  LOOP
    DBMS_OUTPUT.PUT_LINE ( 'mkdir d' || TO_CHAR(j) );
  END LOOP;
END;
/
SPOOL OFF
```

Next, set the `PLSQL_NATIVE_LIBARY_SUBDIR_COUNT` initialization parameter to the number of subdirectories you have created. For example, if you created 1000 subdirectories, you can use SQL*Plus to enter the following SQL statement:

```
ALTER SYSTEM SET PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT=1000;
```

See "PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT Initialization Parameter" on page 11-26.

Setting Up and Testing PL/SQL Native Compilation

To set up and test one or more subprograms through native compilation:

1. Set up the necessary initialization parameter. See "Setting up Initialization Parameters for PL/SQL Native Compilation" on page 11-25.
2. Compile one or more subprograms, using one of these methods:
   - Use `CREATE OR REPLACE` to create or recompile the subprogram.

- Use the `ALTER PROCEDURE`, `ALTER FUNCTION`, or `ALTER PACKAGE` command with the `COMPILE` option to recompile a specific subprogram or entire package, as shown in Example 11–18.
- Drop the subprogram and create it again.
- Run one of the SQL*Plus scripts that creates a set of Oracle-supplied packages.
- Create a database using a preconfigured initialization file with `PLSQL_CODE_TYPE=NATIVE`. During database creation, the `utlirp` script is run to compile all the Oracle-supplied packages.

Example 11–18 illustrates the process of altering and testing a procedure using native compilation. The procedure is immediately available to call, and runs as a shared library directly within the Oracle process. If any errors occur during compilation, you can see them using the `USER_ERRORS` view or the `SHOW ERRORS` command in SQL*Plus.

Example 11–18 Compiling a PL/SQL Procedure for Native Execution

```
-- PLSQL_NATIVE_LIBRARY_DIR must be set to an existing, accessible directory
SET SERVEROUTPUT ON FORMAT WRAPPED

CREATE OR REPLACE PROCEDURE hello_native AS
BEGIN
  DBMS_OUTPUT.PUT_LINE('Hello world. Today is ' || TO_CHAR(SYSDATE) || '.');
END hello_native;
/

ALTER PROCEDURE hello_native COMPILE PLSQL_CODE_TYPE=NATIVE REUSE SETTINGS;
SHOW ERRORS
-- check for a file HELLO_NATIVE... in the PLSQL_NATIVE_LIBRARY_DIR directory
CALL hello_native();
```

3. To be sure that the process worked, you can query the data dictionary to see that a procedure is compiled for native execution. To check whether an existing procedure is compiled for native execution or not, you can query the `ALL_PLSQL_OBJECT_SETTINGS` view. The `PLSQL_CODE_TYPE` column has a value of `NATIVE` for procedures that are compiled for native execution, and `INTERPRETED` otherwise. For information, see *Oracle Database Reference*.

For example, to check the status of the procedure `hello_native`, use the query in Example 11–19.

Example 11–19 Checking plsql_code_type For a Compiled Procedure

```
SELECT PLSQL_CODE_TYPE FROM USER_PLSQL_OBJECT_SETTINGS
   WHERE NAME = 'HELLO_NATIVE';
```

Setting Up a New Database for PL/SQL Native Compilation

Use the procedures in this section to set up an new database for PL/SQL native compilation. The performance benefits apply to all the built-in PL/SQL packages, which are used for many database operations. If using a Real Applications Cluster environment, see "Real Application Clusters and PL/SQL Native Compilation" on page 11-25.

1. Check that `spnc_commands` file has the correct command templates. Contact your system administrator to ensure that you have the required C compiler on your operating system. See "The spnc_commands File" on page 11-25.
2. Ensure that the PL/SQL native library directory is created for each Oracle database. See "PLSQL_NATIVE_LIBRARY_DIR Initialization Parameter" on page 11-26.
   - You must set up PL/SQL libraries for each Oracle database. Shared libraries (`.so` and `.dll` files) are logically connected to the database. They cannot be shared between databases. If you set up PL/SQL libraries to be shared, the databases will be corrupted.
   - Create a directory in a secure place, in accordance with OFA rules, to prevent `.so` and `.dll` files from unauthorized access.
   - Ensure that the compiler executables used for PL/SQL native compilation are writable only by a properly secured user.
   - Ensure that the original copies of the shared libraries are stored inside the database, so they are backed up automatically with the database.
3. Set up the necessary initialization parameters. See "Setting up Initialization Parameters for PL/SQL Native Compilation" on page 11-25.

   If you use Database Configuration Assistant, use it to set the initialization parameters required for PL/SQL native compilation. Make sure that you set `PLSQL_NATIVE_LIBRARY_DIR` to an accessible directory and `PLSQL_CODE_TYPE` to `NATIVE`.

Modifying the Entire Database for PL/SQL Native or Interpreted Compilation

You can recompile all PL/SQL modules in an existing database to `NATIVE` or `INTERPRETED`, using the `dbmsupgnv.sql` and `dbmsupgin.sql` scripts respectively during the process described in this section. Before making the conversion, review "Determining Whether to Use PL/SQL Native Compilation" on page 11-23.

During the conversion to native compilation, `TYPE` specifications are not recompiled by `dbmsupgnv.sql` to `NATIVE` because these specifications do not contain executable code.

Package specifications seldom contain executable code so the runtime benefits of compiling to NATIVE are not measurable. You can use the `TRUE` command line parameter with the `dbmsupgnv.sql` script to exclude package specs from recompilation to `NATIVE`, saving time in the conversion process.

When converting to interpreted compilation, the `dbmsupgin.sql` script does not accept any parameters and does not exclude any PL/SQL units.

Note: The following procedure describes the conversion to native compilation. If you need to recompile all PL/SQL modules to interpreted compilation, make these changes in the steps.

- Skip the first step.
- Set the `PLSQL_CODE_TYPE` initialization parameter to `INTERPRETED` rather than `NATIVE`.
- Substitute `dbmsupgin.sql` for the `dbmsupgnv`.sql script.

1. Ensure that following are properly configured to support native compilation:
   - A supported C compiler is installed in the database environment and that the `spnc_commands` file has the correct command templates for this compiler.
   - The `PLSQL_NATIVE_LIBRARY_DIR` is set. See "PLSQL_NATIVE_LIBRARY_DIR Initialization Parameter" on page 11-26.
   - The `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` is set correctly for the number of natively compiled units after conversion. See "PLSQL_NATIVE_LIBRARY_DIR Initialization Parameter" on page 11-26 and "Setting Up PL/SQL Native Library Subdirectories" on page 11-27.
   - A test PL/SQL unit can be compiled as in Example 11–18 on page 11-28. For example:

```
ALTER PROCEDURE my_proc COMPILE PLSQL_CODE_TYPE=NATIVE
     REUSE SETTINGS;
```

2. Shut down application services, the listener, and the database.
   - Shut down all of the Application services including the Forms Processes, Web Servers, Reports Servers, and Concurrent Manager Servers. After shutting down all of the Application services, ensure that all of the connections to the database have been terminated.
   - Shut down the TNS listener of the database to ensure that no new connections are made.
   - Shut down the database in normal or immediate mode as the user `SYS`. See "Starting Up and Shutting Down" in the *Oracle Database Administrator's Guide*.
3. Set `PLSQL_CODE_TYPE` to `NATIVE` in the initialization parameter file. If the database is using a server parameter file, then set this after the database has started. See "PLSQL_CODE_TYPE Initialization Parameter" on page 11-26.

   The value of `PLSQL_CODE_TYPE` does not affect the conversion of the PL/SQL units in these steps. However, it does affect all subsequently compiled units and it should be explicitly set to the compilation type that you want.
4. Start up the database in upgrade mode, using the `UPGRADE` option. For information on SQL*Plus `STARTUP`, see the *SQL*Plus User's Guide and Reference*.
5. Execute the following code to list the invalid PL/SQL units. You can save the output of the query for future reference with the SQL `SPOOL` command.

Example 11–20   Checking for Invalid PL/SQL Units

```
REM To save the output of the query to a file: SPOOL pre_update_invalid.log
SELECT o.OWNER, o.OBJECT_NAME, o.OBJECT_TYPE
  FROM DBA_OBJECTS o, DBA_PLSQL_OBJECT_SETTINGS s
  WHERE o.OBJECT_NAME = s.NAME AND o.STATUS='INVALID';
REM To stop spooling the output: SPOOL OFF
```

   If any Oracle supplied units are invalid, try to validate them. For example:

```
ALTER PACKAGE OLAPSYS.DBMS_AWM COMPILE BODY REUSE SETTINGS;
```

   See `ALTER FUNCTION`, `ALTER PACKAGE`, and `ALTER PROCEDURE`, in the *Oracle Database SQL Reference*.If the units cannot be validated, save the spooled log for future resolution and continue.
6. Execute the following query to determine how many objects are compiled `NATIVE` and `INTERPRETED`. Use the SQL `SPOOL` command if you want to save the output.

Example 11–21 Checking for PLSQL Compilation Type

```
SELECT TYPE, PLSQL_CODE_TYPE, COUNT(*) FROM DBA_PLSQL_OBJECT_SETTINGS
  WHERE PLSQL_CODE_TYPE IS NOT NULL
  GROUP BY TYPE, PLSQL_CODE_TYPE
  ORDER BY TYPE, PLSQL_CODE_TYPE;
```

Any objects with a `NULL` `plsql_code_type` are special internal objects and can be ignored.

7. Run the `$ORACLE_HOME/rdbms/admin/dbmsupgnv.sql` script as the user `SYS` to update the `plsql_code_type` setting to `NATIVE` in the dictionary tables for all PL/SQL units. This process also invalidates the units. Use `TRUE` with the script to exclude package specifications; `FALSE` to include the package specifications.

   This update must be done when the database is in `UPGRADE` mode. The script is guaranteed to complete successfully or rollback all the changes.

8. Shut down the database and restart in `NORMAL` mode.

9. Before you run the `utlrp.sql` script, Oracle recommends that no other sessions are connected to avoid possible problems. You can ensure this with:

   ```
   ALTER SYSTEM ENABLE RESTRICTED SESSION;
   ```

10. Run the `$ORACLE_HOME/rdbms/admin/utlrp.sql` script as the user `SYS`. This script recompiles all the PL/SQL modules using a default degree of parellelism. See the comments in the script for information on setting the degree explicitly.

    If for any reason the script is abnormally terminated, rerun the `utlrp.sql` script to recompile any remaining invalid PL/SQL modules.

11. After the compilation completes successfully, verify that there are no new invalid PL/SQL units using the query in Example 11–20. You can spool the output of the query to the `post_upgrade_invalid.log` file and compare the contents with the `pre_upgrade_invalid.log` file, if it was created previously.

12. Re-execute the query in Example 11–21. If recompiling with `dbmsupgnv.sql`, confirm that all PL/SQL units, except `TYPE` specifications and package specifications if excluded, are `NATIVE`. If recompiling with `dbmsupgin.sql`, confirm that all PL/SQL units are `INTERPRETED`.

13. Disable the restricted session mode for the database, then start the services that you previously shut down. To disable restricted session mode:

    ```
    ALTER SYSTEM DISABLE RESTRICTED SESSION;
    ```

Setting Up Transformations with Pipelined Functions

This section describes how to chain together special kinds of functions known as pipelined table functions. These functions are used in situations such as data warehousing to apply multiple transformations to data.

See Also:

- Information about "Table functions and cursor expressions" in:

  `http://www.oracle.com/technology/tech/pl_sql/pdf/PLSQL_9i_New_Features_Doc.pdf`
- "Table functions and cursor expressions" examples at:

  `http://www.oracle.com/technology/sample_code/tech/pl_sql/index.html`
- Information about pipelined and parallel table functions in *Oracle Database Data Cartridge Developer's Guide*

Overview of Pipelined Table Functions

Pipelined table functions are functions that produce a collection of rows (either a nested table or a varray) that can be queried like a physical database table or assigned to a PL/SQL collection variable. You can use a table function in place of the name of a database table in the `FROM` clause of a query or in place of a column name in the `SELECT` list of a query.

A table function can take a collection of rows as input. An input collection parameter can be either a collection type (such as a `VARRAY` or a PL/SQL table) or a `REF CURSOR`.

Execution of a table function can be parallelized, and returned rows can be streamed directly to the next process without intermediate staging. Rows from a collection returned by a table function can also be pipelined, that is, iteratively returned as they are produced instead of in a batch after all processing of the table function's input is completed.

Streaming, pipelining, and parallel execution of table functions can improve performance:

- By enabling multi-threaded, concurrent execution of table functions
- By eliminating intermediate staging between processes
- By improving query response time: With non-pipelined table functions, the entire collection returned by a table function must be constructed and returned to the server before the query can return a single result row. Pipelining enables rows to be returned iteratively, as they are produced. This also reduces the memory that a table function requires, as the object cache does not need to materialize the entire collection.
- By iteratively providing result rows from the collection returned by a table function as the rows are produced instead of waiting until the entire collection is staged in tables or memory and then returning the entire collection.

Writing a Pipelined Table Function

You declare a pipelined table function by specifying the `PIPELINED` keyword. Pipelined functions can be defined at the schema level with `CREATE FUNCTION` or in a package. The `PIPELINED` keyword indicates that the function returns rows iteratively. The return type of the pipelined table function must be a supported collection type, such as a nested table or a varray. This collection type can be declared at the schema level or inside a package. Inside the function, you return individual elements of the collection type. The elements of the collection type must be supported SQL datatypes, such as `NUMBER` and `VARCHAR2`. PL/SQL datatypes, such as `PLS_INTEGER` and `BOOLEAN`, are not supported as collection elements in a pipelined function.

Example 11–22 shows how to assign the result of a pipelined table function to a PL/SQL collection variable and use the function in a SELECT statement.

Example 11–22 Assigning the Result of a Table Function

```
CREATE PACKAGE pkg1 AS
  TYPE numset_t IS TABLE OF NUMBER;
  FUNCTION f1(x NUMBER) RETURN numset_t PIPELINED;
END pkg1;
/

CREATE PACKAGE BODY pkg1 AS
-- FUNCTION f1 returns a collection of elements (1,2,3,... x)
FUNCTION f1(x NUMBER) RETURN numset_t PIPELINED IS
  BEGIN
    FOR i IN 1..x LOOP
      PIPE ROW(i);
    END LOOP;
    RETURN;
  END;
END pkg1;
/

-- pipelined function is used in FROM clause of SELECT statement
SELECT * FROM TABLE(pkg1.f1(5));
```

Using Pipelined Table Functions for Transformations

A pipelined table function can accept any argument that regular functions accept. A table function that accepts a REF CURSOR as an argument can serve as a transformation function. That is, it can use the REF CURSOR to fetch the input rows, perform some transformation on them, and then pipeline the results out.

In Example 11–23, the f_trans function converts a row of the employees table into two rows.

Example 11–23 Using a Pipelined Table Function For a Transformation

```
-- Define the ref cursor types and function
CREATE OR REPLACE PACKAGE refcur_pkg IS
  TYPE refcur_t IS REF CURSOR RETURN employees%ROWTYPE;
  TYPE outrec_typ IS RECORD (
    var_num    NUMBER(6),
    var_char1  VARCHAR2(30),
    var_char2  VARCHAR2(30));
  TYPE outrecset IS TABLE OF outrec_typ;
 FUNCTION f_trans(p refcur_t)
      RETURN outrecset PIPELINED;
END refcur_pkg;
/

CREATE OR REPLACE PACKAGE BODY refcur_pkg IS
  FUNCTION f_trans(p refcur_t)
   RETURN outrecset PIPELINED IS
    out_rec outrec_typ;
    in_rec  p%ROWTYPE;
  BEGIN
  LOOP
    FETCH p INTO in_rec;
    EXIT WHEN p%NOTFOUND;
    -- first row
    out_rec.var_num := in_rec.employee_id;
    out_rec.var_char1 := in_rec.first_name;
    out_rec.var_char2 := in_rec.last_name;
    PIPE ROW(out_rec);
    -- second row
    out_rec.var_char1 := in_rec.email;
    out_rec.var_char2 := in_rec.phone_number;
    PIPE ROW(out_rec);
  END LOOP;
  CLOSE p;
  RETURN;
  END;
END refcur_pkg;
/
-- SELECT query using the f_transc table function
SELECT * FROM TABLE(
   refcur_pkg.f_trans(CURSOR(SELECT * FROM employees WHERE department_id = 60)));
```

In the preceding query, the pipelined table function `f_trans` fetches rows from the `CURSOR` subquery `SELECT * FROM employees ...`, performs the transformation, and pipelines the results back to the user as a table. The function produces two output rows (collection elements) for each input row.

Note that when a `CURSOR` subquery is passed from SQL to a `REF CURSOR` function argument as in Example 11–23, the referenced cursor is already open when the function begins executing.

Returning Results from Pipelined Table Functions

In PL/SQL, the `PIPE ROW` statement causes a pipelined table function to pipe a row and continue processing. The statement enables a PL/SQL table function to return rows as soon as they are produced. For performance, the PL/SQL runtime system provides the rows to the consumer in batches.

In Example 11–23, the `PIPE ROW(out_rec)` statement pipelines data out of the PL/SQL table function. `out_rec` is a record, and its type matches the type of an element of the output collection.

The `PIPE ROW` statement may be used only in the body of pipelined table functions; an error is raised if it is used anywhere else. The `PIPE ROW` statement can be omitted for a pipelined table function that returns no rows.

A pipelined table function may have a `RETURN` statement that does not return a value. The `RETURN` statement transfers the control back to the consumer and ensures that the next fetch gets a `NO_DATA_FOUND` exception.

Because table functions pass control back and forth to a calling routine as rows are produced, there is a restriction on combining table functions and `PRAGMA AUTONOMOUS_TRANSACTION`. If a table function is part of an autonomous transaction, it must `COMMIT` or `ROLLBACK` before each `PIPE ROW` statement, to avoid an error in the calling subprogram.

Oracle has three special SQL datatypes that enable you to dynamically encapsulate and access type descriptions, data instances, and sets of data instances of any other SQL type, including object and collection types. You can also use these three special types to create anonymous (that is, unnamed) types, including anonymous collection types. The types are `SYS.ANYTYPE`, `SYS.ANYDATA`, and `SYS.ANYDATASET`. The

SYS.ANYDATA type can be useful in some situations as a return value from table functions.

> **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for information about the interfaces to the ANYTYPE, ANYDATA, and ANYDATASET types and about the DBMS_TYPES package for use with these types.

Pipelining Data Between PL/SQL Table Functions

With serial execution, results are pipelined from one PL/SQL table function to another using an approach similar to co-routine execution. For example, the following statement pipelines results from function g to function f:

```
SELECT * FROM TABLE(f(CURSOR(SELECT * FROM TABLE(g()))));
```

Parallel execution works similarly except that each function executes in a different process (or set of processes).

Optimizing Multiple Calls to Pipelined Table Functions

Multiple invocations of a pipelined table function, either within the same query or in separate queries result in multiple executions of the underlying implementation. By default, there is no buffering or reuse of rows. For example:

```
SELECT * FROM TABLE(f(...)) t1, TABLE(f(...)) t2
  WHERE t1.id = t2.id;
SELECT * FROM TABLE(f());
SELECT * FROM TABLE(f());
```

If the function always produces the same result value for each combination of values passed in, you can declare the function DETERMINISTIC, and Oracle automatically buffers rows for it. If the function is not really deterministic, results are unpredictable.

Fetching from the Results of Pipelined Table Functions

PL/SQL cursors and ref cursors can be defined for queries over table functions. For example:

```
OPEN c FOR SELECT * FROM TABLE(f(...));
```

Cursors over table functions have the same fetch semantics as ordinary cursors. REF CURSOR assignments based on table functions do not have any special semantics.

However, the SQL optimizer will not optimize across PL/SQL statements. For example:

```
DECLARE
  r SYS_REFCURSOR;
BEGIN
  OPEN r FOR SELECT *
    FROM TABLE(f(CURSOR(SELECT * FROM tab)));
  SELECT * BULK COLLECT INTO rec_tab FROM TABLE(g(r));
END;
/
```

does not execute as well as:

```
SELECT * FROM TABLE(g(CURSOR(SELECT * FROM
  TABLE(f(CURSOR(SELECT * FROM tab))))));
```

This is so even ignoring the overhead associated with executing two SQL statements and assuming that the results can be pipelined between the two statements.

Passing Data with Cursor Variables

You can pass a set of rows to a PL/SQL function in a `REF CURSOR` parameter. For example, this function is declared to accept an argument of the predefined weakly typed `REF CURSOR` type `SYS_REFCURSOR`:

```
FUNCTION f(p1 IN SYS_REFCURSOR) RETURN ... ;
```

Results of a subquery can be passed to a function directly:

```
SELECT * FROM TABLE(f(CURSOR(SELECT empid FROM tab)));
```

In the preceding example, the `CURSOR` keyword is required to indicate that the results of a subquery should be passed as a `REF CURSOR` parameter.

A predefined weak `REF CURSOR` type `SYS_REFCURSOR` is also supported. With `SYS_REFCURSOR`, you do not need to first create a `REF CURSOR` type in a package before you can use it.

To use a strong `REF CURSOR` type, you still must create a PL/SQL package and declare a strong `REF CURSOR` type in it. Also, if you are using a strong `REF CURSOR` type as an argument to a table function, then the actual type of the `REF CURSOR` argument must match the column type, or an error is generated. Weak `REF CURSOR` arguments to table functions can only be partitioned using the `PARTITION BY ANY` clause. You cannot use range or hash partitioning for weak `REF CURSOR` arguments.

PL/SQL functions can accept multiple `REF CURSOR` input variables as shown in Example 11–24.

Example 11–24 Using Multiple REF CURSOR Input Variables

```
-- Define the ref cursor types
CREATE PACKAGE refcur_pkg IS
  TYPE refcur_t1 IS REF CURSOR RETURN employees%ROWTYPE;
  TYPE refcur_t2 IS REF CURSOR RETURN departments%ROWTYPE;
  TYPE outrec_typ IS RECORD (
    var_num    NUMBER(6),
    var_char1  VARCHAR2(30),
    var_char2  VARCHAR2(30));
  TYPE outrecset IS TABLE OF outrec_typ;
  FUNCTION g_trans(p1 refcur_t1, p2 refcur_t2)
    RETURN outrecset PIPELINED;
END refcur_pkg;
/

CREATE PACKAGE BODY refcur_pkg IS
FUNCTION g_trans(p1 refcur_t1, p2 refcur_t2)
    RETURN outrecset PIPELINED IS
    out_rec outrec_typ;
    in_rec1 p1%ROWTYPE;
    in_rec2 p2%ROWTYPE;
BEGIN
  LOOP
    FETCH p2 INTO in_rec2;
    EXIT WHEN p2%NOTFOUND;
  END LOOP;
  CLOSE p2;
  LOOP
    FETCH p1 INTO in_rec1;
    EXIT WHEN p1%NOTFOUND;
    -- first row
    out_rec.var_num := in_rec1.employee_id;
    out_rec.var_char1 := in_rec1.first_name;
    out_rec.var_char2 := in_rec1.last_name;
    PIPE ROW(out_rec);
    -- second row
    out_rec.var_num := in_rec2.department_id;
    out_rec.var_char1 := in_rec2.department_name;
    out_rec.var_char2 := TO_CHAR(in_rec2.location_id);
    PIPE ROW(out_rec);
  END LOOP;
  CLOSE p1;
  RETURN;
END;
END refcur_pkg;
/

-- SELECT query using the g_trans table function
SELECT * FROM TABLE(refcur_pkg.g_trans(
  CURSOR(SELECT * FROM employees WHERE department_id = 60),
  CURSOR(SELECT * FROM departments WHERE department_id = 60)));
```

You can pass table function return values to other table functions by creating a `REF CURSOR` that iterates over the returned data:

```
SELECT * FROM TABLE(f(CURSOR(SELECT * FROM TABLE(g(...)))));
```

You can explicitly open a `REF CURSOR` for a query and pass it as a parameter to a table function:

```
DECLARE
  r SYS_REFCURSOR;
  rec ...;
BEGIN
  OPEN r FOR SELECT * FROM TABLE(f(...));
  -- Must return a single row result set.
  SELECT * INTO rec FROM TABLE(g(r));
END;
/
```

In this case, the table function closes the cursor when it completes, so your program should not explicitly try to close the cursor.

A table function can compute aggregate results using the input ref cursor. Example 11–25 computes a weighted average by iterating over a set of input rows.

Example 11–25 Using a Pipelined Table Function as an Aggregate Function

```
CREATE TABLE gradereport (student VARCHAR2(30), subject VARCHAR2(30),
                          weight NUMBER, grade NUMBER);
INSERT INTO gradereport VALUES('Mark', 'Physics', 4, 4);
INSERT INTO gradereport VALUES('Mark','Chemistry', 4, 3);
INSERT INTO gradereport VALUES('Mark','Maths', 3, 3);
INSERT INTO gradereport VALUES('Mark','Economics', 3, 4);

CREATE PACKAGE pkg_gpa IS
  TYPE gpa IS TABLE OF NUMBER;
  FUNCTION weighted_average(input_values SYS_REFCURSOR)
```

```
    RETURN gpa PIPELINED;
END pkg_gpa;
/
CREATE PACKAGE BODY pkg_gpa IS
FUNCTION weighted_average(input_values SYS_REFCURSOR)
  RETURN gpa PIPELINED IS
  grade NUMBER;
  total NUMBER := 0;
  total_weight NUMBER := 0;
  weight NUMBER := 0;
BEGIN
-- The function accepts a ref cursor and loops through all the input rows
  LOOP
     FETCH input_values INTO weight, grade;
     EXIT WHEN input_values%NOTFOUND;
-- Accumulate the weighted average
     total_weight := total_weight + weight;
     total := total + grade*weight;
  END LOOP;
  PIPE ROW (total / total_weight);
  RETURN; -- the function returns a single result
END;
END pkg_gpa;
/
-- the query result comes back as a nested table with a single row
-- COLUMN_VALUE is a keyword that returns the contents of a nested table
SELECT w.column_value "weighted result" FROM TABLE(
       pkg_gpa.weighted_average(CURSOR(SELECT weight, grade FROM gradereport))) w;
```

Performing DML Operations Inside Pipelined Table Functions

To execute DML statements, declare a pipelined table function with the AUTONOMOUS_TRANSACTION pragma, which causes the function to execute in a new transaction not shared by other processes:

```
CREATE FUNCTION f(p SYS_REFCURSOR)
  RETURN CollType PIPELINED IS
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN NULL; END;
/
```

During parallel execution, each instance of the table function creates an independent transaction.

Performing DML Operations on Pipelined Table Functions

Pipelined table functions cannot be the target table in UPDATE, INSERT, or DELETE statements. For example, the following statements will raise an error:

```
UPDATE F(CURSOR(SELECT * FROM tab)) SET col = value;
  INSERT INTO f(...) VALUES ('any', 'thing');
```

However, you can create a view over a table function and use INSTEAD OF triggers to update it. For example:

```
CREATE VIEW BookTable AS SELECT x.Name, x.Author
  FROM TABLE(GetBooks('data.txt')) x;
```

The following `INSTEAD OF` trigger is fired when the user inserts a row into the `BookTable` view:

```
CREATE TRIGGER BookTable_insert
INSTEAD OF INSERT ON BookTable
REFERENCING NEW AS n
FOR EACH ROW
BEGIN
  ...
END;
/
INSERT INTO BookTable VALUES (...);
```

`INSTEAD OF` triggers can be defined for all DML operations on a view built on a table function.

Handling Exceptions in Pipelined Table Functions

Exception handling in pipelined table functions works just as it does with regular functions.

Some languages, such as C and Java, provide a mechanism for user-supplied exception handling. If an exception raised within a table function is handled, the table function executes the exception handler and continues processing. Exiting the exception handler takes control to the enclosing scope. If the exception is cleared, execution proceeds normally.

An unhandled exception in a table function causes the parent transaction to roll back.

12 Using PL/SQL With Object Types

Object-oriented programming is especially suited for building reusable components and complex applications. In PL/SQL, object-oriented programming is based on object types. They let you model real-world objects, separate interfaces and implementation details, and store object-oriented data persistently in the database.

This chapter contains these topics:

For information about object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*.

Declaring and Initializing Objects in PL/SQL

An object type can represent any real-world entity. For example, an object type can represent a student, bank account, computer screen, rational number, or data structure such as a queue, stack, or list.

Currently, you cannot define object types in a PL/SQL block, subprogram, or package. You can define them interactively in SQL*Plus using the SQL statement `CREATE TYPE`. See Example 1–17, "Defining an Object Type" on page 1-17.

For information on the `CREATE TYPE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE TYPE BODY` SQL statement, see *Oracle Database SQL Reference*.

After an object type is defined and installed in the schema, you can use it to declare objects in any PL/SQL block, subprogram, or package. For example, you can use the object type to specify the datatype of an attribute, column, variable, bind variable, record field, table element, formal parameter, or function result. At run time, instances of the object type are created; that is, objects of that type are instantiated. Each object can hold different values.

Such objects follow the usual scope and instantiation rules. In a block or subprogram, local objects are instantiated when you enter the block or subprogram and cease to exist when you exit. In a package, objects are instantiated when you first reference the package and cease to exist when you end the database session.

Example 12–1 shows how to create an object type, object body type, and a table of object types.

Example 12–1 Working With Object Types

```
CREATE TYPE address_typ AS OBJECT (
   street          VARCHAR2(30),
   city            VARCHAR2(20),
   state           CHAR(2),
   postal_code     VARCHAR2(6) );
/
CREATE TYPE employee_typ AS OBJECT (
  employee_id       NUMBER(6),
  first_name        VARCHAR2(20),
  last_name         VARCHAR2(25),
  email             VARCHAR2(25),
  phone_number      VARCHAR2(20),
  hire_date         DATE,
  job_id            VARCHAR2(10),
  salary            NUMBER(8,2),
  commission_pct    NUMBER(2,2),
  manager_id        NUMBER(6),
  department_id     NUMBER(4),
  address           address_typ,
  MAP MEMBER FUNCTION get_idno RETURN NUMBER,
  MEMBER PROCEDURE display_address ( SELF IN OUT NOCOPY employee_typ ) );
/
CREATE TYPE BODY employee_typ AS
  MAP MEMBER FUNCTION get_idno RETURN NUMBER IS
  BEGIN
    RETURN employee_id;
  END;
  MEMBER PROCEDURE display_address ( SELF IN OUT NOCOPY employee_typ ) IS
  BEGIN
    DBMS_OUTPUT.PUT_LINE(first_name || ' '  || last_name);
    DBMS_OUTPUT.PUT_LINE(address.street);
    DBMS_OUTPUT.PUT_LINE(address.city || ', '  || address.state || ' ' ||
                         address.postal_code);
  END;
END;
/
CREATE TABLE employee_tab OF employee_typ;
```

Declaring Objects in a PL/SQL Block

You can use object types wherever built-in types such as CHAR or NUMBER can be used. In Example 12–2, you declare object emp of type employee_typ. Then, you call the constructor for object type employee_typ to initialize the object.

Example 12–2 Declaring Object Types in a PL/SQL Block

```
DECLARE
  emp employee_typ; -- emp is atomically null
BEGIN
-- call the constructor for employee_typ
  emp := employee_typ(315, 'Francis', 'Logan', 'FLOGAN',
        '555.777.2222', '01-MAY-04', 'SA_MAN', 11000, .15, 101, 110,
         address_typ('376 Mission', 'San Francisco', 'CA', '94222'));
  DBMS_OUTPUT.PUT_LINE(emp.first_name || ' ' || emp.last_name); -- display details
  emp.display_address();  -- call object method to display details
```

```
END;
/
```

You can declare objects as the formal parameters of functions and procedures. That way, you can pass objects to stored subprograms and from one subprogram to another. In the next example, you use object type `employee_typ` to specify the datatype of a formal parameter:

```
PROCEDURE open_acct (new_acct IN OUT employee_typ) IS ...
```

In the following example, you use object type `employee_typ` to specify the return type of a function:

```
FUNCTION get_acct (acct_id IN NUMBER) RETURN employee_typ IS ...
```

How PL/SQL Treats Uninitialized Objects

Until you initialize an object by calling the constructor for its object type, the object is atomically null. That is, the object itself is null, not just its attributes.

A null object is never equal to another object. In fact, comparing a null object with any other object always yields `NULL`. Also, if you assign an atomically null object to another object, the other object becomes atomically null (and must be reinitialized). Likewise, if you assign the non-value `NULL` to an object, the object becomes atomically null.

In an expression, attributes of an uninitialized object evaluate to `NULL`. When applied to an uninitialized object or its attributes, the `IS NULL` comparison operator yields `TRUE`.

Example 12–3 illustrates null objects and objects with null attributes.

Example 12–3 Null Objects in a PL/SQL Block

```
DECLARE
  emp employee_typ; -- emp is atomically null
BEGIN
  IF emp IS NULL THEN DBMS_OUTPUT.PUT_LINE('emp is NULL #1'); END IF;
  IF emp.employee_id IS NULL THEN
     DBMS_OUTPUT.PUT_LINE('emp.employee_id is NULL #1');
  END IF;
  emp.employee_id := 330;
  IF emp IS NULL THEN DBMS_OUTPUT.PUT_LINE('emp is NULL #2'); END IF;
  IF emp.employee_id IS NULL THEN
    DBMS_OUTPUT.PUT_LINE('emp.employee_id is NULL #2');
  END IF;
  emp := employee_typ(NULL, NULL, NULL, NULL,
        NULL, NULL, NULL, NULL, NULL, NULL, NULL,
         address_typ(NULL, NULL, NULL, NULL));
  -- emp := NULL; -- this would have made the following IF statement TRUE
  IF emp IS NULL THEN DBMS_OUTPUT.PUT_LINE('emp is NULL #3'); END IF;
  IF emp.employee_id IS NULL THEN
    DBMS_OUTPUT.PUT_LINE('emp.employee_id is NULL #3');
  END IF;
EXCEPTION
   WHEN ACCESS_INTO_NULL THEN
     DBMS_OUTPUT.PUT_LINE('Cannot assign value to NULL object');
END;
/
```

The output is:

```
emp is NULL #1
emp.employee_id is NULL #1
emp is NULL #2
emp.employee_id is NULL #3
```

Calls to methods of an uninitialized object raise the predefined exception `NULL_SELF_DISPATCH`. When passed as arguments to `IN` parameters, attributes of an uninitialized object evaluate to `NULL`. When passed as arguments to `OUT` or `IN OUT` parameters, they raise an exception if you try to write to them.

Manipulating Objects in PL/SQL

This section describes how to manipulate object attributes and methods in PL/SQL.

Accessing Object Attributes With Dot Notation

You refer to an attribute by name. To access or change the value of an attribute, you use dot notation. Attribute names can be chained, which lets you access the attributes of a nested object type. For example:

Example 12–4 Accessing Object Attributes

```
DECLARE
  emp employee_typ;
BEGIN
  emp := employee_typ(315, 'Francis', 'Logan', 'FLOGAN',
        '555.777.2222', '01-MAY-04', 'SA_MAN', 11000, .15, 101, 110,
         address_typ('376 Mission', 'San Francisco', 'CA', '94222'));
  DBMS_OUTPUT.PUT_LINE(emp.first_name || ' '  || emp.last_name);
  DBMS_OUTPUT.PUT_LINE(emp.address.street);
  DBMS_OUTPUT.PUT_LINE(emp.address.city || ', '  ||emp. address.state || ' ' ||
                       emp.address.postal_code);
END;
/
```

Calling Object Constructors and Methods

Calls to a constructor are allowed wherever function calls are allowed. Like all functions, a constructor is called as part of an expression, as shown in Example 12–4 on page 12-4 and Example 12–5.

Example 12–5 Inserting Rows in an Object Table

```
DECLARE
  emp employee_typ;
BEGIN
  INSERT INTO employee_tab VALUES (employee_typ(310, 'Evers', 'Boston', 'EBOSTON',
   '555.111.2222', '01-AUG-04', 'SA_REP', 9000, .15, 101, 110,
    address_typ('123 Main', 'San Francisco', 'CA', '94111')) );
  INSERT INTO employee_tab VALUES (employee_typ(320, 'Martha', 'Dunn', 'MDUNN',
    '555.111.3333', '30-SEP-04', 'AC_MGR', 12500, 0, 101, 110,
    address_typ('123 Broadway', 'Redwood City', 'CA', '94065')) );
END;
/
```

When you pass parameters to a constructor, the call assigns initial values to the attributes of the object being instantiated. When you call the default constructor to fill in all attribute values, you must supply a parameter for every attribute; unlike constants and variables, attributes cannot have default values. You can call a constructor using named notation instead of positional notation.

Like packaged subprograms, methods are called using dot notation. In Example 12–6, the `display_address` method is called to display attributes of an object. Note the use of the `VALUE` function which returns the value of an object. `VALUE` takes as its argument a correlation variable. In this context, a correlation variable is a row variable or table alias associated with a row in an object table.

Example 12–6 Accessing Object Methods

```
DECLARE
  emp employee_typ;
BEGIN
  SELECT VALUE(e) INTO emp FROM employee_tab e WHERE e.employee_id = 310;
  emp.display_address();
END;
/
```

In SQL statements, calls to a parameterless method require an empty parameter list. In procedural statements, an empty parameter list is optional unless you chain calls, in which case it is required for all but the last call. You cannot chain additional method calls to the right of a procedure call because a procedure is called as a statement, not as part of an expression. Also, if you chain two function calls, the first function must return an object that can be passed to the second function.

For static methods, calls use the notation *`type_name.method_name`* rather than specifying an instance of the type.

When you call a method using an instance of a subtype, the actual method that is executed depends on the exact declarations in the type hierarchy. If the subtype overrides the method that it inherits from its supertype, the call uses the subtype's implementation. Or, if the subtype does not override the method, the call uses the supertype's implementation. This capability is known as dynamic method dispatch.

Note: When implementing methods using PL/SQL, you cannot call a base or supertype object method with the `super` keyword or an equivalent method in a derived object. See *Oracle Database Application Developer's Guide - Object-Relational Features* for additional information on supertypes, subtypes, and object methods.

Updating and Deleting Objects

From inside a PL/SQL block you can modify and delete rows in an object table.

Example 12–7 Updating and Deleting Rows in an Object Table

```
DECLARE
  emp employee_typ;
BEGIN
  INSERT INTO employee_tab VALUES (employee_typ(370, 'Robert', 'Myers', 'RMYERS',
   '555.111.2277', '07-NOV-04', 'SA_REP', 8800, .12, 101, 110,
    address_typ('540 Fillmore', 'San Francisco', 'CA', '94011')) );
  UPDATE employee_tab e SET e.address.street = '1040 California'
     WHERE e.employee_id = 370;
  DELETE FROM employee_tab e WHERE e.employee_id = 310;
END;
```

```
/
```

Manipulating Objects Through Ref Modifiers

You can retrieve refs using the function `REF`, which takes as its argument a correlation variable.

Example 12–8 Updating Rows in an Object Table With a REF Modifier

```
DECLARE
  emp         employee_typ;
  emp_ref REF employee_typ;
BEGIN
  SELECT REF(e) INTO emp_ref FROM employee_tab e WHERE e.employee_id = 370;
  UPDATE employee_tab e
    SET e.address = address_typ('8701 College', 'Oakland', 'CA', '94321')
    WHERE REF(e) = emp_ref;
END;
/
```

You can declare refs as variables, parameters, fields, or attributes. You can use refs as input or output variables in SQL data manipulation statements.

You cannot navigate through refs in PLSQL. For example, the assignment in Example 12–9 using a ref is not allowed. Instead, use the function `DEREF` or make calls to the package `UTL_REF` to access the object. For information on the `REF` function, see *Oracle Database SQL Reference*.

Example 12–9 Using DEREF in a SELECT INTO Statement

```
DECLARE
  emp           employee_typ;
  emp_ref   REF employee_typ;
  emp_name      VARCHAR2(50);
BEGIN
  SELECT REF(e) INTO emp_ref FROM employee_tab e WHERE e.employee_id = 370;
-- the following assignment raises an error, not allowed in PL/SQL
-- emp_name := emp_ref.first_name || ' ' || emp_ref.last_name;
-- emp := DEREF(emp_ref); not allowed, cannot use DEREF in procedural statements
  SELECT DEREF(emp_ref) INTO emp FROM DUAL; -- use dummy table DUAL
  emp_name := emp.first_name || ' ' || emp.last_name;
  DBMS_OUTPUT.PUT_LINE(emp_name);
END;
/
```

For information on the `DEREF` function, see *Oracle Database SQL Reference*.

Defining SQL Types Equivalent to PL/SQL Collection Types

To store nested tables and varrays inside database tables, you must also declare SQL types using the `CREATE TYPE` statement. The SQL types can be used as columns or as attributes of SQL object types. For information on the `CREATE TYPE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE TYPE BODY` SQL statement, see *Oracle Database SQL Reference*. For more information on object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*.

You can declare equivalent types within PL/SQL, or use the SQL type name in a PL/SQL variable declaration.

Example 12–10 shows how you might declare a nested table in SQL, and use it as an attribute of an object type.

Example 12–10 Declaring a Nested Table in SQL

```
CREATE TYPE CourseList AS TABLE OF VARCHAR2(10)  -- define type
/
CREATE TYPE student AS OBJECT (  -- create object
   id_num  INTEGER(4),
   name    VARCHAR2(25),
   address VARCHAR2(35),
   status  CHAR(2),
   courses CourseList);  -- declare nested table as attribute
/
CREATE TABLE sophomores of student
  NESTED TABLE courses STORE AS courses_nt;
```

The identifier `courses` represents an entire nested table. Each element of `courses` stores the name of a college course such as `'Math 1020'`.

Example 12–11 creates a database column that stores varrays. Each varray element contains a `VARCHAR2`.

Example 12–11 Creating a Table with a Varray Column

```
-- Each project has a 16-character code name.
-- We will store up to 50 projects at a time in a database column.
CREATE TYPE ProjectList AS VARRAY(50) OF VARCHAR2(16);
/
CREATE TABLE dept_projects (  -- create database table
   dept_id  NUMBER(2),
   name     VARCHAR2(15),
   budget   NUMBER(11,2),
-- Each department can have up to 50 projects.
   projects ProjectList);
```

In Example 12–12, you insert a row into database table `dept_projects`. The varray constructor `ProjectList()` provides a value for column `projects`.

Example 12–12 Varray Constructor Within a SQL Statement

```
BEGIN
  INSERT INTO dept_projects
    VALUES(60, 'Security', 750400,
      ProjectList('New Badges', 'Track Computers', 'Check Exits'));
END;
/
```

In Example 12–13, you insert several scalar values and a `CourseList` nested table into the `sophomores` table.

Example 12–13 Nested Table Constructor Within a SQL Statement

```
CREATE TABLE sophomores of student
  NESTED TABLE courses STORE AS courses_nt;
BEGIN
   INSERT INTO sophomores
      VALUES (5035, 'Janet Alvarez', '122 Broad St', 'FT',
         CourseList('Econ 2010', 'Acct 3401', 'Mgmt 3100'));
END;
/
```

Manipulating Individual Collection Elements with SQL

By default, SQL operations store and retrieve whole collections rather than individual elements. To manipulate the individual elements of a collection with SQL, use the `TABLE` operator. The `TABLE` operator uses a subquery to extract the varray or nested table, so that the `INSERT`, `UPDATE`, or `DELETE` statement applies to the nested table rather than the top-level table.

To perform DML operations on a PL/SQL nested table, use the operators `TABLE` and `CAST`. This way, you can do set operations on nested tables using SQL notation, without actually storing the nested tables in the database.

The operands of `CAST` are PL/SQL collection variable and a SQL collection type (created by the `CREATE TYPE` statement). `CAST` converts the PL/SQL collection to the SQL type.

Example 12–14 Performing Operations on PL/SQL Nested Tables With CAST

```
CREATE TYPE Course AS OBJECT
           (course_no  NUMBER,
            title      VARCHAR2(64),
            credits    NUMBER);
/
CREATE TYPE CourseList AS TABLE OF course;
/

-- create department table
CREATE TABLE department (
   name     VARCHAR2(20),
   director VARCHAR2(20),
   office   VARCHAR2(20),
   courses  CourseList)
   NESTED TABLE courses STORE AS courses_tab;

INSERT INTO department VALUES ('English', 'June Johnson', '491C',
                 CourseList(Course(1002, 'Expository Writing', 4),
                 Course(2020, 'Film and Literature', 4),
                 Course(4210, '20th-Century Poetry', 4),
                 Course(4725, 'Advanced Workshop in Poetry', 4)));

DECLARE
   revised CourseList :=
      CourseList(Course(1002, 'Expository Writing', 3),
                 Course(2020, 'Film and Literature', 4),
                 Course(4210, '20th-Century Poetry', 4),
                 Course(4725, 'Advanced Workshop in Poetry', 5));
   num_changed INTEGER;
BEGIN
   SELECT COUNT(*) INTO num_changed
      FROM TABLE(CAST(revised AS CourseList)) new,
      TABLE(SELECT courses FROM department
         WHERE name = 'English') old
      WHERE new.course_no = old.course_no AND
         (new.title != old.title OR new.credits != old.credits);
   DBMS_OUTPUT.PUT_LINE(num_changed);
END;
/
```

Using PL/SQL Collections with SQL Object Types

Collections let you manipulate complex datatypes within PL/SQL. Your program can compute subscripts to process specific elements in memory, and use SQL to store the results in database tables.

In SQL*Plus, you can create SQL object types whose definitions correspond to PL/SQL nested tables and varrays, as shown in Example 12–15. Each item in column `dept_names` is a nested table that will store the department names for a specific region. The `NESTED TABLE` clause is required whenever a database table has a nested table column. The clause identifies the nested table and names a system-generated store table, in which Oracle stores the nested table data.

Within PL/SQL, you can manipulate the nested table by looping through its elements, using methods such as `TRIM` or `EXTEND`, and updating some or all of the elements. Afterwards, you can store the updated table in the database again. You can insert table rows containing nested tables, update rows to replace its nested table, and select nested tables into PL/SQL variables. You cannot update or delete individual nested table elements directly with SQL; you have to select the nested table from the table, change it in PL/SQL, then update the table to include the new nested table.

Example 12–15 Using INSERT, UPDATE, DELETE, and SELECT Statements With Nested Tables

```
CREATE TYPE dnames_tab AS TABLE OF VARCHAR2(30);
/
CREATE TABLE depts (region VARCHAR2(25), dept_names dnames_tab)
   NESTED TABLE dept_names STORE AS dnames_nt;
BEGIN
   INSERT INTO depts VALUES('Europe', dnames_tab('Shipping','Sales','Finance'));
   INSERT INTO depts VALUES('Americas', dnames_tab('Sales','Finance','Shipping'));
   INSERT INTO depts VALUES('Asia', dnames_tab('Finance','Payroll'));
   COMMIT;
END;
/
DECLARE
-- Type declaration is not needed, because PL/SQL can access the SQL object type
-- TYPE dnames_tab IS TABLE OF VARCHAR2(30); not needed
-- Declare a variable that can hold a set of department names
   v_dnames dnames_tab;
-- Declare a record that can hold a row from the table
-- One of the record fields is a set of department names
   v_depts depts%ROWTYPE;
   new_dnames dnames_tab;
BEGIN
-- Look up a region and query just the associated department names
   SELECT dept_names INTO v_dnames FROM depts WHERE region = 'Europe';
   FOR i IN v_dnames.FIRST .. v_dnames.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('Department names: ' || v_dnames(i));
   END LOOP;
-- Look up a region and query the entire row
   SELECT * INTO v_depts FROM depts WHERE region = 'Asia';
-- Now dept_names is a field in a record, so we access it with dot notation
   FOR i IN v_depts.dept_names.FIRST .. v_depts.dept_names.LAST LOOP
-- Because we have all the table columns in the record, we can refer to region
     DBMS_OUTPUT.PUT_LINE(v_depts.region || ' dept_names = ' ||
                          v_depts.dept_names(i));
   END LOOP;
-- We can replace a set of department names with a new collection
-- in an UPDATE statement
   new_dnames := dnames_tab('Sales','Payroll','Shipping');
   UPDATE depts SET dept_names = new_dnames WHERE region = 'Europe';
-- Or we can modify the original collection and use it in the UPDATE.
-- We'll add a new final element and fill in a value
   v_depts.dept_names.EXTEND(1);
   v_depts.dept_names(v_depts.dept_names.COUNT) := 'Finance';
   UPDATE depts SET dept_names = v_depts.dept_names
     WHERE region = v_depts.region;
-- We can even treat the nested table column like a real table and
-- insert, update, or delete elements. The TABLE operator makes the statement
-- apply to the nested table produced by the subquery.
   INSERT INTO TABLE(SELECT dept_names FROM depts WHERE region = 'Asia')
     VALUES('Sales');
   DELETE FROM TABLE(SELECT dept_names FROM depts WHERE region = 'Asia')
      WHERE column_value = 'Payroll';
   UPDATE TABLE(SELECT dept_names FROM depts WHERE region = 'Americas')
      SET column_value = 'Payroll' WHERE column_value = 'Finance';
   COMMIT;
END;
/
```

Example 12–16 shows how you can manipulate SQL varray object types with PL/SQL statements. In this example, varrays are transferred between PL/SQL variables and SQL tables. You can insert table rows containing varrays, update a row to replace its varray, and select varrays into PL/SQL variables. You cannot update or delete individual varray elements directly with SQL; you have to select the varray from the table, change it in PL/SQL, then update the table to include the new varray.

Example 12–16 Using INSERT, UPDATE, DELETE, and SELECT Statements With Varrays

```
-- By using a varray, we put an upper limit on the number of elements
-- and ensure they always come back in the same order
CREATE TYPE dnames_var IS VARRAY(7) OF VARCHAR2(30);
/
CREATE TABLE depts (region VARCHAR2(25), dept_names dnames_var);
BEGIN
   INSERT INTO depts VALUES('Europe', dnames_var('Shipping','Sales','Finance'));
   INSERT INTO depts VALUES('Americas', dnames_var('Sales','Finance','Shipping'));
   INSERT INTO depts
     VALUES('Asia', dnames_var('Finance','Payroll','Shipping','Sales'));
   COMMIT;
END;
/
DECLARE
   new_dnames dnames_var := dnames_var('Benefits', 'Advertising', 'Contracting',
                                       'Executive', 'Marketing');
   some_dnames dnames_var;
BEGIN
   UPDATE depts SET dept_names  = new_dnames WHERE region = 'Europe';
   COMMIT;
   SELECT dept_names INTO some_dnames FROM depts WHERE region = 'Europe';
   FOR i IN some_dnames.FIRST .. some_dnames.LAST
   LOOP
      DBMS_OUTPUT.PUT_LINE('dept_names = ' || some_dnames(i));
   END LOOP;
END;
/
```

In Example 12–17, PL/SQL BULK COLLECT is used with a multilevel collection that includes an object type.

Example 12–17 Using BULK COLLECT with Nested Tables

```
CREATE TYPE dnames_var IS VARRAY(7) OF VARCHAR2(30);
/
CREATE TABLE depts (region VARCHAR2(25), dept_names dnames_var);
BEGIN
   INSERT INTO depts VALUES('Europe', dnames_var('Shipping','Sales','Finance'));
   INSERT INTO depts VALUES('Americas', dnames_var('Sales','Finance','Shipping'));
   INSERT INTO depts
     VALUES('Asia', dnames_var('Finance','Payroll','Shipping','Sales'));
   COMMIT;
END;
/
DECLARE
   TYPE dnames_tab IS TABLE OF dnames_var;
   v_depts dnames_tab;
BEGIN
    SELECT dept_names BULK COLLECT INTO v_depts FROM depts;
    DBMS_OUTPUT.PUT_LINE(v_depts.COUNT); -- prints 3
END;
/
```

Using Dynamic SQL With Objects

Example 12–18 illustrates the use of objects and collections with dynamic SQL. First, define object type person_typ and VARRAY type hobbies_var, then write a package that uses these types.

Example 12–18 TEAMS Package Using Dynamic SQL for Object Types and Collections

```
CREATE TYPE person_typ AS OBJECT (name VARCHAR2(25), age NUMBER);
/
CREATE TYPE hobbies_var AS VARRAY(10) OF VARCHAR2(25);
/
CREATE OR REPLACE PACKAGE teams
   AUTHID CURRENT_USER AS
   PROCEDURE create_table (tab_name VARCHAR2);
   PROCEDURE insert_row (tab_name VARCHAR2, p person_typ, h hobbies_var);
   PROCEDURE print_table (tab_name VARCHAR2);
END;
/
CREATE OR REPLACE PACKAGE BODY teams AS
   PROCEDURE create_table (tab_name VARCHAR2) IS
   BEGIN
      EXECUTE IMMEDIATE 'CREATE TABLE ' || tab_name ||
                        ' (pers person_typ, hobbs hobbies_var)';
   END;
   PROCEDURE insert_row (
      tab_name VARCHAR2,
      p person_typ,
      h hobbies_var) IS
   BEGIN
      EXECUTE IMMEDIATE 'INSERT INTO ' || tab_name ||
         ' VALUES (:1, :2)' USING p, h;
   END;
   PROCEDURE print_table (tab_name VARCHAR2) IS
```

```
      TYPE  refcurtyp IS REF CURSOR;
      v_cur refcurtyp;
      p     person_typ;
      h     hobbies_var;
   BEGIN
      OPEN v_cur FOR 'SELECT pers, hobbs FROM ' || tab_name;
      LOOP
         FETCH v_cur INTO p, h;
         EXIT WHEN v_cur%NOTFOUND;
         -- print attributes of 'p' and elements of 'h'
         DBMS_OUTPUT.PUT_LINE('Name: ' || p.name || ' - Age: ' || p.age);
         FOR i IN h.FIRST..h.LAST
         LOOP
           DBMS_OUTPUT.PUT_LINE('Hobby(' || i || '): ' || h(i));
         END LOOP;
      END LOOP;
      CLOSE v_cur;
   END;
END;
/
```

From an anonymous block, you might call the procedures in package `TEAMS`:

Example 12–19 Calling Procedures from the TEAMS Package

```
DECLARE
   team_name VARCHAR2(15);
BEGIN
   team_name := 'Notables';
   TEAMS.create_table(team_name);
   TEAMS.insert_row(team_name, person_typ('John', 31),
      hobbies_var('skiing', 'coin collecting', 'tennis'));
   TEAMS.insert_row(team_name, person_typ('Mary', 28),
      hobbies_var('golf', 'quilting', 'rock climbing', 'fencing'));
   TEAMS.print_table(team_name);
END;
/
```

13

PL/SQL Language Elements

This chapter is a quick reference guide to PL/SQL syntax and semantics. It shows you how commands, parameters, and other language elements are combined to form PL/SQL statements. It also provides usage notes and links to examples.

To understand the syntax of a PL/SQL statement, trace through its syntax diagram, reading from left to right and top to bottom. The diagrams represent Backus-Naur Form (BNF) productions. Within the diagrams, keywords are enclosed in boxes, delimiters in circles, and identifiers in ovals. Each diagram defines a syntactic element. Every path through the diagram describes a possible form of that element. Follow in the direction of the arrows. If a line loops back on itself, you can repeat the element enclosed by the loop.

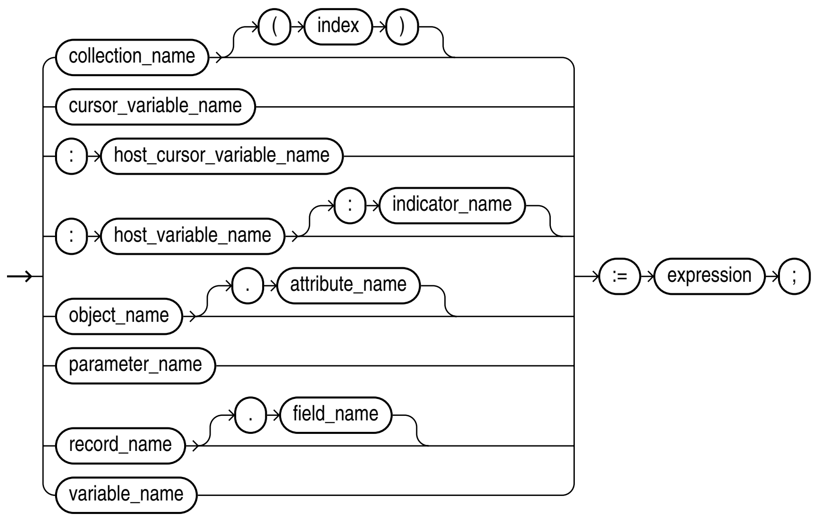
This chapter contains these topics:

Assignment Statement

An assignment statement sets the current value of a variable, field, parameter, or element. The statement consists of an assignment target followed by the assignment operator and an expression. When the statement is executed, the expression is evaluated and the resulting value is stored in the target. For more information, see "Assigning Values to Variables" on page 2-18.

Syntax

assignment statement ::=



Keyword and Parameter Description

attribute_name

An attribute of an object type. The name must be unique within the object type (but can be reused in other object types). You cannot initialize an attribute in its declaration using the assignment operator or `DEFAULT` clause. Also, you cannot impose the `NOT NULL` constraint on an attribute.

collection_name

A nested table, index-by table, or varray previously declared within the current scope.

cursor_variable_name

A PL/SQL cursor variable previously declared within the current scope. Only the value of another cursor variable can be assigned to a cursor variable.

expression

A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. For the syntax of `expression`, see "Expression Definition" on page 13-45. When the assignment statement is executed, the expression is evaluated and the resulting value is stored in the assignment target. The value and target must have compatible datatypes.

field_name

A field in a user-defined or %ROWTYPE record.

host_cursor_variable_name

A cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

host_variable_name

A variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. Host variables must be prefixed with a colon.

index

A numeric expression that must return a value of type PLS_INTEGER, BINARY_INTEGER, or a value implicitly convertible to that datatype.

indicator_name

An indicator variable declared in a PL/SQL host environment and passed to PL/SQL. Indicator variables must be prefixed with a colon. An indicator variable indicates the value or condition of its associated host variable. For example, in the Oracle Precompiler environment, indicator variables let you detect nulls or truncated values in output host variables.

object_name

An instance of an object type previously declared within the current scope.

parameter_name

A formal OUT or IN OUT parameter of the subprogram in which the assignment statement appears.

record_name

A user-defined or %ROWTYPE record previously declared within the current scope.

variable_name

A PL/SQL variable previously declared within the current scope.

Usage Notes

By default, unless a variable is initialized in its declaration, it is initialized to NULL every time a block or subprogram is entered. Always assign a value to a variable before using that variable in an expression.

You cannot assign nulls to a variable defined as NOT NULL. If you try, PL/SQL raises the predefined exception VALUE_ERROR. Only the values TRUE, FALSE, and NULL can be assigned to a Boolean variable. You can assign the result of a comparison or other test to a Boolean variable.

You can assign the value of an expression to a specific field in a record. You can assign values to all fields in a record at once. PL/SQL allows aggregate assignment between entire records if their declarations refer to the same cursor or table. Example 1–2, "Assigning Values to Variables With the Assignment Operator" on page 1-6 shows how to copy values from all the fields of one record to another:

You can assign the value of an expression to a specific element in a collection, by subscripting the collection name.

Examples

Example 13–1 illustrates various ways to declare and then assign values to variables.

Example 13–1 Declaring and Assigning Values to Variables

```
DECLARE
  wages         NUMBER;
  hours_worked  NUMBER := 40;
  hourly_salary CONSTANT NUMBER := 17.50; -- constant value does not change
  country       VARCHAR2(64) := 'UNKNOWN';
  unknown       BOOLEAN;
  TYPE comm_tab IS TABLE OF NUMBER INDEX BY PLS_INTEGER;
  commissions   comm_tab;
  TYPE jobs_var IS VARRAY(10) OF employees.job_id%TYPE;
  jobids        jobs_var;
  CURSOR c1 IS SELECT department_id FROM departments; -- cursor declaration
  deptid        departments.department_id%TYPE;
  emp_rec       employees%ROWTYPE; -- do not need TYPE declaration in this case
BEGIN
/* the following are examples of assignment statements */
  wages := hours_worked * hourly_salary; -- compute wages
  country := UPPER('italy');
  unknown := (country = 'UNKNOWN');
  commissions(5) := 20000 * 0.15; commissions(8) := 20000 * 0.18;
  jobids := jobs_var('ST_CLERK'); jobids.EXTEND(1); jobids(2) := 'SH_CLERK';
  OPEN c1; FETCH c1 INTO deptid; CLOSE c1;
  emp_rec.department_id := deptid; emp_rec.job_id := jobids(2);
END;
/
```

For examples, see the following:

Example 1–2, "Assigning Values to Variables With the Assignment Operator" on page 1-6
Example 1–3, "Assigning Values to Variables by SELECTing INTO" on page 1-6
Example 1–4, "Assigning Values to Variables as Parameters of a Subprogram" on page 1-7
Example 2–10, "Assigning Values to a Record With a %ROWTYPE Declaration" on page 2-12

Related Topics

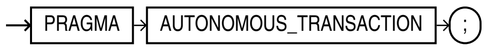
"Assigning Values to Variables" on page 2-18
"Constant and Variable Declaration" on page 13-25
"Expression Definition" on page 13-45
"SELECT INTO Statement" on page 13-107

AUTONOMOUS_TRANSACTION Pragma

The `AUTONOMOUS_TRANSACTION` pragma changes the way a subprogram works within a transaction. A subprogram marked with this pragma can do SQL operations and commit or roll back those operations, without committing or rolling back the data in the main transaction. For more information, see "Doing Independent Units of Work with Autonomous Transactions" on page 6-37.

Syntax

pragma autonomous_transaction ::=



Keyword and Parameter Description

PRAGMA

Signifies that the statement is a pragma (compiler directive). Pragmas are processed at compile time, not at run time. They pass information to the compiler.

Usage Notes

You can apply this pragma to:

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

You cannot apply this pragma to an entire package or an entire an object type. Instead, you can apply the pragma to each packaged subprogram or object method.

You can code the pragma anywhere in the declarative section. For readability, code the pragma at the top of the section.

Once started, an autonomous transaction is fully independent. It shares no locks, resources, or commit-dependencies with the main transaction. You can log events, increment retry counters, and so on, even if the main transaction rolls back.

Unlike regular triggers, autonomous triggers can contain transaction control statements such as `COMMIT` and `ROLLBACK`, and can issue DDL statements (such as `CREATE` and `DROP`) through the `EXECUTE IMMEDIATE` statement.

Changes made by an autonomous transaction become visible to other transactions when the autonomous transaction commits. The changes also become visible to the main transaction when it resumes, but only if its isolation level is set to `READ COMMITTED` (the default). If you set the isolation level of the main transaction to `SERIALIZABLE`, changes made by its autonomous transactions are *not* visible to the main transaction when it resumes.

In the main transaction, rolling back to a savepoint located before the call to the autonomous subprogram does *not* roll back the autonomous transaction. Remember, autonomous transactions are fully independent of the main transaction.

If an autonomous transaction attempts to access a resource held by the main transaction (which cannot resume until the autonomous routine exits), a deadlock can occur. Oracle raises an exception in the autonomous transaction, which is rolled back if the exception goes unhandled.

If you try to exit an active autonomous transaction without committing or rolling back, Oracle raises an exception. If the exception goes unhandled, or if the transaction ends because of some other unhandled exception, the transaction is rolled back.

Examples

For examples, see the following:

Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38
Example 6–44, "Declaring an Autonomous Standalone Procedure" on page 6-38
Example 6–45, "Declaring an Autonomous PL/SQL Block" on page 6-38
Example 6–46, "Declaring an Autonomous Trigger" on page 6-38

Related Topics

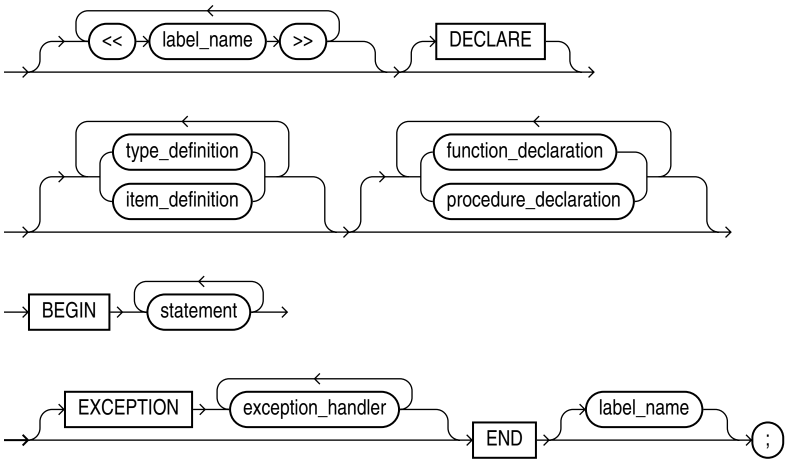
"EXCEPTION_INIT Pragma" on page 13-38
"RESTRICT_REFERENCES Pragma" on page 13-98
"SERIALLY_REUSABLE Pragma" on page 13-111

Block Declaration

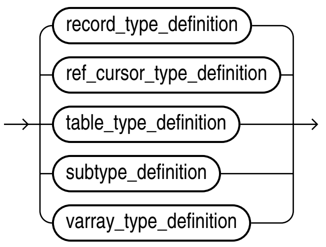
The basic program unit in PL/SQL is the block. A PL/SQL block is defined by the keywords `DECLARE`, `BEGIN`, `EXCEPTION`, and `END`. These keywords partition the block into a declarative part, an executable part, and an exception-handling part. Only the executable part is required. You can nest a block within another block wherever you can place an executable statement. For more information, see "Understanding PL/SQL Block Structure" on page 1-4 and "Scope and Visibility of PL/SQL Identifiers" on page 2-15.

Syntax

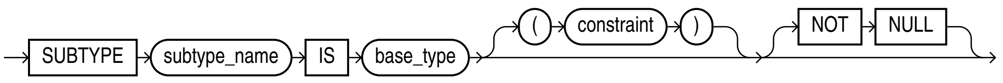
plsql block ::=



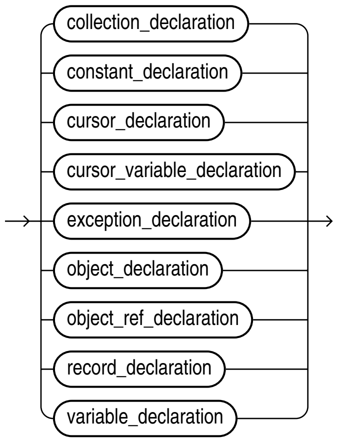
type definition ::=



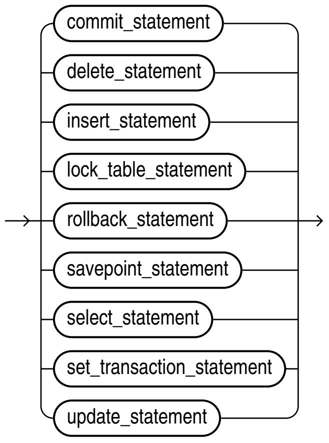
subtype definition ::=



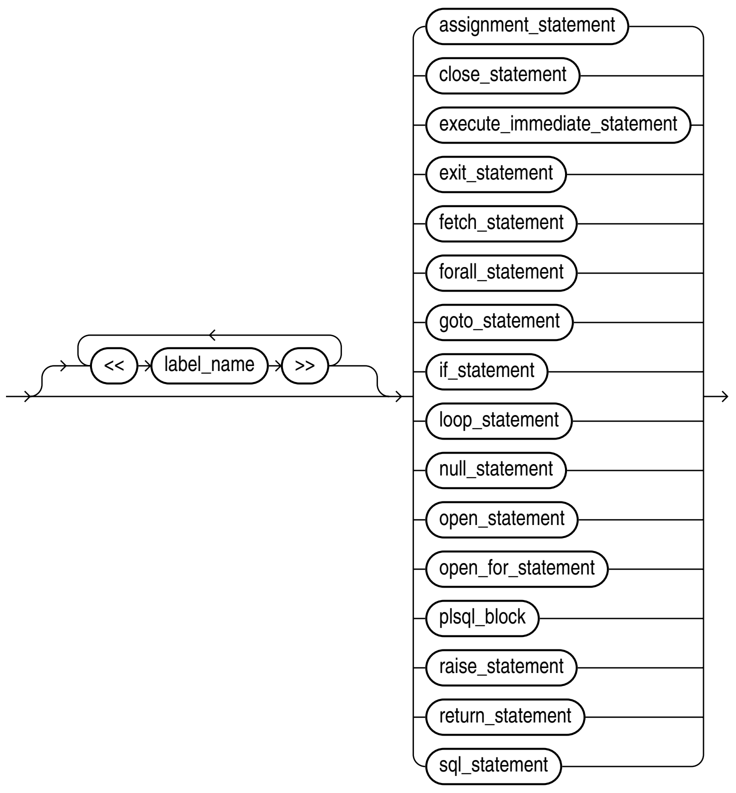
item definition ::=



sql_statement ::=



statement ::=



Keyword and Parameter Description

base_type

Any scalar or user-defined PL/SQL datatype specifier such as `CHAR`, `DATE`, or `RECORD`.

BEGIN

Signals the start of the executable part of a PL/SQL block, which contains executable statements. A PL/SQL block must contain at least one executable statement (even just the `NULL` statement). See "Understanding PL/SQL Block Structure" on page 1-4.

collection_declaration

Declares a collection (index-by table, nested table, or varray). For the syntax of `collection_declaration`, see "Collection Definition" on page 13-17.

constant_declaration

Declares a constant. For the syntax of `constant_declaration`, see "Constant and Variable Declaration" on page 13-25.

constraint

Applies only to datatypes that can be constrained such as `CHAR` and `NUMBER`. For character datatypes, this specifies a maximum size in bytes. For numeric datatypes, this specifies a maximum precision and scale.

cursor_declaration

Declares an explicit cursor. For the syntax of `cursor_declaration`, see "Cursor Declaration" on page 13-33.

cursor_variable_declaration

Declares a cursor variable. For the syntax of `cursor_variable_declaration`, see "Cursor Variables" on page 13-30.

DECLARE

Signals the start of the declarative part of a PL/SQL block, which contains local declarations. Items declared locally exist only within the current block and all its sub-blocks and are not visible to enclosing blocks. The declarative part of a PL/SQL block is optional. It is terminated implicitly by the keyword `BEGIN`, which introduces the executable part of the block. For more information, see "Declarations" on page 2-8.

PL/SQL does not allow forward references. You must declare an item before referencing it in any other statements. Also, you must declare subprograms at the end of a declarative section after all other program items.

END

Signals the end of a PL/SQL block. It must be the last keyword in a block. Remember, `END` does not signal the end of a transaction. Just as a block can span multiple transactions, a transaction can span multiple blocks. See "Understanding PL/SQL Block Structure" on page 1-4.

EXCEPTION

Signals the start of the exception-handling part of a PL/SQL block. When an exception is raised, normal execution of the block stops and control transfers to the appropriate exception handler. After the exception handler completes, execution proceeds with the statement following the block. See "Understanding PL/SQL Block Structure" on page 1-4.

If there is no exception handler for the raised exception in the current block, control passes to the enclosing block. This process repeats until an exception handler is found or there are no more enclosing blocks. If PL/SQL can find no exception handler for the exception, execution stops and an `unhandled exception` error is returned to the host environment. For more information on exceptions, see Chapter 10.

exception_declaration

Declares an exception. For the syntax of `exception_declaration`, see "Exception Definition" on page 13-39.

exception_handler

Associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see "Exception Definition" on page 13-39.

function_declaration

Declares a function. For the syntax of `function_declaration`, see "Function Declaration" on page 13-59.

label_name
An undeclared identifier that optionally labels a PL/SQL block or statement. If used, `label_name` must be enclosed by double angle brackets and must appear at the beginning of the block or statement which it labels. Optionally, when used to label a block, the `label_name` can also appear at the end of the block without the angle brackets. Multiple labels are allowed for a block or statement, but they must be unique for each block or statement.

A global identifier declared in an enclosing block can be redeclared in a sub-block, in which case the local declaration prevails and the sub-block cannot reference the global identifier unless you use a block label to qualify the reference. See Example 2–19, "PL/SQL Block Using Multiple and Duplicate Labels" on page 2-17.

object_declaration
Declares an instance of an object type. For the syntax of `object_declaration`, see "Object Type Declaration" on page 13-78.

procedure_declaration
Declares a procedure. For the syntax of `procedure_declaration`, see "Procedure Declaration" on page 13-90.

record_declaration
Declares a user-defined record. For the syntax of `record_declaration`, see "Record Definition" on page 13-95.

statement
An executable (not declarative) statement that. A sequence of statements can include procedural statements such as `RAISE`, SQL statements such as `UPDATE`, and PL/SQL blocks. PL/SQL statements are free format. That is, they can continue from line to line if you do not split keywords, delimiters, or literals across lines. A semicolon (`;`) serves as the statement terminator.

subtype_name
A user-defined subtype that was defined using any scalar or user-defined PL/SQL datatype specifier such as `CHAR`, `DATE`, or `RECORD`.

variable_declaration
Declares a variable. For the syntax of `variable_declaration`, see "Constant and Variable Declaration" on page 13-25.

PL/SQL supports a subset of SQL statements that includes data manipulation, cursor control, and transaction control statements but excludes data definition and data control statements such as `ALTER`, `CREATE`, `GRANT`, and `REVOKE`.

Examples

For examples, see the following:

Example 1–4, "Assigning Values to Variables as Parameters of a Subprogram" on page 1-7
Example 2–19, "PL/SQL Block Using Multiple and Duplicate Labels" on page 2-17
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

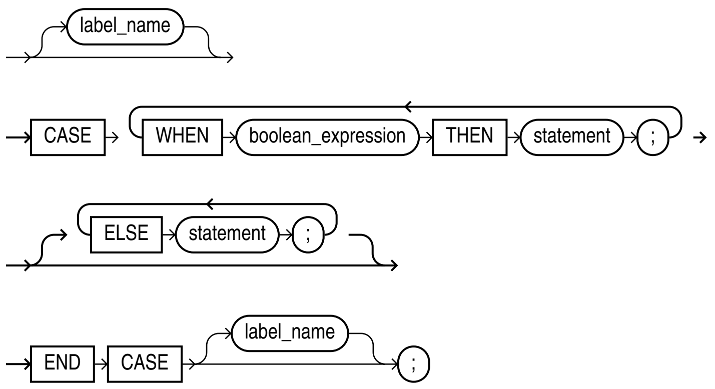
"Constant and Variable Declaration" on page 13-25
"Exception Definition" on page 13-39
"Function Declaration" on page 13-59
"Procedure Declaration" on page 13-90

CASE Statement

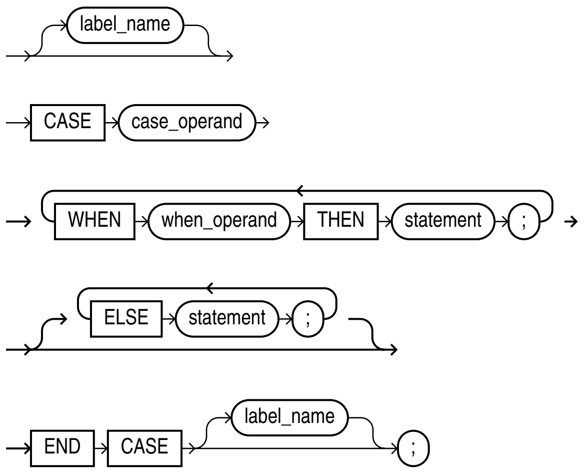
The CASE statement chooses from a sequence of conditions, and executes a corresponding statement. The CASE statement evaluates a single expression and compares it against several potential values, or evaluates multiple Boolean expressions and chooses the first one that is TRUE.

Syntax

searched case statement ::=



simple case statement ::=



Keyword and Parameter Description

The value of the CASE operand and WHEN operands in a simple CASE statement can be any PL/SQL type other than BLOB, BFILE, an object type, a PL/SQL record, an index-by table, a varray, or a nested table.

If the ELSE clause is omitted, the system substitutes a default action. For a CASE statement, the default when none of the conditions matches is to raise a CASE_NOT_FOUND exception. For a CASE expression, the default is to return NULL.

Usage Notes

The WHEN clauses are executed in order. Each WHEN clause is executed only once. After a matching WHEN clause is found, subsequent WHEN clauses are not executed. You can use multiple statements after a WHEN clause, and that the expression in the WHEN clause can be a literal, variable, function call, or any other kind of expression. The WHEN clauses can use different conditions rather than all testing the same variable or using the same operator.

The statements in a WHEN clause can modify the database and call non-deterministic functions. There is no fall-through mechanism as in the C switch statement. Once a WHEN clause is matched and its statements are executed, the CASE statement ends.

The CASE statement is appropriate when there is some different action to be taken for each alternative. If you just need to choose among several values to assign to a variable, you can code an assignment statement using a CASE expression instead.

You can include CASE expressions inside SQL queries, for example instead of a call to the DECODE function or some other function that translates from one value to another.

Examples

Example 13–2 shows the use of a simple CASE statement.

Example 13–2 Using a CASE Statement

```
DECLARE
   jobid      employees.job_id%TYPE;
   empid      employees.employee_id%TYPE := 115;
   sal_raise  NUMBER(3,2);
BEGIN
  SELECT job_id INTO jobid from employees WHERE employee_id = empid;
  CASE
    WHEN jobid = 'PU_CLERK' THEN sal_raise := .09;
    WHEN jobid = 'SH_CLERK' THEN sal_raise := .08;
    WHEN jobid = 'ST_CLERK' THEN sal_raise := .07;
    ELSE sal_raise := 0;
  END CASE;
END;
/
```

For examples, see the following:

Example 1–7, "Using the IF-THEN_ELSE and CASE Statement for Conditional Control" on page 1-10
Example 4–6, "Using the CASE-WHEN Statement" on page 4-4
Example 4–7, "Using the Searched CASE Statement" on page 4-5

Related Topics

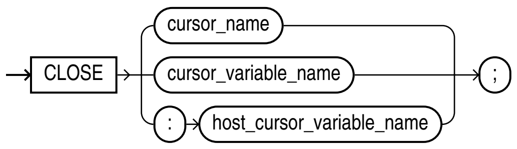
"Testing Conditions: IF and CASE Statements" on page 4-2
"CASE Expressions" on page 2-26
"Using CASE Statements" on page 4-4
NULLIF and COALESCE functions in *Oracle Database SQL Reference*

CLOSE Statement

The CLOSE statement indicates that you are finished fetching from a cursor or cursor variable, and that the resources held by the cursor can be reused.

Syntax

close ::=



Keyword and Parameter Description

cursor_name, cursor_variable_name, host_cursor_variable_name

When you close the cursor, you can specify an explicit cursor or a PL/SQL cursor variable, previously declared within the current scope and currently open.

You can also specify a cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

Usage Notes

Once a cursor or cursor variable is closed, you can reopen it using the OPEN or OPEN-FOR statement, respectively. You must close a cursor before opening it again, otherwise PL/SQL raises the predefined exception CURSOR_ALREADY_OPEN. You do not need to close a cursor variable before opening it again.

If you try to close an already-closed or never-opened cursor or cursor variable, PL/SQL raises the predefined exception INVALID_CURSOR.

Examples

For examples, see the following:

Example 4–17, "Using EXIT in a LOOP" on page 4-12
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"Closing a Cursor" on page 6-12
"FETCH Statement" on page 13-53
"OPEN Statement" on page 13-80
"OPEN-FOR Statement" on page 13-82
"Querying Data with PL/SQL" on page 6-14

Collection Definition

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 three kinds of collections: associative arrays, nested tables, and varrays (short for variable-size arrays). Nested tables extend the functionality of associative arrays (formerly called PL/SQL tables or index-by tables).

Collections work like the arrays found in most third-generation programming languages. Collections can have only one dimension. Most collections are indexed by integers, although associative arrays can also be indexed by strings. To model multi-dimensional arrays, you can declare collections whose items are other collections.

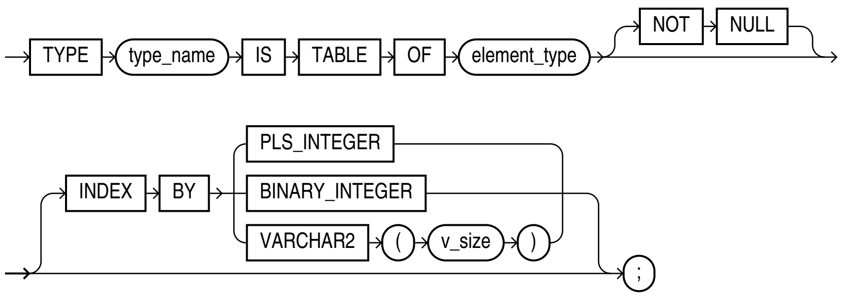
Nested tables and varrays can store instances of an object type and, conversely, can be attributes of an object type. Collections can also be passed as parameters. You can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms.

For more information, see "Defining Collection Types and Declaring Collection Variables" on page 5-6.

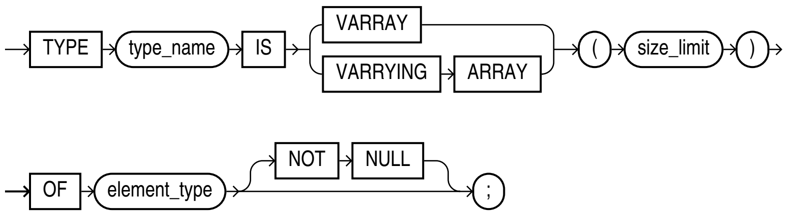
Note: Schema level collection types created with the `CREATE TYPE` statement have a different syntax than PL/SQL collection types. For information on the `CREATE TYPE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE TYPE BODY` SQL statement, see *Oracle Database SQL Reference*.

Syntax

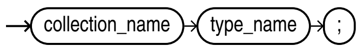
table type definition ::=



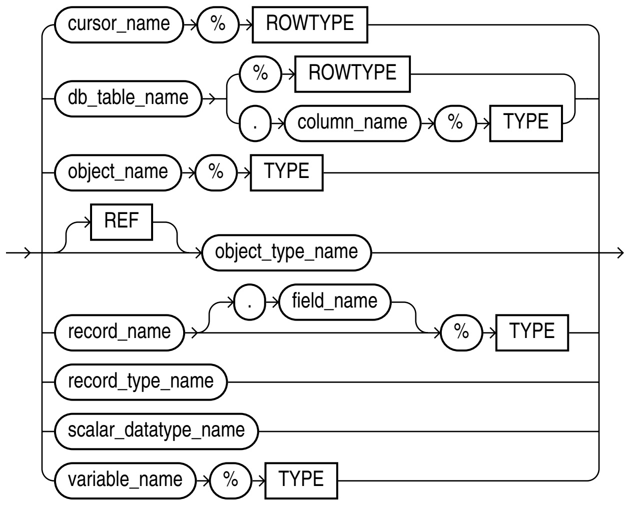
varray type definition ::=



collection type definition ::=



element type definition ::=



Keyword and Parameter Description

element_type

The type of PL/SQL collection element. The type can be any PL/SQL datatype except `REF CURSOR`.

INDEX BY type_name

Optional. Defines an associative array, where you specify the subscript values to use rather than the system defining them in sequence.

`type_name` can be `BINARY_INTEGER`, `PLS_INTEGER`, or `VARCHAR2`, or one of `VARCHAR2` subtypes `VARCHAR`, `STRING`, or `LONG`. `v_size` specifies the length of the `VARCHAR2` key.

size_limit

A positive integer literal that specifies the maximum size of a varray, which is the maximum number of elements the varray can contain. Note that a maximum limit is imposed. See "Referencing Collection Elements" on page 5-11.

type_name

A user-defined collection type that was defined using the datatype specifier `TABLE` or `VARRAY`.

Usage Notes

Nested tables extend the functionality of associative arrays (formerly known as index-by tables), so they differ in several ways. See "Choosing Between Nested Tables and Associative Arrays" on page 5-5.

Every element reference includes the collection name and one or more subscripts enclosed in parentheses; the subscripts determine which element is processed. Except for associative arrays, which can have negative subscripts, collection subscripts have a fixed lower bound of 1. Subscripts for multilevel collections are evaluated in any order; if a subscript includes an expression that modifies the value of a different subscript, the result is undefined. See "Referencing Collection Elements" on page 5-11.

You can define all three collection types in the declarative part of any PL/SQL block, subprogram, or package. But, only nested table and varray types can be created and stored in an Oracle database.

Associative arrays and nested tables can be sparse (have non-consecutive subscripts), but varrays are always dense (have consecutive subscripts). Unlike nested tables, varrays retain their ordering and subscripts when stored in the database. Initially, associative arrays are sparse. That enables you, for example, to store reference data in a temporary variable using a primary key (account numbers or employee numbers for example) as the index.

Collections follow the usual scoping and instantiation rules. In a package, collections are instantiated when you first reference the package and cease to exist when you end the database session. In a block or subprogram, local collections are instantiated when you enter the block or subprogram and cease to exist when you exit.

Until you initialize it, a nested table or varray is atomically null (that is, the collection itself is null, not its elements). To initialize a nested table or varray, you use a constructor, which is a system-defined function with the same name as the collection type. This function constructs (creates) a collection from the elements passed to it.

For information on collection comparisons that are allowed, see "Comparing Collections" on page 5-16.

Collections can store instances of an object type and, conversely, can be attributes of an object type. Collections can also be passed as parameters. You can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms.

When calling a function that returns a collection, you use the following syntax to reference elements in the collection:

```
function_name(parameter_list)(subscript)
```

See Example 5–16, "Referencing an Element of an Associative Array" on page 5-12 and Example B–2, "Using the Dot Notation to Qualify Names" on page B-2.

With the Oracle Call Interface (OCI) or the Oracle Precompilers, you can bind host arrays to associative arrays (index-by tables) declared as the formal parameters of a subprogram. That lets you pass host arrays to stored functions and procedures.

Examples

For examples, see the following:

Example 5–1, "Declaring Collection Types" on page 5-3
Example 5–3, "Declaring Nested Tables, Varrays, and Associative Arrays" on page 5-7
Example 5–4, "Declaring Collections with %TYPE" on page 5-8
Example 5–5, "Declaring a Procedure Parameter as a Nested Table" on page 5-8
Example 5–42, "Declaring and Initializing Record Types" on page 5-29
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"Collection Methods" on page 13-20
"Object Type Declaration" on page 13-78
"Record Definition" on page 13-95

Collection Methods

A collection method is a built-in function or procedure that operates on collections and is called using dot notation. You can use the methods EXISTS, COUNT, LIMIT, FIRST, LAST, PRIOR, NEXT, EXTEND, TRIM, and DELETE to manage collections whose size is unknown or varies.

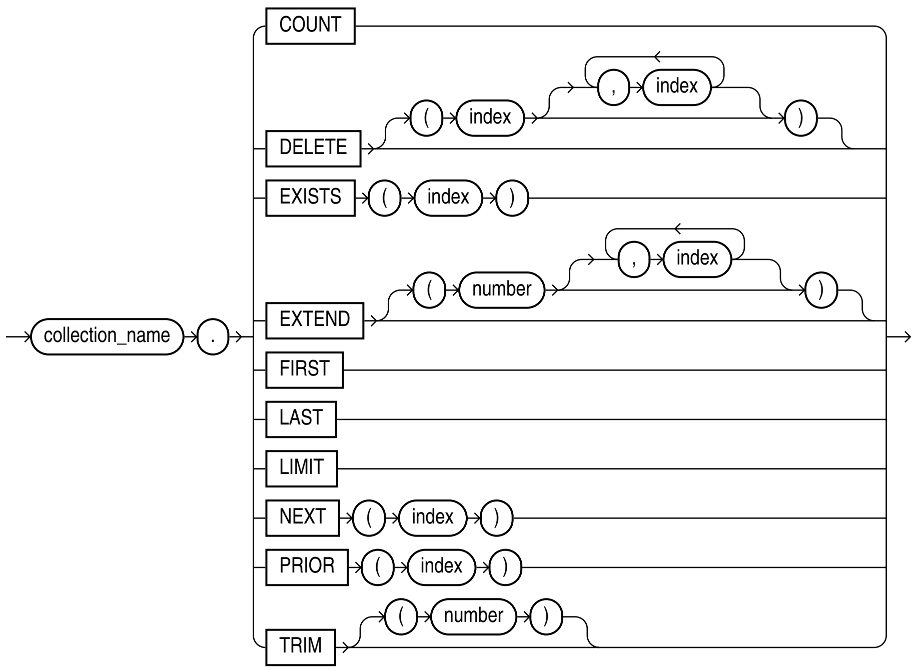
EXISTS, COUNT, LIMIT, FIRST, LAST, PRIOR, and NEXT are functions that check the properties of a collection or individual collection elements. EXTEND, TRIM, and DELETE are procedures that modify a collection.

EXISTS, PRIOR, NEXT, TRIM, EXTEND, and DELETE take integer parameters. EXISTS, PRIOR, NEXT, and DELETE can also take VARCHAR2 parameters for associative arrays with string keys. EXTEND and TRIM cannot be used with index-by tables.

For more information, see "Using Collection Methods" on page 5-19.

Syntax

collection call method ::=



Keyword and Parameter Description

collection_name

An associative array, nested table, or varray previously declared within the current scope.

COUNT

Returns the number of elements that a collection currently contains, which is useful because the current size of a collection is not always known. You can use COUNT wherever an integer expression is allowed. For varrays, COUNT always equals LAST.

For nested tables, normally, `COUNT` equals `LAST`. But, if you delete elements from the middle of a nested table, `COUNT` is smaller than `LAST`.

DELETE

This procedure has three forms. `DELETE` removes all elements from a collection. `DELETE(n)` removes the *n*th element from an associative array or nested table. If `n` is null, `DELETE(n)` does nothing. `DELETE(m,n)` removes all elements in the range `m..n` from an associative array or nested table. If `m` is larger than `n` or if `m` or `n` is null, `DELETE(m,n)` does nothing.

EXISTS

`EXISTS(n)` returns `TRUE` if the *n*th element in a collection exists. Otherwise, `EXISTS(n)` returns `FALSE`. Mainly, you use `EXISTS` with `DELETE` to maintain sparse nested tables. You can also use `EXISTS` to avoid raising an exception when you reference a nonexistent element. When passed an out-of-range subscript, `EXISTS` returns `FALSE` instead of raising `SUBSCRIPT_OUTSIDE_LIMIT`.

EXTEND

This procedure has three forms. `EXTEND` appends one null element to a collection. `EXTEND(n)` appends `n` null elements to a collection. `EXTEND(n,i)` appends `n` copies of the *`i`*th element to a collection. `EXTEND` operates on the internal size of a collection. If `EXTEND` encounters deleted elements, it includes them in its tally. You cannot use `EXTEND` with associative arrays.

FIRST, LAST

`FIRST` and `LAST` return the first and last (smallest and largest) subscript values in a collection. The subscript values are usually integers, but can also be strings for associative arrays. If the collection is empty, `FIRST` and `LAST` return `NULL`. If the collection contains only one element, `FIRST` and `LAST` return the same subscript value. For varrays, `FIRST` always returns 1 and `LAST` always equals `COUNT`. For nested tables, normally, `LAST` equals `COUNT`. But, if you delete elements from the middle of a nested table, `LAST` is larger than `COUNT`.

index

An expression that must return (or convert implicitly to) an integer in most cases, or a string for an associative array declared with string keys.

LIMIT

For nested tables, which have no maximum size, `LIMIT` returns `NULL`. For varrays, `LIMIT` returns the maximum number of elements that a varray can contain (which you must specify in its type definition).

NEXT, PRIOR

`PRIOR(n)` returns the subscript that precedes index `n` in a collection. `NEXT(n)` returns the subscript that succeeds index `n`. If `n` has no predecessor, `PRIOR(n)` returns `NULL`. Likewise, if `n` has no successor, `NEXT(n)` returns `NULL`.

TRIM

This procedure has two forms. `TRIM` removes one element from the end of a collection. `TRIM(n)` removes `n` elements from the end of a collection. If `n` is greater than `COUNT`, `TRIM(n)` raises `SUBSCRIPT_BEYOND_COUNT`. You cannot use `TRIM` with index-by tables.TRIM operates on the internal size of a collection. If TRIM encounters deleted elements, it includes them in its tally.

Usage Notes

You cannot use collection methods in a SQL statement. If you try, you get a compilation error.

Only EXISTS can be applied to atomically null collections. If you apply another method to such collections, PL/SQL raises COLLECTION_IS_NULL.

If the collection elements have sequential subscripts, you can use collection.FIRST .. collection.LAST in a FOR loop to iterate through all the elements. You can use PRIOR or NEXT to traverse collections indexed by any series of subscripts. For example, you can use PRIOR or NEXT to traverse a nested table from which some elements have been deleted, or an associative array where the subscripts are string values.

EXTEND operates on the internal size of a collection, which includes deleted elements. You cannot use EXTEND to initialize an atomically null collection. Also, if you impose the NOT NULL constraint on a TABLE or VARRAY type, you cannot apply the first two forms of EXTEND to collections of that type.

If an element to be deleted does not exist, DELETE simply skips it; no exception is raised. Varrays are dense, so you cannot delete their individual elements. Because PL/SQL keeps placeholders for deleted elements, you can replace a deleted element by assigning it a new value. However, PL/SQL does not keep placeholders for trimmed elements.

The amount of memory allocated to a nested table can increase or decrease dynamically. As you delete elements, memory is freed page by page. If you delete the entire table, all the memory is freed.

In general, do not depend on the interaction between TRIM and DELETE. It is better to treat nested tables like fixed-size arrays and use only DELETE, or to treat them like stacks and use only TRIM and EXTEND.

Within a subprogram, a collection parameter assumes the properties of the argument bound to it. You can apply methods FIRST, LAST, COUNT, and so on to such parameters. For varray parameters, the value of LIMIT is always derived from the parameter type definition, regardless of the parameter mode.

Examples

For examples, see the following:

Example 5–28, "Checking Whether a Collection Element EXISTS" on page 5-20
Example 5–29, "Counting Collection Elements With COUNT" on page 5-20
Example 5–30, "Checking the Maximum Size of a Collection With LIMIT" on page 5-21
Example 5–31, "Using FIRST and LAST With a Collection" on page 5-21
Example 5–32, "Using PRIOR and NEXT to Access Collection Elements" on page 5-22
Example 5–34, "Using EXTEND to Increase the Size of a Collection" on page 5-23
Example 5–35, "Using TRIM to Decrease the Size of a Collection" on page 5-24
Example 5–37, "Using the DELETE Method on a Collection" on page 5-26
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"Collection Definition" on page 13-17

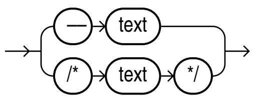
Comments

Comments let you include arbitrary text within your code to explain what the code does. You can also disable obsolete or unfinished pieces of code by turning them into comments.

PL/SQL supports two comment styles: single-line and multi-line. A double hyphen (- -) anywhere on a line (except within a character literal) turns the rest of the line into a comment. Multi-line comments begin with a slash-asterisk (/*) and end with an asterisk-slash (*/). For more information, see "Comments" on page 2-7.

Syntax

comment ::=



Usage Notes

While testing or debugging a program, you might want to disable lines of code. Single-line comments can appear within a statement at the end of a line. You can include single-line comments inside multi-line comments, but you cannot nest multi-line comments.

You cannot use single-line comments in a PL/SQL block that will be processed dynamically by an Oracle Precompiler program. End-of-line characters are ignored, making the single-line comments extend to the end of the block. Instead, use multi-line comments. You can use multi-line comment delimiters to comment-out whole sections of code.

Examples

For examples, see the following:

Example 2–4, "Using Single-Line Comments" on page 2-7
Example 2–5, "Using Multi-Line Comments" on page 2-8
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

COMMIT Statement

The COMMIT statement makes permanent any changes made to the database during the current transaction. A commit also makes the changes visible to other users. For more information on PL/SQL transaction processing, see "Overview of Transaction Processing in PL/SQL" on page 6-30.

The SQL COMMIT statement can be embedded as static SQL in PL/SQL. For syntax details on the SQL COMMIT statement, see the *Oracle Database SQL Reference*. See also "Committing Transactions" in *Oracle Database Application Developer's Guide - Fundamentals* and the COMMIT_WRITE initialization parameter in *Oracle Database Reference*.

Usage Notes

The COMMIT statement releases all row and table locks, and erases any savepoints you marked since the last commit or rollback. Until your changes are committed:

- You can see the changes when you query the tables you modified, but other users cannot see the changes.
- If you change your mind or need to correct a mistake, you can use the ROLLBACK statement to roll back (undo) the changes.

If you commit while a FOR UPDATE cursor is open, a subsequent fetch on that cursor raises an exception. The cursor remains open, so you should still close it. For more information, see "Using FOR UPDATE" on page 6-34.

Examples

For examples, see the following:

Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 6–3, "Substituting PL/SQL Variables" on page 6-2
Example 6–36, "Using COMMIT With the WRITE Clause" on page 6-30
Example 6–40, "Using SET TRANSACTION to Begin a Read-only Transaction" on page 6-33
Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38

Related Topics

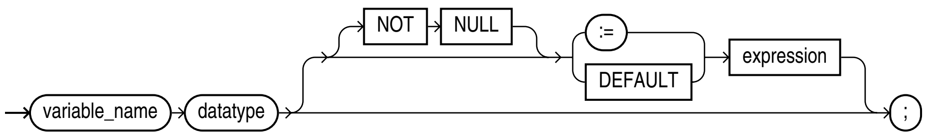
"ROLLBACK Statement" on page 13-103
"SAVEPOINT Statement" on page 13-106
"Transaction Control" on page 6-3
"Fetching Across Commits" on page 6-35

Constant and Variable Declaration

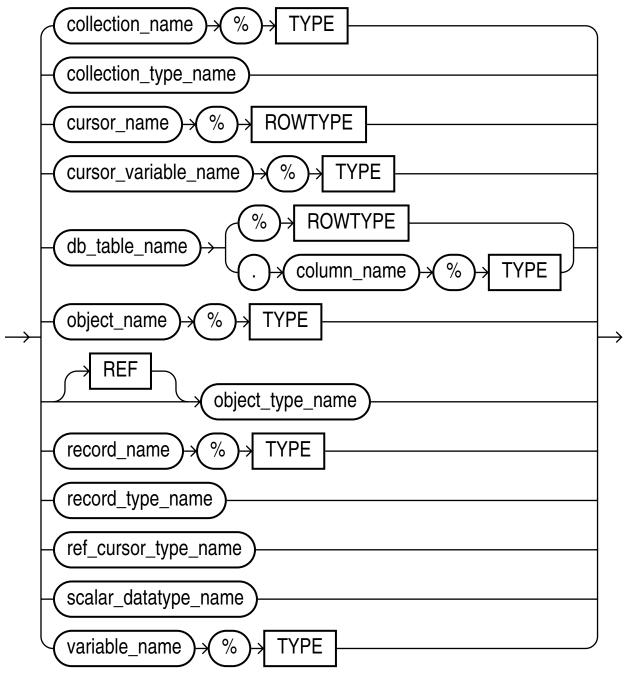
You can declare constants and variables in the declarative part of any PL/SQL block, subprogram, or package. Declarations allocate storage for a value, specify its datatype, and specify a name that you can reference. Declarations can also assign an initial value and impose the `NOT NULL` constraint. For more information, see Declarations on page 2-8.

Syntax

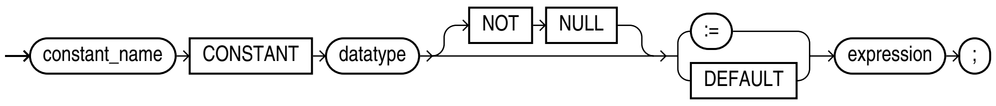
variable declaration ::=



datatype ::=



constant ::=



Keyword and Parameter Description

collection_name
A collection (associative array, nested table, or varray) previously declared within the current scope.

collection_type_name
A user-defined collection type defined using the datatype specifier `TABLE` or `VARRAY`.

CONSTANT
Denotes the declaration of a constant. You must initialize a constant in its declaration. Once initialized, the value of a constant cannot be changed.

constant_name
A program constant. For naming conventions, see "Identifiers" on page 2-3.

cursor_name
An explicit cursor previously declared within the current scope.

cursor_variable_name
A PL/SQL cursor variable previously declared within the current scope.

db_table_name
A database table or view that must be accessible when the declaration is elaborated.

db_table_name.column_name
A database table and column that must be accessible when the declaration is elaborated.

expression
A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. When the declaration is elaborated, the value of `expression` is assigned to the constant or variable. The value and the constant or variable must have compatible datatypes.

NOT NULL
A constraint that prevents the program from assigning a null value to a variable or constant. Assigning a null to a variable defined as `NOT NULL` raises the predefined exception `VALUE_ERROR`. The constraint `NOT NULL` must be followed by an initialization clause.

object_name
An instance of an object type previously declared within the current scope.

record_name
A user-defined or `%ROWTYPE` record previously declared within the current scope.

record_name.field_name
A field in a user-defined or `%ROWTYPE` record previously declared within the current scope.

record_type_name
A user-defined record type that is defined using the datatype specifier `RECORD`.

ref_cursor_type_name
A user-defined cursor variable type, defined using the datatype specifier `REF CURSOR`.

%ROWTYPE
Represents a record that can hold a row from a database table or a cursor. Fields in the record have the same names and datatypes as columns in the row.

scalar_datatype_name
A predefined scalar datatype such as `BOOLEAN`, `NUMBER`, or `VARCHAR2`. Includes any qualifiers for size, precision, or character versus byte semantics.

%TYPE
Represents the datatype of a previously declared collection, cursor variable, field, object, record, database column, or variable.

variable_name
A program variable.

Usage Notes

Constants and variables are initialized every time a block or subprogram is entered. By default, variables are initialized to `NULL`. Whether public or private, constants and variables declared in a package spec are initialized only once for each session.

An initialization clause is required when declaring `NOT NULL` variables and when declaring constants. If you use `%ROWTYPE` to declare a variable, initialization is not allowed.

You can define constants of complex types that have no literal values or predefined constructors, by calling a function that returns a filled-in value. For example, you can make a constant associative array this way.

Examples

For examples, see the following:

Example 1–1, "Declaring Variables in PL/SQL" on page 1-5
Example 1–2, "Assigning Values to Variables With the Assignment Operator" on page 1-6
Example 1–3, "Assigning Values to Variables by SELECTing INTO" on page 1-6
Example 2–9, "Using the %ROWTYPE Attribute" on page 2-11
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"Declaring Variables" on page 1-5
"Declarations" on page 2-8
"Overview of Predefined PL/SQL Datatypes" on page 3-1
"Assignment Statement" on page 13-3
"Expression Definition" on page 13-45
"%ROWTYPE Attribute" on page 13-104
"%TYPE Attribute" on page 13-119

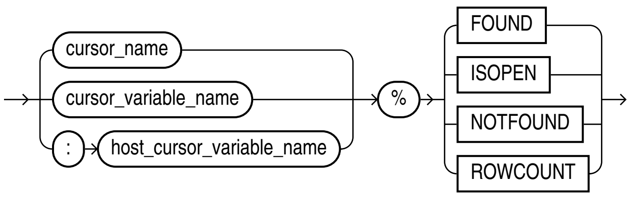
Cursor Attributes

Every explicit cursor and cursor variable has four attributes: `%FOUND`, `%ISOPEN` `%NOTFOUND`, and `%ROWCOUNT`. When appended to the cursor or cursor variable, these attributes return useful information about the execution of a data manipulation statement. For more information, see "Using Cursor Expressions" on page 6-28.

The implicit cursor `SQL` has additional attributes, `%BULK_ROWCOUNT` and `%BULK_EXCEPTIONS`. For more information, see "SQL Cursor" on page 13-115.

Syntax

cursor attribute ::=



Keyword and Parameter Description

cursor_name
An explicit cursor previously declared within the current scope.

cursor_variable_name
A PL/SQL cursor variable (or parameter) previously declared within the current scope.

%FOUND Attribute
A cursor attribute that can be appended to the name of a cursor or cursor variable. Before the first fetch from an open cursor, `cursor_name%FOUND` returns `NULL`. Afterward, it returns `TRUE` if the last fetch returned a row, or `FALSE` if the last fetch failed to return a row.

host_cursor_variable_name
A cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

%ISOPEN Attribute
A cursor attribute that can be appended to the name of a cursor or cursor variable. If a cursor is open, `cursor_name%ISOPEN` returns `TRUE`; otherwise, it returns `FALSE`.

%NOTFOUND Attribute
A cursor attribute that can be appended to the name of a cursor or cursor variable. Before the first fetch from an open cursor, `cursor_name%NOTFOUND` returns `NULL`. Thereafter, it returns `FALSE` if the last fetch returned a row, or `TRUE` if the last fetch failed to return a row.

%ROWCOUNT Attribute

A cursor attribute that can be appended to the name of a cursor or cursor variable. When a cursor is opened, `%ROWCOUNT` is zeroed. Before the first fetch, `cursor_name%ROWCOUNT` returns 0. Thereafter, it returns the number of rows fetched so far. The number is incremented if the latest fetch returned a row.

Usage Notes

The cursor attributes apply to every cursor or cursor variable. For example, you can open multiple cursors, then use `%FOUND` or `%NOTFOUND` to tell which cursors have rows left to fetch. Likewise, you can use `%ROWCOUNT` to tell how many rows have been fetched so far.

If a cursor or cursor variable is not open, referencing it with `%FOUND`, `%NOTFOUND`, or `%ROWCOUNT` raises the predefined exception `INVALID_CURSOR`.

When a cursor or cursor variable is opened, the rows that satisfy the associated query are identified and form the result set. Rows are fetched from the result set one at a time.

If a `SELECT INTO` statement returns more than one row, PL/SQL raises the predefined exception `TOO_MANY_ROWS` and sets `%ROWCOUNT` to 1, not the actual number of rows that satisfy the query.

Before the first fetch, `%NOTFOUND` evaluates to `NULL`. If `FETCH` never executes successfully, the `EXIT WHEN` condition is never `TRUE` and the loop is never exited. To be safe, you might want to use the following `EXIT` statement instead:

```
EXIT WHEN c1%NOTFOUND OR c1%NOTFOUND IS NULL;
```

You can use the cursor attributes in procedural statements, but not in SQL statements.

Examples

For examples, see the following:

Example 6–7, "Using SQL%FOUND" on page 6-7
Example 6–8, "Using SQL%ROWCOUNT" on page 6-7
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–15, "Using %ISOPEN" on page 6-12

Related Topics

"Cursor Declaration" on page 13-33
"Cursor Variables" on page 13-30
"Managing Cursors in PL/SQL" on page 6-6

Cursor Variables

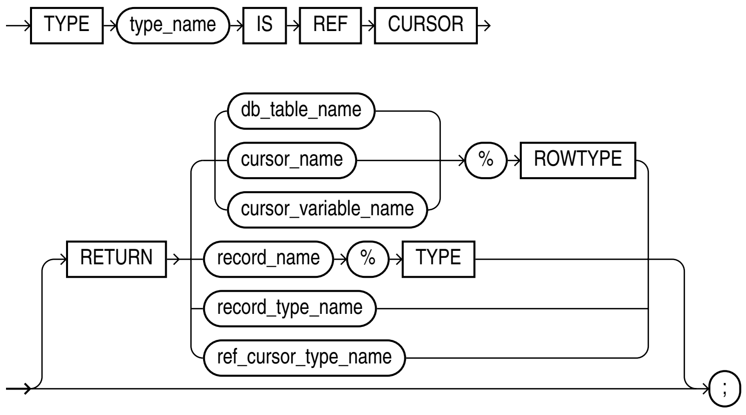
To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. You can access this area through an explicit cursor, which names the work area, or through a cursor variable, which points to the work area. To create cursor variables, you define a `REF CURSOR` type, then declare cursor variables of that type.

Cursor variables are like C or Pascal pointers, which hold the address of some item instead of the item itself. Declaring a cursor variable creates a pointer, not an item.

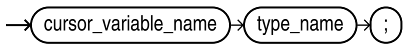
For more information, see "Using Cursor Variables (REF CURSORs)" on page 6-20.

Syntax

ref cursor type definition ::=



ref cursor variable declaration ::=



Keyword and Parameter Description

cursor_name

An explicit cursor previously declared within the current scope.

cursor_variable_name

A PL/SQL cursor variable previously declared within the current scope.

db_table_name

A database table or view, which must be accessible when the declaration is elaborated.

record_name

A user-defined record previously declared within the current scope.

record_type_name

A user-defined record type that was defined using the datatype specifier `RECORD`.

REF CURSOR
Cursor variables all have the datatype REF CURSOR.

RETURN
Specifies the datatype of a cursor variable return value. You can use the %ROWTYPE attribute in the RETURN clause to provide a record type that represents a row in a database table, or a row from a cursor or strongly typed cursor variable. You can use the %TYPE attribute to provide the datatype of a previously declared record.

%ROWTYPE
A record type that represents a row in a database table or a row fetched from a cursor or strongly typed cursor variable. Fields in the record and corresponding columns in the row have the same names and datatypes.

%TYPE
Provides the datatype of a previously declared user-defined record.

type_name
A user-defined cursor variable type that was defined as a REF CURSOR.

Usage Notes

Cursor variables are available to every PL/SQL client. For example, you can declare a cursor variable in a PL/SQL host environment such as an OCI or Pro*C program, then pass it as a bind variable to PL/SQL. Application development tools that have a PL/SQL engine can use cursor variables entirely on the client side.

You can pass cursor variables back and forth between an application and the database server through remote procedure calls using a database link. If you have a PL/SQL engine on the client side, you can use the cursor variable in either location. For example, you can declare a cursor variable on the client side, open and fetch from it on the server side, then continue to fetch from it back on the client side.

You use cursor variables to pass query result sets between PL/SQL stored subprograms and client programs. Neither PL/SQL nor any client program owns a result set; they share a pointer to the work area where the result set is stored. For example, an OCI program, Oracle Forms application, and the database can all refer to the same work area.

REF CURSOR types can be *strong* or *weak*. A strong REF CURSOR type definition specifies a return type, but a weak definition does not. Strong REF CURSOR types are less error-prone because PL/SQL lets you associate a strongly typed cursor variable only with type-compatible queries. Weak REF CURSOR types are more flexible because you can associate a weakly typed cursor variable with any query.

Once you define a REF CURSOR type, you can declare cursor variables of that type. You can use %TYPE to provide the datatype of a record variable. Also, in the RETURN clause of a REF CURSOR type definition, you can use %ROWTYPE to specify a record type that represents a row returned by a strongly (not weakly) typed cursor variable.

Currently, cursor variables are subject to several restrictions. See "Restrictions on Cursor Variables" on page 6-27.

You use three statements to control a cursor variable: OPEN-FOR, FETCH, and CLOSE. First, you OPEN a cursor variable FOR a multi-row query. Then, you FETCH rows from the result set. When all the rows are processed, you CLOSE the cursor variable.

Other OPEN-FOR statements can open the same cursor variable for different queries. You need not close a cursor variable before reopening it. When you reopen a cursor variable for a different query, the previous query is lost.

PL/SQL makes sure the return type of the cursor variable is compatible with the INTO clause of the FETCH statement. For each column value returned by the query associated with the cursor variable, there must be a corresponding, type-compatible field or variable in the INTO clause. Also, the number of fields or variables must equal the number of column values. Otherwise, you get an error.

If both cursor variables involved in an assignment are strongly typed, they must have the same datatype. However, if one or both cursor variables are weakly typed, they need not have the same datatype.

When declaring a cursor variable as the formal parameter of a subprogram that fetches from or closes the cursor variable, you must specify the IN or IN OUT mode. If the subprogram opens the cursor variable, you must specify the IN OUT mode.

Be careful when passing cursor variables as parameters. At run time, PL/SQL raises ROWTYPE_MISMATCH if the return types of the actual and formal parameters are incompatible.

You can apply the cursor attributes %FOUND, %NOTFOUND, %ISOPEN, and %ROWCOUNT to a cursor variable.

If you try to fetch from, close, or apply cursor attributes to a cursor variable that does not point to a query work area, PL/SQL raises the predefined exception INVALID_CURSOR. You can make a cursor variable (or parameter) point to a query work area in two ways:

- OPEN the cursor variable FOR the query.
- Assign to the cursor variable the value of an already OPENed host cursor variable or PL/SQL cursor variable.

A query work area remains accessible as long as any cursor variable points to it. Therefore, you can pass the value of a cursor variable freely from one scope to another. For example, if you pass a host cursor variable to a PL/SQL block embedded in a Pro*C program, the work area to which the cursor variable points remains accessible after the block completes.

Examples

For examples, see the following:

Example 6–9, "Declaring a Cursor" on page 6-9
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 6–27, "Passing a REF CURSOR as a Parameter" on page 6-22
Example 6–29, "Stored Procedure to Open a Ref Cursor" on page 6-23
Example 6–30, "Stored Procedure to Open Ref Cursors with Different Queries" on page 6-23
Example 6–31, "Cursor Variable with Different Return Types" on page 6-24

Related Topics

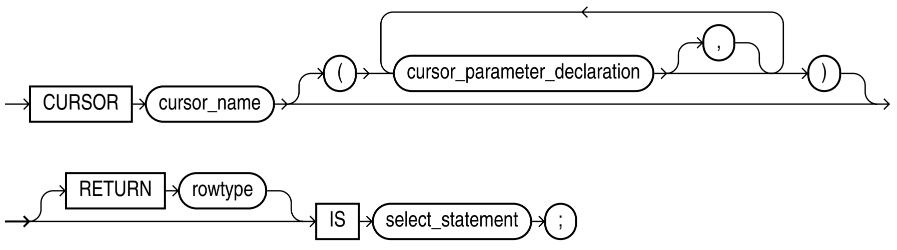
"CLOSE Statement" on page 13-16
"Cursor Attributes" on page 13-28
"Cursor Declaration" on page 13-33
"FETCH Statement" on page 13-53
"OPEN-FOR Statement" on page 13-82

Cursor Declaration

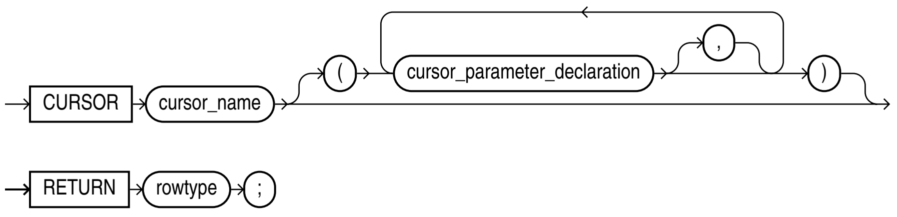
To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. A cursor lets you name the work area, access the information, and process the rows individually. For more information, see "Querying Data with PL/SQL" on page 6-14.

Syntax

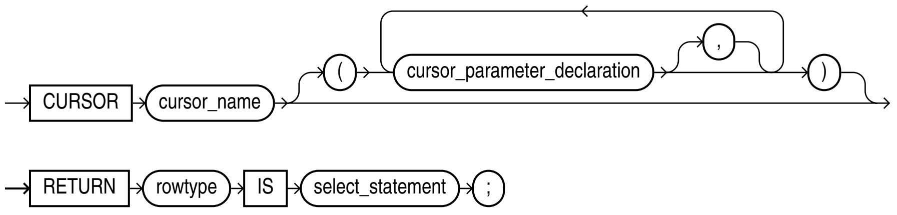
cursor declaration ::=



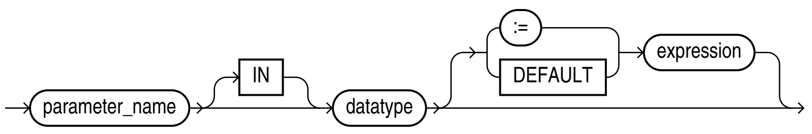
cursor spec ::=



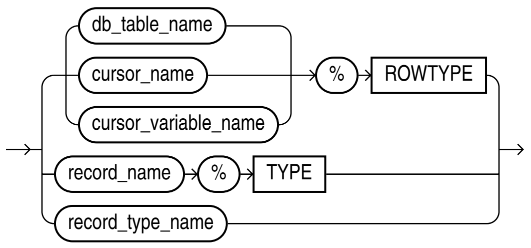
cursor body ::=



cursor parameter declaration ::=



rowtype ::=



Keyword and Parameter Description

cursor_name

An explicit cursor previously declared within the current scope.

datatype

A type specifier. For the syntax of `datatype`, see "Constant and Variable Declaration" on page 13-25.

db_table_name

A database table or view that must be accessible when the declaration is elaborated.

expression

A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. When the declaration is elaborated, the value of `expression` is assigned to the parameter. The value and the parameter must have compatible datatypes.

parameter_name

A variable declared as the formal parameter of a cursor. A cursor parameter can appear in a query wherever a constant can appear. The formal parameters of a cursor must be `IN` parameters. The query can also reference other PL/SQL variables within its scope.

record_name

A user-defined record previously declared within the current scope.

record_type_name

A user-defined record type that was defined using the datatype specifier `RECORD`.

RETURN

Specifies the datatype of a cursor return value. You can use the `%ROWTYPE` attribute in the `RETURN` clause to provide a record type that represents a row in a database table or a row returned by a previously declared cursor. Also, you can use the `%TYPE` attribute to provide the datatype of a previously declared record.

A cursor body must have a `SELECT` statement and the same `RETURN` clause as its corresponding cursor spec. Also, the number, order, and datatypes of select items in the `SELECT` clause must match the `RETURN` clause.

%ROWTYPE

A record type that represents a row in a database table or a row fetched from a previously declared cursor or cursor variable. Fields in the record and corresponding columns in the row have the same names and datatypes.

select_statement

A query that returns a result set of rows. Its syntax is like that of `select_into_statement` without the `INTO` clause. See "SELECT INTO Statement" on page 13-107. If the cursor declaration declares parameters, each parameter must be used in the query.

%TYPE

Provides the datatype of a previously declared user-defined record.

Usage Notes

You must declare a cursor before referencing it in an `OPEN`, `FETCH`, or `CLOSE` statement. You must declare a variable before referencing it in a cursor declaration. The word SQL is reserved by PL/SQL as the default name for implicit cursors, and cannot be used in a cursor declaration.

You cannot assign values to a cursor name or use it in an expression. However, cursors and variables follow the same scoping rules. For more information, see "Scope and Visibility of PL/SQL Identifiers" on page 2-15.

You retrieve data from a cursor by opening it, then fetching from it. Because the `FETCH` statement specifies the target variables, using an `INTO` clause in the `SELECT` statement of a `cursor_declaration` is redundant and invalid.

The scope of cursor parameters is local to the cursor, meaning that they can be referenced only within the query used in the cursor declaration. The values of cursor parameters are used by the associated query when the cursor is opened. The query can also reference other PL/SQL variables within its scope.

The datatype of a cursor parameter must be specified without constraints, that is, without precision and scale for numbers, and without length for strings.

Examples

For examples, see the following:

Example 6–9, "Declaring a Cursor" on page 6-9
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 6–27, "Passing a REF CURSOR as a Parameter" on page 6-22
Example 6–29, "Stored Procedure to Open a Ref Cursor" on page 6-23
Example 6–30, "Stored Procedure to Open Ref Cursors with Different Queries" on page 6-23
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

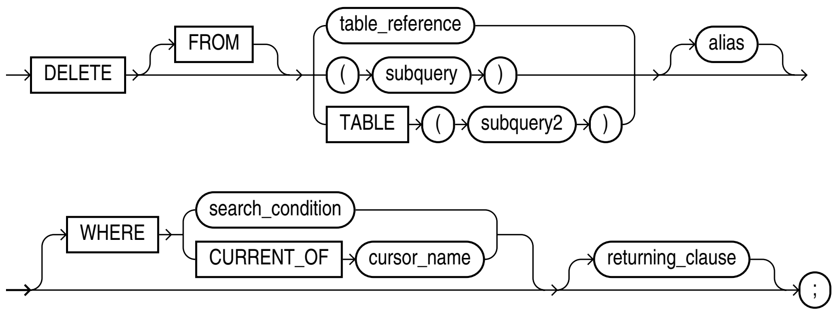
"CLOSE Statement" on page 13-16
"FETCH Statement" on page 13-53
"OPEN Statement" on page 13-80
"SELECT INTO Statement" on page 13-107
"Declaring a Cursor" on page 6-8

DELETE Statement

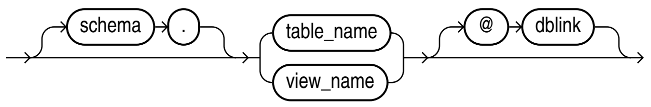
The `DELETE` statement removes entire rows of data from a specified table or view. For a full description of the `DELETE` statement, see *Oracle Database SQL Reference*.

Syntax

delete ::=



table_reference ::=



Keyword and Parameter Description

alias
Another (usually short) name for the referenced table or view. Typically referred to later in the `WHERE` clause.

BULK COLLECT
Returns columns from the deleted rows into PL/SQL collections, as specified by the `RETURNING INTO` list. The corresponding columns must store scalar (not composite) values. For more information, see "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8.

returning_clause
Returns values from the deleted rows, eliminating the need to `SELECT` the rows first. You can retrieve the column values into individual variables or into collections. You cannot use the `RETURNING` clause for remote or parallel deletes. If the statement does not affect any rows, the values of the variables specified in the `RETURNING` clause are undefined. See "RETURNING INTO Clause" on page 13-101.

subquery
A `SELECT` statement that provides a set of rows for processing. Its syntax is like the `select_into_statement` without the `INTO` clause. See "SELECT INTO Statement" on page 13-107.

table_reference

A table or view, which must be accessible when you execute the `DELETE` statement, and for which you must have `DELETE` privileges.

TABLE (subquery2)

The operand of `TABLE` is a `SELECT` statement that returns a single column value, which must be a nested table. Operator `TABLE` informs Oracle that the value is a collection, not a scalar value.

WHERE CURRENT OF cursor_name

Refers to the latest row processed by the `FETCH` statement associated with the cursor identified by `cursor_name`. The cursor must be `FOR UPDATE` and must be open and positioned on a row. If the cursor is not open, the `CURRENT OF` clause causes an error.

If the cursor is open, but no rows have been fetched or the last fetch returned no rows, PL/SQL raises the predefined exception `NO_DATA_FOUND`.

WHERE search_condition

Conditionally chooses rows to be deleted from the referenced table or view. Only rows that meet the search condition are deleted. If you omit the `WHERE` clause, all rows in the table or view are deleted.

Usage Notes

You can use the `DELETE WHERE CURRENT OF` statement after a fetch from an open cursor (this includes implicit fetches executed in a cursor `FOR` loop), provided the associated query is `FOR UPDATE`. This statement deletes the current row; that is, the one just fetched.

The implicit cursor `SQL` and the cursor attributes `%NOTFOUND`, `%FOUND`, and `%ROWCOUNT` let you access useful information about the execution of a `DELETE` statement.

Examples

For examples, see the following:

Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 6–5, "Using CURRVAL and NEXTVAL" on page 6-4
Example 6–7, "Using SQL%FOUND" on page 6-7
Example 6–8, "Using SQL%ROWCOUNT" on page 6-7
Example 6–29, "Stored Procedure to Open a Ref Cursor" on page 6-23
Example 6–30, "Stored Procedure to Open Ref Cursors with Different Queries" on page 6-23
Example 11–2, "Issuing DELETE Statements in a Loop" on page 11-9
Example 11–16, "Using FORALL With BULK COLLECT" on page 11-19

Related Topics

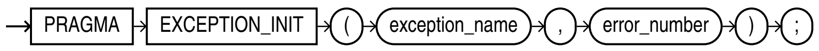
"FETCH Statement" on page 13-53
"INSERT Statement" on page 13-66
"SELECT INTO Statement" on page 13-107
"UPDATE Statement" on page 13-121

EXCEPTION_INIT Pragma

The pragma `EXCEPTION_INIT` associates an exception name with an Oracle error number. You can intercept any ORA- error and write a specific handler for it instead of using the `OTHERS` handler. For more information, see "Associating a PL/SQL Exception with a Number: Pragma EXCEPTION_INIT" on page 10-7.

Syntax

exception_init pragma ::=



Keyword and Parameter Description

error_number

Any valid Oracle error number. These are the same error numbers (always negative) returned by the function `SQLCODE`.

exception_name

A user-defined exception declared within the current scope.

PRAGMA

Signifies that the statement is a compiler directive.

Usage Notes

You can use `EXCEPTION_INIT` in the declarative part of any PL/SQL block, subprogram, or package. The pragma must appear in the same declarative part as its associated exception, somewhere after the exception declaration.

Be sure to assign only one exception name to an error number.

Examples

For examples, see the following:

Example 10–4, "Using PRAGMA EXCEPTION_INIT" on page 10-7
Example 11–9, "Bulk Operation That Continues Despite Exceptions" on page 11-15

Related Topics

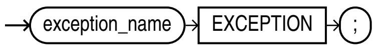
"AUTONOMOUS_TRANSACTION Pragma" on page 13-6
"Exception Definition" on page 13-39
"SQLCODE Function" on page 13-117

Exception Definition

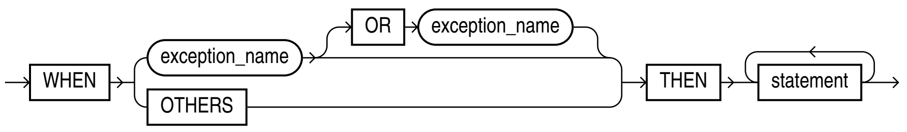
An exception is a runtime error or warning condition, which can be predefined or user-defined. Predefined exceptions are raised implicitly (automatically) by the runtime system. User-defined exceptions must be raised explicitly by `RAISE` statements. To handle raised exceptions, you write separate routines called exception handlers. For more information, see Chapter 10, "Handling PL/SQL Errors".

Syntax

exception ::=



exception handler ::=



Keyword and Parameter Description

exception_name

A predefined exception such as `ZERO_DIVIDE`, or a user-defined exception previously declared within the current scope.

OTHERS

Stands for all the exceptions not explicitly named in the exception-handling part of the block. The use of `OTHERS` is optional and is allowed only as the last exception handler. You cannot include `OTHERS` in a list of exceptions following the keyword `WHEN`.

statement

An executable statement. For the syntax of `statement`, see "Block Declaration" on page 13-8.

WHEN

Introduces an exception handler. You can have multiple exceptions execute the same sequence of statements by following the keyword `WHEN` with a list of the exceptions, separating them by the keyword `OR`. If any exception in the list is raised, the associated statements are executed.

Usage Notes

An exception declaration can appear only in the declarative part of a block, subprogram, or package. The scope rules for exceptions and variables are the same. But, unlike variables, exceptions cannot be passed as parameters to subprograms.

Some exceptions are predefined by PL/SQL. For a list of these exceptions, see "Summary of Predefined PL/SQL Exceptions" on page 10-4. PL/SQL declares predefined exceptions globally in package STANDARD, so you need not declare them yourself.

Redeclaring predefined exceptions is error prone because your local declaration overrides the global declaration. In such cases, you must use dot notation to specify the predefined exception, as follows:

```
EXCEPTION
    WHEN invalid_number OR STANDARD.INVALID_NUMBER THEN ...
```

The exception-handling part of a PL/SQL block is optional. Exception handlers must come at the end of the block. They are introduced by the keyword EXCEPTION. The exception-handling part of the block is terminated by the same keyword END that terminates the entire block. An exception handler can reference only those variables that the current block can reference.

An exception should be raised only when an error occurs that makes it undesirable or impossible to continue processing. If there is no exception handler in the current block for a raised exception, the exception propagates according to the following rules:

- If there is an enclosing block for the current block, the exception is passed on to that block. The enclosing block then becomes the current block. If a handler for the raised exception is not found, the process repeats.
- If there is no enclosing block for the current block, an *unhandled exception* error is passed back to the host environment.

Only one exception at a time can be active in the exception-handling part of a block. Therefore, if an exception is raised inside a handler, the block that encloses the current block is the first block searched to find a handler for the newly raised exception. From there on, the exception propagates normally.

Example

For examples, see the following:

Example 1–9, "Using WHILE-LOOP for Control" on page 1-11
Example 1–12, "Creating a Stored Subprogram" on page 1-13
Example 2–19, "PL/SQL Block Using Multiple and Duplicate Labels" on page 2-17
Example 5–35, "Using TRIM to Decrease the Size of a Collection" on page 5-24
Example 5–38, "Collection Exceptions" on page 5-27
Example 6–37, "Using ROLLBACK" on page 6-31
Example 7–1, "Examples of Dynamic SQL" on page 7-3
Example 8–1, "Simple PL/SQL Procedure" on page 8-2
Example 9–3, "Creating the emp_admin Package" on page 9-6
Example 10–1, "Runtime Error Handling" on page 10-2
Example 10–3, "Scope of PL/SQL Exceptions" on page 10-6
Example 10–9, "Reraising a PL/SQL Exception" on page 10-12
Example 11–6, "Using Rollbacks With FORALL" on page 11-12
Example 11–9, "Bulk Operation That Continues Despite Exceptions" on page 11-15
Example 12–3, "Null Objects in a PL/SQL Block" on page 12-3

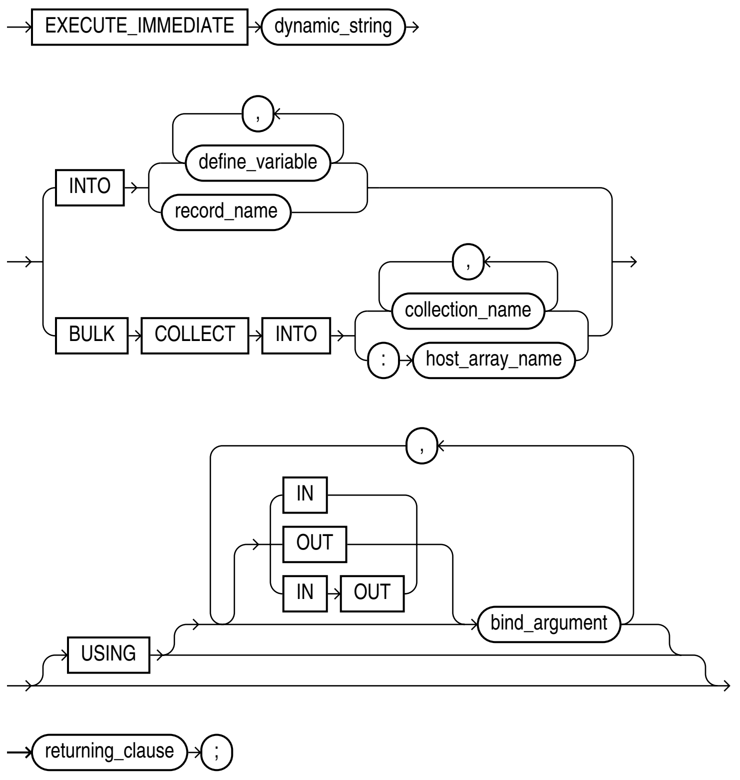
Related Topics

"Block Declaration" on page 13-8
"EXCEPTION_INIT Pragma" on page 13-38
"RAISE Statement" on page 13-94

EXECUTE IMMEDIATE Statement

The EXECUTE IMMEDIATE statement executes a dynamic SQL statement or anonymous PL/SQL block. You can use it to issue SQL statements that cannot be represented directly in PL/SQL, or to build up statements where you do not know all the table names, WHERE clauses, and so on in advance. For more information, see "Using the EXECUTE IMMEDIATE Statement in PL/SQL" on page 7-2.

Syntax



Keyword and Parameter Description

bind_argument

An expression whose value is passed to the dynamic SQL statement, or a variable that stores a value returned by the dynamic SQL statement.

BULK COLLECT

Stores result values in one or more collections, for faster queries than loops with FETCH statements. For more information, see "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8.

collection_name

A declared collection into which `select_item` values are fetched. For each `select_item`, there must be a corresponding, type-compatible collection in the list.

host_array_name

An array (declared in a PL/SQL host environment and passed to PL/SQL as a bind variable) into which select_item values are fetched. For each select_item, there must be a corresponding, type-compatible array in the list. Host arrays must be prefixed with a colon.

define_variable

A variable that stores a selected column value.

dynamic_string

A string literal, variable, or expression that represents a single SQL statement or a PL/SQL block. It must be of type CHAR or VARCHAR2, not NCHAR or NVARCHAR2.

INTO ...

Used only for single-row queries, this clause specifies the variables or record into which column values are retrieved. For each value retrieved by the query, there must be a corresponding, type-compatible variable or field in the INTO clause.

record_name

A user-defined or %ROWTYPE record that stores a selected row.

returning_clause

Returns values from inserted rows, eliminating the need to SELECT the rows afterward. You can retrieve the column values into variables or into collections. You cannot use the RETURNING clause for remote or parallel inserts. If the statement does not affect any rows, the values of the variables specified in the RETURNING clause are undefined. For the syntax of returning_clause, see the "RETURNING INTO Clause" on page 13-101.

USING ...

Specifies a list of input and/or output bind arguments. The parameter mode defaults to IN.

Usage Notes

Except for multi-row queries, the dynamic string can contain any SQL statement (without the final semicolon) or any PL/SQL block (with the final semicolon). The string can also contain placeholders for bind arguments. You cannot use bind arguments to pass the names of schema objects to a dynamic SQL statement.

You can place all bind arguments in the USING clause. The default parameter mode is IN. For DML statements that have a RETURNING clause, you can place OUT arguments in the RETURNING INTO clause without specifying the parameter mode, which, by definition, is OUT. If you use both the USING clause and the RETURNING INTO clause, the USING clause can contain only IN arguments.

At run time, bind arguments replace corresponding placeholders in the dynamic string. Every placeholder must be associated with a bind argument in the USING clause and/or RETURNING INTO clause. You can use numeric, character, and string literals as bind arguments, but you cannot use Boolean literals (TRUE, FALSE, and NULL). To pass nulls to the dynamic string, you must use a workaround. See "Passing Nulls to Dynamic SQL" on page 7-10.

Dynamic SQL supports all the SQL datatypes. For example, define variables and bind arguments can be collections, LOBs, instances of an object type, and refs. Dynamic SQL does not support PL/SQL-specific types. For example, define variables and bind arguments cannot be BOOLEANs or index-by tables. The only exception is that a PL/SQL record can appear in the INTO clause.

You can execute a dynamic SQL statement repeatedly using new values for the bind arguments. You still incur some overhead, because EXECUTE IMMEDIATE re-prepares the dynamic string before every execution.

The string argument to the EXECUTE IMMEDIATE command cannot be one of the national character types, such as NCHAR or NVARCHAR2.

Note: When using dynamic SQL with PL/SQL, be aware of the risks of SQL injection, which is a possible security issue. For more information on SQL injection and possible problems, see *Oracle Database Application Developer's Guide - Fundamentals*. You can also search for "SQL injection" on the Oracle Technology Network at http://www.oracle.com/technology/

Examples

For examples, see the following:

Example 7–1, "Examples of Dynamic SQL" on page 7-3
Example 7–2, "Dynamic SQL Procedure that Accepts Table Name and WHERE Clause" on page 7-4
Example 7–4, "Dynamic SQL with BULK COLLECT INTO Clause" on page 7-6
Example 7–5, "Dynamic SQL with RETURNING BULK COLLECT INTO Clause" on page 7-6
Example 7–6, "Dynamic SQL Inside FORALL Statement" on page 7-7

Related Topics

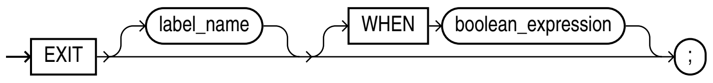
"OPEN-FOR Statement" on page 13-82

EXIT Statement

The EXIT statement breaks out of a loop. The EXIT statement has two forms: the unconditional EXIT and the conditional EXIT WHEN. With either form, you can name the loop to be exited. For more information, see "Controlling Loop Iterations: LOOP and EXIT Statements" on page 4-7.

Syntax

exit ::=



Keyword and Parameter Description

boolean_expression

An expression that returns the Boolean value TRUE, FALSE, or NULL. It is evaluated with each iteration of the loop. If the expression returns TRUE, the current loop (or the loop labeled by label_name) is exited immediately. For the syntax of boolean_expression, see "Expression Definition" on page 13-45.

EXIT

An unconditional EXIT statement (that is, one without a WHEN clause) exits the current loop immediately. Execution resumes with the statement following the loop.

label_name

Identifies the loop exit from: either the current loop, or any enclosing labeled loop.

Usage Notes

The EXIT statement can be used only inside a loop; you cannot exit from a block directly. PL/SQL lets you code an infinite loop. For example, the following loop will never terminate normally so you must use an EXIT statement to exit the loop.

```
WHILE TRUE LOOP ... END LOOP;
```

If you use an EXIT statement to exit a cursor FOR loop prematurely, the cursor is closed automatically. The cursor is also closed automatically if an exception is raised inside the loop.

Examples

For examples, see the following:

Example 4–8, "Using an EXIT Statement" on page 4-7
Example 4–17, "Using EXIT in a LOOP" on page 4-12
Example 4–18, "Using EXIT With a Label in a LOOP" on page 4-13

Related Topics

"Expression Definition" on page 13-45
"LOOP Statements" on page 13-72

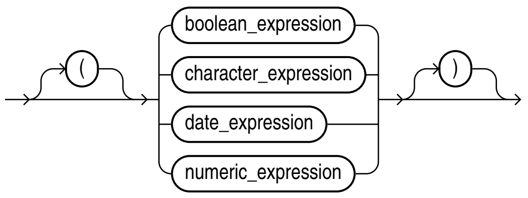
Expression Definition

An expression is an arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression is a single variable.

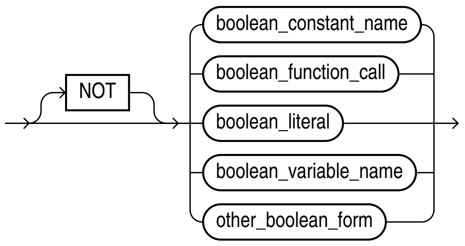
The PL/SQL compiler determines the datatype of an expression from the types of the variables, constants, literals, and operators that comprise the expression. Every time the expression is evaluated, a single value of that type results. For more information, see "PL/SQL Expressions and Comparisons" on page 2-19.

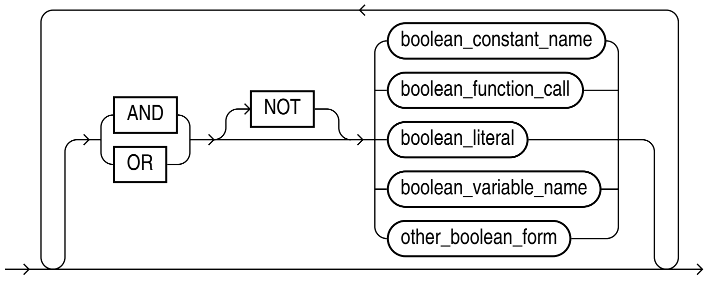
Syntax

expression ::=

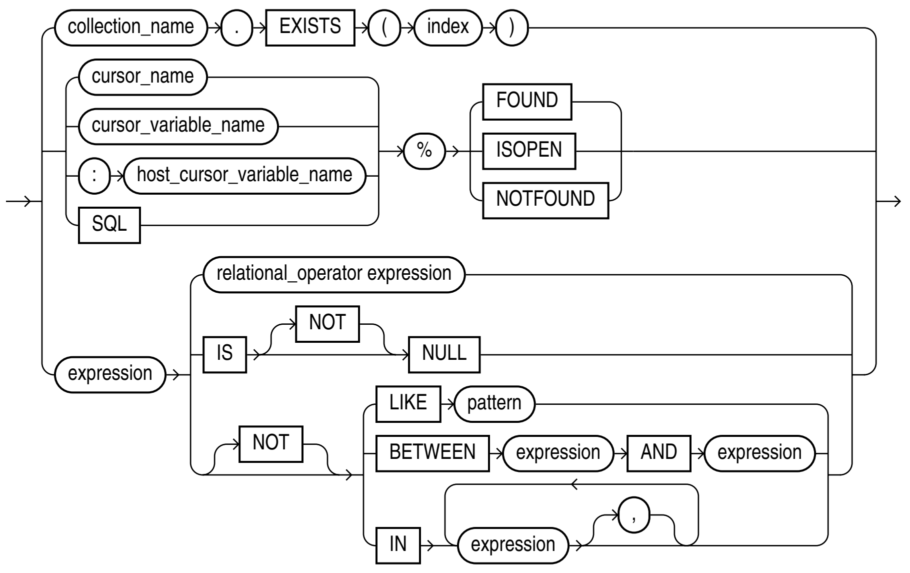


boolean_expression ::=

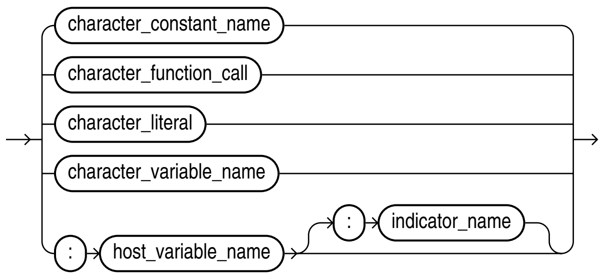


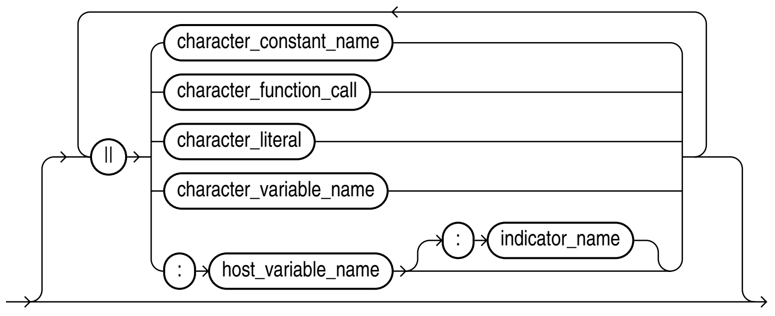


other boolean form ::=

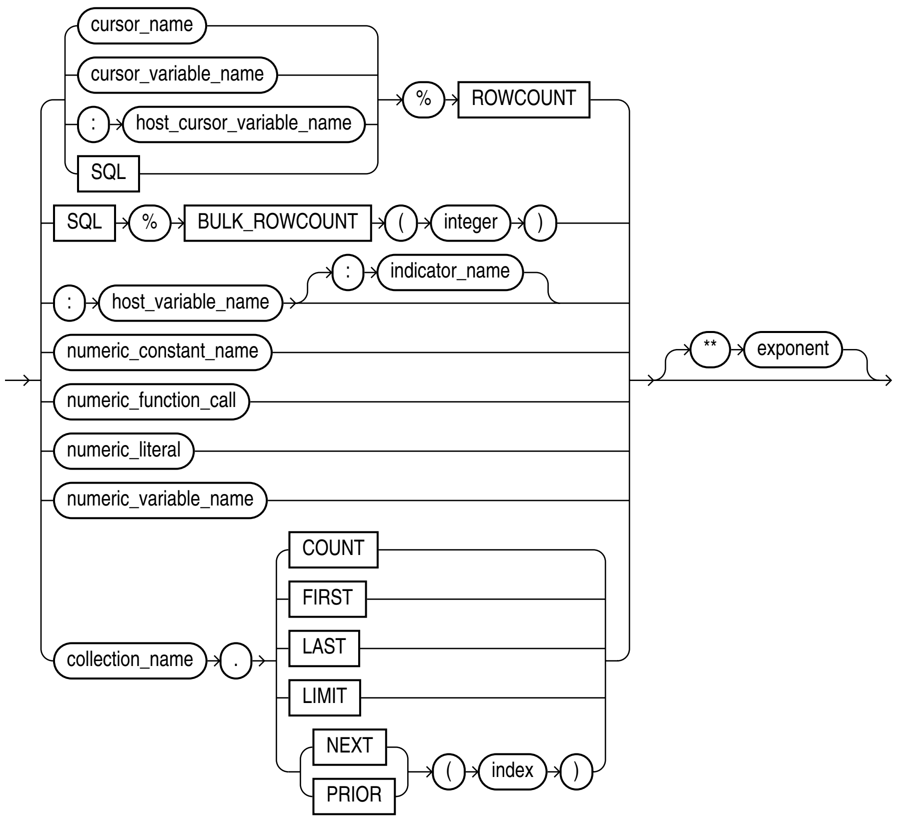


character expression ::=

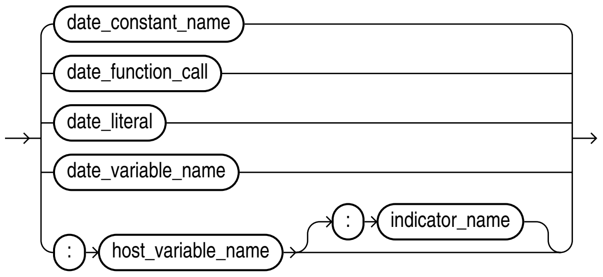


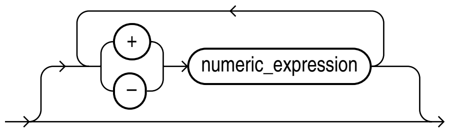


numeric subexpression ::=

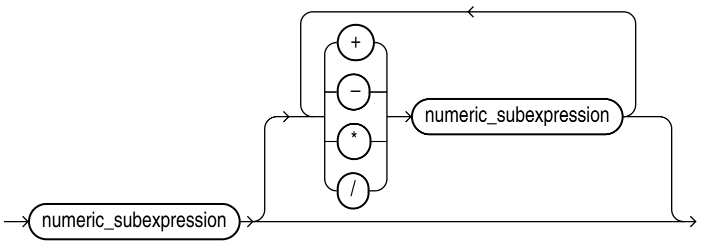


date expression ::=





numeric expression ::=



Keyword and Parameter Description

BETWEEN

This comparison operator tests whether a value lies in a specified range. It means: greater than or equal to low value and less than or equal to high value.

boolean_constant_name

A constant of type `BOOLEAN`, which must be initialized to the value `TRUE`, `FALSE`, or `NULL`. Arithmetic operations on Boolean constants are not allowed.

boolean_expression

An expression that returns the Boolean value `TRUE`, `FALSE`, or `NULL`.

boolean_function_call

Any function call that returns a Boolean value.

boolean_literal

The predefined values `TRUE`, `FALSE`, or `NULL` (which stands for a missing, unknown, or inapplicable value). You cannot insert the value `TRUE` or `FALSE` into a database column.

boolean_variable_name

A variable of type `BOOLEAN`. Only the values `TRUE`, `FALSE`, and `NULL` can be assigned to a `BOOLEAN` variable. You cannot select or fetch column values into a `BOOLEAN` variable. Also, arithmetic operations on `BOOLEAN` variables are not allowed.

%BULK_ROWCOUNT

Designed for use with the `FORALL` statement, this is a composite attribute of the implicit cursor `SQL`. For more information, see "SQL Cursor" on page 13-115.

character_constant_name

A previously declared constant that stores a character value. It must be initialized to a character value or a value implicitly convertible to a character value.

character_expression

An expression that returns a character or character string.

character_function_call

A function call that returns a character value or a value implicitly convertible to a character value.

character_literal
A literal that represents a character value or a value implicitly convertible to a character value.

character_variable_name
A previously declared variable that stores a character value.

collection_name
A collection (nested table, index-by table, or varray) previously declared within the current scope.

cursor_name
An explicit cursor previously declared within the current scope.

cursor_variable_name
A PL/SQL cursor variable previously declared within the current scope.

date_constant_name
A previously declared constant that stores a date value. It must be initialized to a date value or a value implicitly convertible to a date value.

date_expression
An expression that returns a date/time value.

date_function_call
A function call that returns a date value or a value implicitly convertible to a date value.

date_literal
A literal representing a date value or a value implicitly convertible to a date value.

date_variable_name
A previously declared variable that stores a date value.

EXISTS, COUNT, FIRST, LAST, LIMIT, NEXT, PRIOR
Collection methods. When appended to the name of a collection, these methods return useful information. For example, `EXISTS(n)` returns `TRUE` if the *n*th element of a collection exists. Otherwise, `EXISTS(n)` returns `FALSE`. For more information, see "Collection Methods" on page 13-20.

exponent
An expression that must return a numeric value.

%FOUND, %ISOPEN, %NOTFOUND, %ROWCOUNT
Cursor attributes. When appended to the name of a cursor or cursor variable, these attributes return useful information about the execution of a multi-row query. You can also append them to the implicit cursor `SQL`.

host_cursor_variable_name

A cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. Host cursor variables must be prefixed with a colon.

host_variable_name

A variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host variable must be implicitly convertible to the appropriate PL/SQL datatype. Also, host variables must be prefixed with a colon.

IN

Comparison operator that tests set membership. It means: equal to any member of. The set can contain nulls, but they are ignored. Also, expressions of the form

```
value NOT IN set
```

return `FALSE` if the set contains a null.

index

A numeric expression that must return a value of type `BINARY_INTEGER`, `PLS_INTEGER`, or a value implicitly convertible to that datatype.

indicator_name

An indicator variable declared in a PL/SQL host environment and passed to PL/SQL. Indicator variables must be prefixed with a colon. An indicator variable indicates the value or condition of its associated host variable. For example, in the Oracle Precompiler environment, indicator variables can detect nulls or truncated values in output host variables.

IS NULL

Comparison operator that returns the Boolean value `TRUE` if its operand is null, or `FALSE` if its operand is not null.

LIKE

Comparison operator that compares a character value to a pattern. Case is significant. `LIKE` returns the Boolean value `TRUE` if the character patterns match, or `FALSE` if they do not match.

NOT, AND, OR

Logical operators, which follow the tri-state logic of Table 2–3 on page 2-20. `AND` returns the value `TRUE` only if both its operands are true. `OR` returns the value `TRUE` if either of its operands is true. `NOT` returns the opposite value (logical negation) of its operand. For more information, see "Logical Operators" on page 2-20.

NULL

Keyword that represents a null. It stands for a missing, unknown, or inapplicable value. When `NULL` is used in a numeric or date expression, the result is a null.

numeric_constant_name

A previously declared constant that stores a numeric value. It must be initialized to a numeric value or a value implicitly convertible to a numeric value.

numeric_expression
An expression that returns an integer or real value.

numeric_function_call
A function call that returns a numeric value or a value implicitly convertible to a numeric value.

numeric_literal
A literal that represents a number or a value implicitly convertible to a number.

numeric_variable_name
A previously declared variable that stores a numeric value.

pattern
A character string compared by the `LIKE` operator to a specified string value. It can include two special-purpose characters called wildcards. An underscore (_) matches exactly one character; a percent sign (%) matches zero or more characters. The pattern can be followed by `ESCAPE '`*`character_literal`*`'`, which turns off wildcard expansion wherever the escape character appears in the string followed by a percent sign or underscore.

relational_operator
Operator that compares expressions. For the meaning of each operator, see "Comparison Operators" on page 2-22.

SQL
A cursor opened implicitly by Oracle to process a SQL data manipulation statement. The implicit cursor `SQL` always refers to the most recently executed SQL statement.

+, -, /, *, **
Symbols for the addition, subtraction, division, multiplication, and exponentiation operators.

||
The concatenation operator. As the following example shows, the result of concatenating *string1* with *string2* is a character string that contains *string1* followed by *string2*:

```
'Good' || ' morning!' = 'Good morning!'
```

The next example shows that nulls have no effect on the result of a concatenation:

```
'suit' || NULL || 'case' = 'suitcase'
```

A null string (`''`), which is zero characters in length, is treated like a null.

Usage Notes
In a Boolean expression, you can only compare values that have compatible datatypes. For more information, see "Converting PL/SQL Datatypes" on page 3-21.

In conditional control statements, if a Boolean expression returns `TRUE`, its associated sequence of statements is executed. But, if the expression returns `FALSE` or `NULL`, its associated sequence of statements is *not* executed.

The relational operators can be applied to operands of type `BOOLEAN`. By definition, `TRUE` is greater than `FALSE`. Comparisons involving nulls always return a null. The value of a Boolean expression can be assigned only to Boolean variables, not to host variables or database columns. Also, datatype conversion to or from type `BOOLEAN` is not supported.

You can use the addition and subtraction operators to increment or decrement a date value, as the following examples show:

```
hire_date := '10-MAY-95';
hire_date := hire_date + 1;  -- makes hire_date '11-MAY-95'
hire_date := hire_date - 5;  -- makes hire_date '06-MAY-95'
```

When PL/SQL evaluates a boolean expression, `NOT` has the highest precedence, `AND` has the next-highest precedence, and `OR` has the lowest precedence. However, you can use parentheses to override the default operator precedence.

Within an expression, operations occur in their predefined order of precedence. From first to last (top to bottom), the default order of operations is

parentheses
exponents
unary operators
multiplication and division
addition, subtraction, and concatenation

PL/SQL evaluates operators of equal precedence in no particular order. When parentheses enclose an expression that is part of a larger expression, PL/SQL evaluates the parenthesized expression first, then uses the result in the larger expression. When parenthesized expressions are nested, PL/SQL evaluates the innermost expression first and the outermost expression last.

Examples

Several examples of expressions follow:

```
(a + b) > c              -- Boolean expression
NOT finished             -- Boolean expression
TO_CHAR(acct_no)         -- character expression
'Fat ' || 'cats'         -- character expression
'15-NOV-05'              -- date expression
MONTHS_BETWEEN(d1, d2)   -- date expression
pi * r**2                -- numeric expression
emp_cv%ROWCOUNT          -- numeric expression
```

See also Example 1–2, "Assigning Values to Variables With the Assignment Operator" on page 1-6.

Related Topics

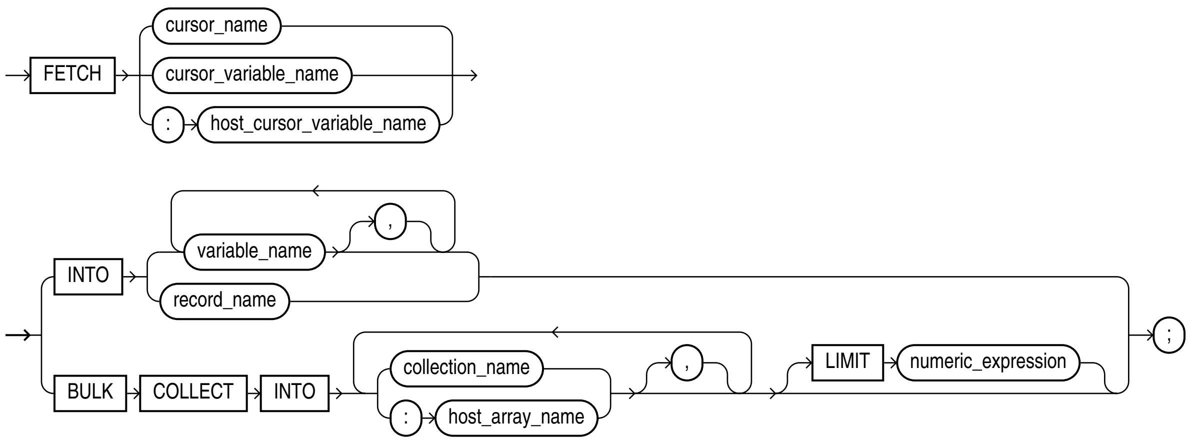
"Assignment Statement" on page 13-3
"Constant and Variable Declaration" on page 13-25
"EXIT Statement" on page 13-44"IF Statement" on page 13-64
"LOOP Statements" on page 13-72

FETCH Statement

The FETCH statement retrieves rows of data from the result set of a multi-row query. You can fetch rows one at a time, several at a time, or all at once. The data is stored in variables or fields that correspond to the columns selected by the query. For more information, see "Querying Data with PL/SQL" on page 6-14.

Syntax

fetch statement ::=



Keyword and Parameter Description

BULK COLLECT

Instructs the SQL engine to bulk-bind output collections before returning them to the PL/SQL engine. The SQL engine bulk-binds all collections referenced in the INTO list.

collection_name

A declared collection into which column values are bulk fetched. For each query select_item, there must be a corresponding, type-compatible collection in the list.

cursor_name

An explicit cursor declared within the current scope.

cursor_variable_name

A PL/SQL cursor variable (or parameter) declared within the current scope.

host_array_name

An array (declared in a PL/SQL host environment and passed to PL/SQL as a bind variable) into which column values are bulk fetched. For each query select_item, there must be a corresponding, type-compatible array in the list. Host arrays must be prefixed with a colon.

host_cursor_variable_name
A cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

LIMIT
This optional clause, allowed only in bulk (not scalar) `FETCH` statements, lets you bulk fetch several rows at a time, rather than the entire result set.

record_name
A user-defined or `%ROWTYPE` record into which rows of values are fetched. For each column value returned by the query associated with the cursor or cursor variable, there must be a corresponding, type-compatible field in the record.

variable_name
A variable into which a column value is fetched. For each column value returned by the query associated with the cursor or cursor variable, there must be a corresponding, type-compatible variable in the list.

Usage Notes
You must use either a cursor `FOR` loop or the `FETCH` statement to process a multi-row query.

Any variables in the `WHERE` clause of the query are evaluated only when the cursor or cursor variable is opened. To change the result set or the values of variables in the query, you must reopen the cursor or cursor variable with the variables set to their new values.

To reopen a cursor, you must close it first. However, you need not close a cursor variable before reopening it.

You can use different `INTO` lists on separate fetches with the same cursor or cursor variable. Each fetch retrieves another row and assigns values to the target variables.

If you `FETCH` past the last row in the result set, the values of the target fields or variables are indeterminate and the `%NOTFOUND` attribute returns `TRUE`.

PL/SQL makes sure the return type of a cursor variable is compatible with the `INTO` clause of the `FETCH` statement. For each column value returned by the query associated with the cursor variable, there must be a corresponding, type-compatible field or variable in the `INTO` clause. Also, the number of fields or variables must equal the number of column values.

When you declare a cursor variable as the formal parameter of a subprogram that fetches from the cursor variable, you must specify the `IN` or `IN OUT` mode. However, if the subprogram also opens the cursor variable, you must specify the `IN OUT` mode.

Because a sequence of `FETCH` statements always runs out of data to retrieve, no exception is raised when a `FETCH` returns no data. To detect this condition, you must use the cursor attribute `%FOUND` or `%NOTFOUND`.

PL/SQL raises the predefined exception `INVALID_CURSOR` if you try to fetch from a closed or never-opened cursor or cursor variable.

Restrictions on BULK COLLECT
The following restrictions apply to the `BULK COLLECT` clause:

- You cannot bulk collect into an associative array that has a string type for the key.
- You can use the `BULK COLLECT` clause only in server-side programs (not in client-side programs). Otherwise, you get the error `this feature is not supported in client-side programs`.
- All target variables listed in a `BULK COLLECT INTO` clause must be collections.
- Composite targets (such as objects) cannot be used in the `RETURNING INTO` clause. Otherwise, you get the `error unsupported feature with RETURNING clause`.
- When implicit datatype conversions are needed, multiple composite targets cannot be used in the `BULK COLLECT INTO` clause.
- When an implicit datatype conversion is needed, a collection of a composite target (such as a collection of objects) cannot be used in the `BULK COLLECT INTO` clause.

Examples

For examples, see the following:

Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 6–23, "Passing Parameters to Explicit Cursors" on page 6-19
Example 6–27, "Passing a REF CURSOR as a Parameter" on page 6-22
Example 6–32, "Fetching from a Cursor Variable into a Record" on page 6-25
Example 6–33, "Fetching from a Cursor Variable into Collections" on page 6-25
Example 6–35, "Using a Cursor Expression" on page 6-29
Example 6–41, "Using CURRENT OF to Update the Latest Row Fetched From a Cursor" on page 6-35
Example 7–4, "Dynamic SQL with BULK COLLECT INTO Clause" on page 7-6
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

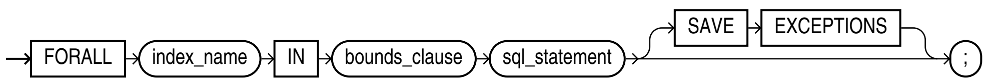
"CLOSE Statement" on page 13-16,
"Cursor Declaration" on page 13-33
"Cursor Variables" on page 13-30
"LOOP Statements" on page 13-72
"OPEN Statement" on page 13-80
"OPEN-FOR Statement" on page 13-82
"RETURNING INTO Clause" on page 13-101

FORALL Statement

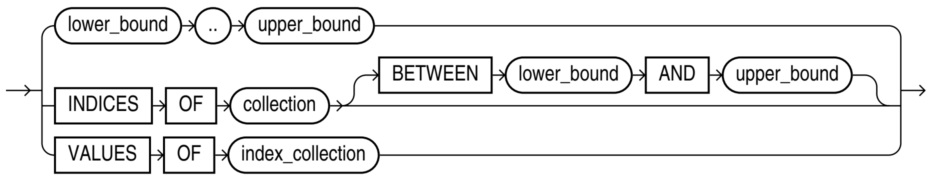
The FORALL statement issues a series of static or dynamic DML statements, usually much faster than an equivalent FOR loop. It requires some setup code, because each iteration of the loop must use values from one or more collections in its VALUES or WHERE clauses. For more information, see "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8.

Syntax

for all statement ::=



bounds_clause ::=



Keyword and Parameter Description

INDICES OF collection_name

A clause specifying that the values of the index variable correspond to the subscripts of the elements of the specified collection. With this clause, you can use FORALL with nested tables where some elements have been deleted, or with associative arrays that have numeric subscripts.

BETWEEN lower_bound AND upper_bound

Limits the range of subscripts in the INDICES OF clause. If a subscript in the range does not exist in the collection, that subscript is skipped.

VALUES OF index_collection_name

A clause specifying that the subscripts for the FORALL index variable are taken from the values of the elements in another collection, specified by index_collection_name. This other collection acts as a set of pointers; FORALL can iterate through subscripts in arbitrary order, even using the same subscript more than once, depending on what elements you include in index_collection_name.

The index collection must be a nested table, or an associative array indexed by PLS_INTEGER or BINARY_INTEGER, whose elements are also PLS_INTEGER or BINARY_INTEGER. If the index collection is empty, an exception is raised and the FORALL statement is not executed.

index_name

An undeclared identifier that can be referenced only within the FORALL statement and only as a collection subscript.

The implicit declaration of `index_name` overrides any other declaration outside the loop. You cannot refer to another variable with the same name inside the statement. Inside a `FORALL` statement, `index_name` cannot appear in expressions and cannot be assigned a value.

lower_bound .. upper_bound

Numeric expressions that specify a valid range of consecutive index numbers. PL/SQL rounds them to the nearest integer, if necessary. The SQL engine executes the SQL statement once for each index number in the range. The expressions are evaluated once, when the `FORALL` statement is entered.

SAVE EXCEPTIONS

Optional keywords that cause the `FORALL` loop to continue even if some DML operations fail. Instead of raising an exception immediately, the program raises a single exception after the `FORALL` statement finishes. The details of the errors are available after the loop in `SQL%BULK_EXCEPTIONS`. The program can report or clean up all the errors after the `FORALL` loop, rather than handling each exception as it happens. See "Handling FORALL Exceptions with the %BULK_EXCEPTIONS Attribute" on page 11-14.

sql_statement

A static, such as `UPDATE` or `DELETE`, or dynamic (`EXECUTE IMMEDIATE`) DML statement that references collection elements in the `VALUES` or `WHERE` clauses.

Usage Notes

Although the SQL statement can reference more than one collection, the performance benefits apply only to subscripted collections.

If a `FORALL` statement fails, database changes are rolled back to an implicit savepoint marked before each execution of the SQL statement. Changes made during previous iterations of the `FORALL` loop are *not* rolled back.

Restrictions

The following restrictions apply to the `FORALL` statement:

- You cannot loop through the elements of an associative array that has a string type for the key.
- Within a `FORALL` loop, you cannot refer to the same collection in both the `SET` clause and the `WHERE` clause of an `UPDATE` statement. You might need to make a second copy of the collection and refer to the new name in the `WHERE` clause.
- You can use the `FORALL` statement only in server-side programs, not in client-side programs.
- The `INSERT`, `UPDATE`, or `DELETE` statement must reference at least one collection. For example, a `FORALL` statement that inserts a set of constant values in a loop raises an exception.
- When you specify an explicit range, all collection elements in that range must exist. If an element is missing or was deleted, you get an error.
- When you use the `INDICES OF` or `VALUES OF` clauses, all the collections referenced in the DML statement must have subscripts matching the values of the index variable. Make sure that any `DELETE`, `EXTEND`, and so on operations are applied to all the collections so that they have the same set of subscripts. If any of

the collections is missing a referenced element, you get an error. If you use the `SAVE EXCEPTIONS` clause, this error is treated like any other error and does not stop the `FORALL` statement.

- You cannot refer to individual record fields within DML statements called by a `FORALL` statement. Instead, you can specify the entire record with the `SET ROW` clause in an `UPDATE` statement, or the `VALUES` clause in an `INSERT` statement.
- Collection subscripts must be just the index variable rather than an expression, such as `i` rather than `i+1`.
- The cursor attribute `%BULK_ROWCOUNT` cannot be assigned to other collections, or be passed as a parameter to subprograms.

Examples

For examples, see the following:

Example 11–2, "Issuing DELETE Statements in a Loop" on page 11-9
Example 11–3, "Issuing INSERT Statements in a Loop" on page 11-9
Example 11–4, "Using FORALL with Part of a Collection" on page 11-10
Example 11–5, "Using FORALL with Non-Consecutive Index Values" on page 11-10
Example 11–9, "Bulk Operation That Continues Despite Exceptions" on page 11-15
Example 11–16, "Using FORALL With BULK COLLECT" on page 11-19

Related Topics

"Retrieving Query Results into Collections with the BULK COLLECT Clause" on page 11-15

Function Declaration

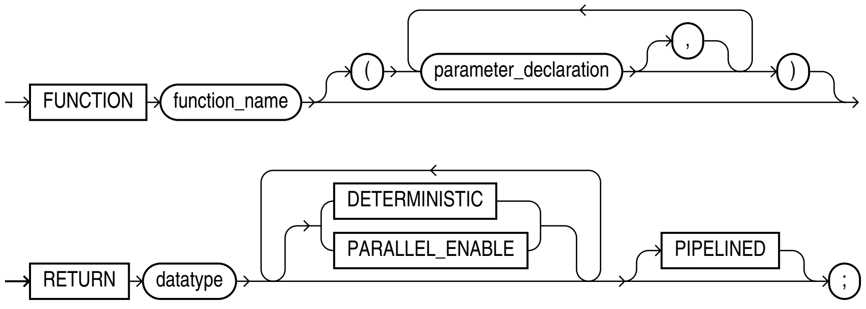
A function is a subprogram that can take parameters and return a single value. A function has two parts: the specification and the body. The specification (spec for short) begins with the keyword `FUNCTION` and ends with the `RETURN` clause, which specifies the datatype of the return value. Parameter declarations are optional. Functions that take no parameters are written without parentheses. The function body begins with the keyword `IS` (or `AS`) and ends with the keyword `END` followed by an optional function name.

The function body has three parts: an optional declarative part, an executable part, and an optional exception-handling part. The declarative part contains declarations of types, cursors, constants, variables, exceptions, and subprograms. These items are local and cease to exist when you exit the function. The executable part contains statements that assign values, control execution, and manipulate data. The exception-handling part contains handlers that deal with exceptions raised during execution. For more information, see "Understanding PL/SQL Functions" on page 8-4. For an example of a function declaration, see Example 9–3 on page 9-6.

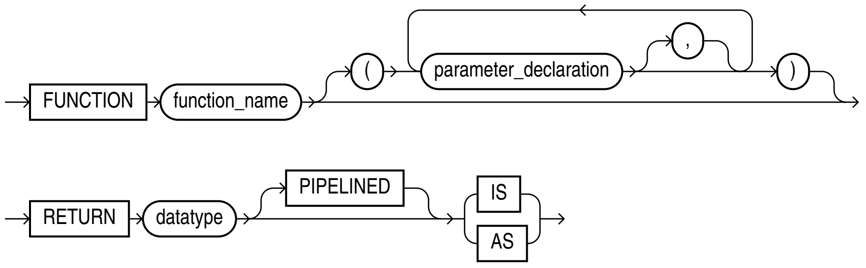
Note that the function declaration in a PL/SQL block or package is not the same as creating a function in SQL. For information on the `CREATE FUNCTION` SQL statement, see *Oracle Database SQL Reference*.

Syntax

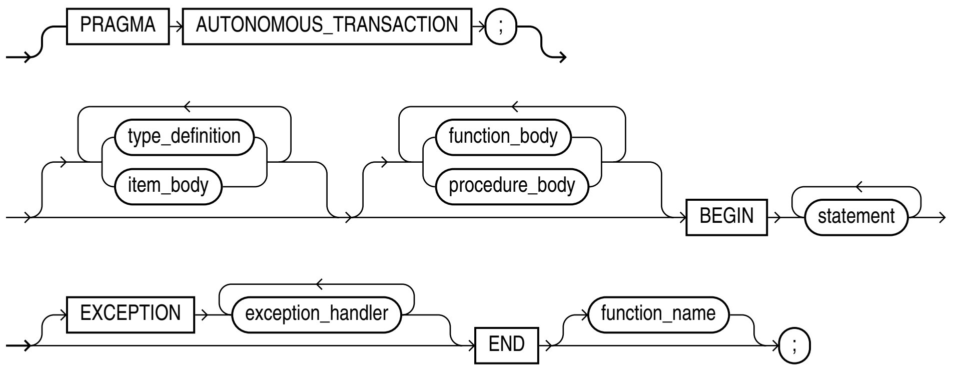
function specification ::=



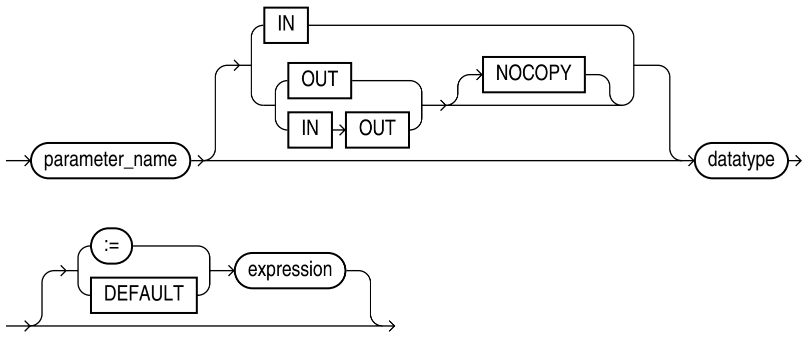
function declaration ::=



function body ::=



parameter declaration ::=



Keyword and Parameter Description

datatype

A type specifier. For the syntax of `datatype`, see "Constant and Variable Declaration" on page 13-25.

DETERMINISTIC

A hint that helps the optimizer avoid redundant function calls. If a stored function was called previously with the same arguments, the optimizer can elect to use the previous result. The function result should not depend on the state of session variables or schema objects. Otherwise, results might vary across calls. Only `DETERMINISTIC` functions can be called from a function-based index or a materialized view that has query-rewrite enabled. For more information and possible limitations of the `DETERMINISTIC` option, see the `CREATE FUNCTION` statement in the *Oracle Database SQL Reference*. See also the `CREATE INDEX` statement in *Oracle Database SQL Reference*.

exception_handler

Associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see "Exception Definition" on page 13-39.

expression

An arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. When the declaration is elaborated, the value of `expression` is assigned to the parameter. The value and the parameter must have compatible datatypes.

function_name
Specifies the name you choose for the function.

IN, OUT, IN OUT
Parameter modes that define the behavior of formal parameters. An `IN` parameter passes values to the subprogram being called. An `OUT` parameter returns values to the caller of the subprogram. An `IN OUT` parameter passes initial values to the subprogram being called, and returns updated values to the caller.

item_declaration
Declares a program object. For its syntax, see "Block Declaration" on page 13-8.

NOCOPY
A compiler hint (not directive) that allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference instead of by value (the default). The function can run faster, because it does not have to make temporary copies of these parameters, but the results can be different if the function ends with an unhandled exception. For more information, see "Using Default Values for Subprogram Parameters" on page 8-9.

PARALLEL_ENABLE
Declares that a stored function can be used safely in the slave sessions of parallel DML evaluations. The state of a main (logon) session is never shared with slave sessions. Each slave session has its own state, which is initialized when the session begins. The function result should not depend on the state of session (`static`) variables. Otherwise, results might vary across sessions. For information on the `PARALLEL_ENABLE` option, see the `CREATE FUNCTION` statement in the *Oracle Database SQL Reference*.

parameter_name
A formal parameter, a variable declared in a function spec and referenced in the function body.

PIPELINED
`PIPELINED` specifies to return the results of a table function iteratively. A table function returns a collection type (a nested table or varray) with elements that are SQL datatypes. You can query table functions using the `TABLE` keyword before the function name in the `FROM` clause of a SQL query. For more information, see "Setting Up Transformations with Pipelined Functions" on page 11-31.

PRAGMA AUTONOMOUS_TRANSACTION
Marks a function as autonomous. An autonomous transaction is an independent transaction started by the main transaction. Autonomous transactions let you suspend the main transaction, do SQL operations, commit or roll back those operations, then resume the main transaction. For more information, see "Doing Independent Units of Work with Autonomous Transactions" on page 6-37.

procedure_declaration
Declares a procedure. For the syntax of `procedure_declaration`, see "Procedure Declaration" on page 13-90.

RETURN

Introduces the `RETURN` clause, which specifies the datatype of the return value.

type_definition

Specifies a user-defined datatype. For `its syntax`, see "Block Declaration" on page 13-8.

:= | DEFAULT

Initializes `IN` parameters to default values.

Usage Notes

A function is called as part of an expression:

```
promotable := sal_ok(new_sal, new_title) AND (rating > 3);
```

To be callable from SQL statements, a stored function must obey certain rules that control side effects. See "Controlling Side Effects of PL/SQL Subprograms" on page 8-23.

In a function, at least one execution path must lead to a `RETURN` statement. Otherwise, you get a `function returned without value` error at run time. The `RETURN` statement must contain an expression, which is evaluated when the `RETURN` statement is executed. The resulting value is assigned to the function identifier, which acts like a variable.

You can write the function spec and body as a unit. Or, you can separate the function spec from its body. That way, you can hide implementation details by placing the function in a package. You can define functions in a package body without declaring their specs in the package spec. However, such functions can be called only from inside the package.

Inside a function, an `IN` parameter acts like a constant; you cannot assign it a value. An `OUT` parameter acts like a local variable; you can change its value and reference the value in any way. An `IN OUT` parameter acts like an initialized variable; you can assign it a value, which can be assigned to another variable. For information about the parameter modes, see Table 8–1 on page 8-9.

Avoid using the `OUT` and `IN OUT` modes with functions. The purpose of a function is to take zero or more parameters and return a single value. Functions should be free from side effects, which change the values of variables not local to the subprogram.

Examples

For examples, see the following:

Example 1–13, "Creating a Package and Package Body" on page 1-14
Example 2–15, "Using a Subprogram Name for Name Resolution" on page 2-15
Example 2–27, "Using a Search Condition With a CASE Statement" on page 2-27
Example 5–44, "Returning a Record from a Function" on page 5-31
Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38
Example 6–48, "Calling an Autonomous Function" on page 6-42
Example 9–3, "Creating the emp_admin Package" on page 9-6

Related Topics

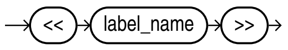
"Package Declaration" on page 13-85
"Procedure Declaration" on page 13-90

GOTO Statement

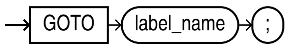
The GOTO statement branches unconditionally to a statement label or block label. The label must be unique within its scope and must precede an executable statement or a PL/SQL block. The GOTO statement transfers control to the labelled statement or block. For more information, see "Using the GOTO Statement" on page 4-13.

Syntax

label declaration ::=



goto statement ::=



Keyword and Parameter Description

label_name

A label that you assigned to an executable statement or a PL/SQL block. A GOTO statement transfers control to the statement or block following `<<label_name>>`.

Usage Notes

A GOTO label must precede an executable statement or a PL/SQL block. A GOTO statement cannot branch into an IF statement, LOOP statement, or sub-block. To branch to a place that does not have an executable statement, add the NULL statement.

From the current block, a GOTO statement can branch to another place in the block or into an enclosing block, but not into an exception handler. From an exception handler, a GOTO statement can branch into an enclosing block, but not into the current block.

If you use the GOTO statement to exit a cursor FOR loop prematurely, the cursor is closed automatically. The cursor is also closed automatically if an exception is raised inside the loop.

A given label can appear only once in a block. However, the label can appear in other blocks including enclosing blocks and sub-blocks. If a GOTO statement cannot find its target label in the current block, it branches to the first enclosing block in which the label appears.

Examples

For examples, see the following:

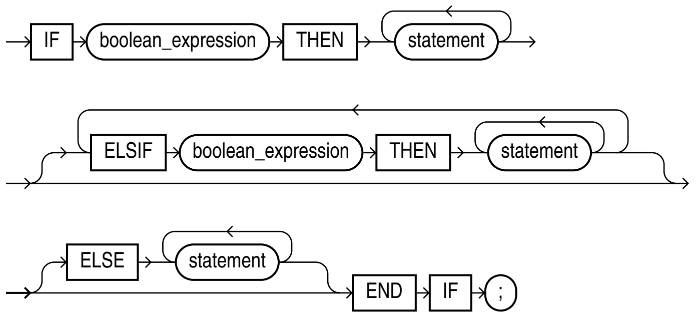
Example 4–19, "Using a Simple GOTO Statement" on page 4-14
Example 4–21, "Using a GOTO Statement to Branch an Enclosing Block" on page 4-14

IF Statement

The IF statement executes or skips a sequence of statements, depending on the value of a Boolean expression. For more information, see "Testing Conditions: IF and CASE Statements" on page 4-2.

Syntax

if statement ::=



Keyword and Parameter Description

boolean_expression

An expression that returns the Boolean value TRUE, FALSE, or NULL. Examples are comparisons for equality, greater-than, or less-than. The sequence following the THEN keyword is executed only if the expression returns TRUE.

ELSE

If control reaches this keyword, the sequence of statements that follows it is executed. This occurs when none of the previous conditional tests returned TRUE.

ELSIF

Introduces a Boolean expression that is evaluated if none of the preceding conditions returned TRUE.

THEN

If the expression returns TRUE, the statements after the THEN keyword are executed.

Usage Notes

There are three forms of IF statements: IF-THEN, IF-THEN-ELSE, and IF-THEN-ELSIF. The simplest form of IF statement associates a Boolean expression with a sequence of statements enclosed by the keywords THEN and END IF. The sequence of statements is executed only if the expression returns TRUE. If the expression returns FALSE or NULL, the IF statement does nothing. In either case, control passes to the next statement.

The second form of IF statement adds the keyword ELSE followed by an alternative sequence of statements. The sequence of statements in the ELSE clause is executed only if the Boolean expression returns FALSE or NULL. Thus, the ELSE clause ensures that a sequence of statements is executed.

The third form of IF statement uses the keyword ELSIF to introduce additional Boolean expressions. If the first expression returns FALSE or NULL, the ELSIF clause evaluates another expression. An IF statement can have any number of ELSIF clauses; the final ELSE clause is optional. Boolean expressions are evaluated one by one from top to bottom. If any expression returns TRUE, its associated sequence of statements is executed and control passes to the next statement. If all expressions return FALSE or NULL, the sequence in the ELSE clause is executed.

An IF statement never executes more than one sequence of statements because processing is complete after any sequence of statements is executed. However, the THEN and ELSE clauses can include more IF statements. That is, IF statements can be nested.

Examples

Example 13–3 shows an example of the IF-THEN-ELSIF-ELSE statement.

Example 13–3 Using the IF Statement

```
DECLARE
   jobid      employees.job_id%TYPE;
   empid      employees.employee_id%TYPE := 115;
   sal_raise  NUMBER(3,2);
BEGIN
  SELECT job_id INTO jobid from employees WHERE employee_id = empid;
  IF jobid = 'PU_CLERK' THEN sal_raise := .09;
  ELSIF jobid = 'SH_CLERK' THEN sal_raise := .08;
  ELSIF jobid = 'ST_CLERK' THEN sal_raise := .07;
  ELSE sal_raise := 0;
  END IF;
END;
/
```

For examples, see the following:

Example 1–7, "Using the IF-THEN_ELSE and CASE Statement for Conditional Control" on page 1-10
Example 4–1, "Using a Simple IF-THEN Statement" on page 4-2
Example 4–2, "Using a Simple IF-THEN-ELSE Statement" on page 4-2
Example 4–3, "Nested IF Statements" on page 4-3
Example 4–4, "Using the IF-THEN-ELSEIF Statement" on page 4-3

Related Topics

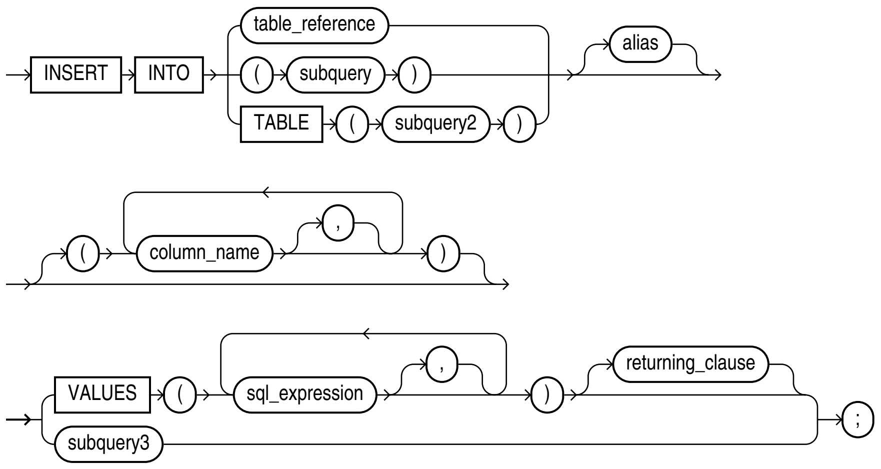
"Testing Conditions: IF and CASE Statements" on page 4-2
"CASE Statement" on page 13-14
"Expression Definition" on page 13-45

INSERT Statement

The `INSERT` statement adds one or more new rows of data to a database table. For a full description of the `INSERT` statement, see *Oracle Database SQL Reference*.

Syntax

insert statement ::=



Keyword and Parameter Description

alias

Another (usually short) name for the referenced table or view.

column_name[, column_name]...

A list of columns in a database table or view. The columns can be listed in any order, as long as the expressions in the `VALUES` clause are listed in the same order. Each column name can only be listed once. If the list does not include all the columns in a table, each missing columns is set to `NULL` or to a default value specified in the `CREATE TABLE` statement.

returning_clause

Returns values from inserted rows, eliminating the need to `SELECT` the rows afterward. You can retrieve the column values into variables or into collections. You cannot use the `RETURNING` clause for remote or parallel inserts. If the statement does not affect any rows, the values of the variables specified in the `RETURNING` clause are undefined. For the syntax of `returning_clause`, see "RETURNING INTO Clause" on page 13-101.

sql_expression

Any expression valid in SQL. For example, it could be a literal, a PL/SQL variable, or a SQL query that returns a single value. For more information, see *Oracle Database SQL Reference*. PL/SQL also lets you use a record variable here.

subquery
A `SELECT` statement that provides a set of rows for processing. Its syntax is like that of `select_into_statement` without the `INTO` clause. See "SELECT INTO Statement" on page 13-107.

subquery3
A `SELECT` statement that returns a set of rows. Each row returned by the select statement is inserted into the table. The subquery must return a value for every column in the column list, or for every column in the table if there is no column list.

table_reference
A table or view that must be accessible when you execute the `INSERT` statement, and for which you must have `INSERT` privileges. For the syntax of `table_reference`, see "DELETE Statement" on page 13-36.

TABLE (subquery2)
The operand of `TABLE` is a `SELECT` statement that returns a single column value representing a nested table. This operator specifies that the value is a collection, not a scalar value.

VALUES (...)
Assigns the values of expressions to corresponding columns in the column list. If there is no column list, the first value is inserted into the first column defined by the `CREATE TABLE` statement, the second value is inserted into the second column, and so on. There must be one value for each column in the column list. The datatypes of the values being inserted must be compatible with the datatypes of corresponding columns in the column list.

Usage Notes

Character and date literals in the `VALUES` list must be enclosed by single quotes ('). Numeric literals are not enclosed by quotes.

The implicit cursor `SQL` and the cursor attributes `%NOTFOUND`, `%FOUND`, `%ROWCOUNT`, and `%ISOPEN` let you access useful information about the execution of an `INSERT` statement.

Examples

For examples, see the following:

Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 6–5, "Using CURRVAL and NEXTVAL" on page 6-4
Example 6–7, "Using SQL%FOUND" on page 6-7
Example 6–37, "Using ROLLBACK" on page 6-31
Example 6–38, "Using SAVEPOINT With ROLLBACK" on page 6-31
Example 6–46, "Declaring an Autonomous Trigger" on page 6-38
Example 6–48, "Calling an Autonomous Function" on page 6-42
Example 7–1, "Examples of Dynamic SQL" on page 7-3
Example 9–3, "Creating the emp_admin Package" on page 9-6

Related Topics

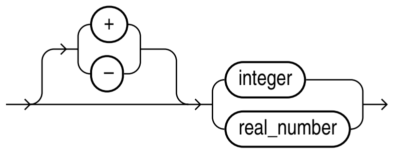
"DELETE Statement" on page 13-36
"SELECT INTO Statement" on page 13-107
"UPDATE Statement" on page 13-121

Literal Declaration

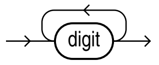
A literal is an explicit numeric, character, string, or Boolean value not represented by an identifier. The numeric literal 135 and the string literal `'hello world'` are examples. For more information, see "Literals" on page 2-4.

Syntax

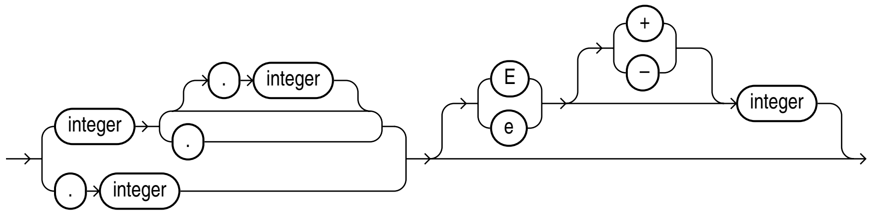
numeric literal ::=



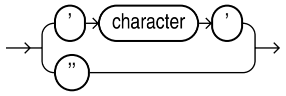
integer literal ::=



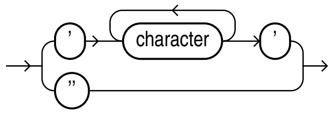
real number literal ::=



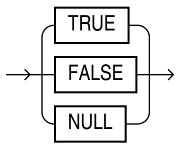
character literal ::=



string literal ::=



boolean literal ::=



Keyword and Parameter Description

character

A member of the PL/SQL character set. For more information, see "Character Sets and Lexical Units" on page 2-1.

digit

One of the numerals 0 .. 9.

TRUE, FALSE, NULL

A predefined Boolean value.

Usage Notes

Integer and real numeric literals can be used in arithmetic expressions. Numeric literals must be separated by punctuation. Spaces can be used in addition to the punctuation. For additional information, see "Numeric Literals" on page 2-5.

A character literal is an individual character enclosed by single quotes (apostrophes). Character literals include all the printable characters in the PL/SQL character set: letters, numerals, spaces, and special symbols. PL/SQL is case sensitive within character literals. For example, PL/SQL considers the literals `'Q'` and `'q'` to be different. For additional information, see "Character Literals" on page 2-6.

A string literal is a sequence of zero or more characters enclosed by single quotes. The null string (`''`) contains zero characters. A string literal can hold up to 32,767 characters. PL/SQL is case sensitive within string literals. For example, PL/SQL considers the literals `'white'` and `'White'` to be different.

To represent an apostrophe within a string, enter two single quotes instead of one. For literals where doubling the quotes is inconvenient or hard to read, you can designate an escape character using the notation `q'`*esc_char* `...` *esc_char*`'`. This escape character must not occur anywhere else inside the string.

Trailing blanks are significant within string literals, so `'abc'` and `'abc '` are different. Trailing blanks in a string literal are not trimmed during PL/SQL processing, although they are trimmed if you insert that value into a table column of type `CHAR`. For additional information, including `NCHAR` string literals, see "String Literals" on page 2-6.

The `BOOLEAN` values `TRUE` and `FALSE` cannot be inserted into a database column. For additional information, see "BOOLEAN Literals" on page 2-7.

Examples

Several examples of numeric literals are:

```
25  6.34  7E2  25e-03  .1  1.  +17  -4.4  -4.5D  -4.6F
```

Several examples of character literals are:

```
'H'   '&'   ' '   '9'   ']'   'g'
```

Several examples of string literals are:

```
'$5,000'
'02-AUG-87'
'Don''t leave until you''re ready and I''m ready.'
q'#Don't leave until you're ready and I'm ready.#'
```

For examples, see the following:

Example 2–3, "Using DateTime Literals" on page 2-7
Example 2–34, "Using Conditional Compilation With Database Versions" on page 2-35

Related Topics

"Constant and Variable Declaration" on page 13-25
"Expression Definition" on page 13-45
"Literals" on page 2-4

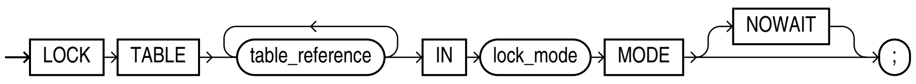
LOCK TABLE Statement

The `LOCK TABLE` statement locks entire database tables in a specified lock mode. That enables you to share or deny access to tables while maintaining their integrity. For more information, see "Using LOCK TABLE" on page 6-35.

Oracle has extensive automatic features that allow multiple programs to read and write data simultaneously, while each program sees a consistent view of the data; you should rarely, if ever, need to lock tables yourself. For additional information on the `LOCK TABLE` SQL statement, see *Oracle Database SQL Reference*.

Syntax

lock table statement ::=



Keyword and Parameter Description

table_reference

A table or view that must be accessible when you execute the `LOCK TABLE` statement. For the syntax of `table_reference`, see "DELETE Statement" on page 13-36.

lock_mode

The type of lock. It must be one of the following: `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE`, `SHARE`, `SHARE ROW EXCLUSIVE`, or `EXCLUSIVE`.

NOWAIT

This optional keyword tells Oracle not to wait if the table has been locked by another user. Control is immediately returned to your program, so it can do other work before trying again to acquire the lock.

Usage Notes

If you omit the keyword `NOWAIT`, Oracle waits until the table is available; the wait has no set limit. Table locks are released when your transaction issues a commit or rollback. A table lock never keeps other users from querying a table, and a query never acquires a table lock. If your program includes SQL locking statements, make sure the Oracle users requesting locks have the privileges needed to obtain the locks. Your DBA can lock any table. Other users can lock tables they own or tables for which they have a privilege, such as `SELECT`, `INSERT`, `UPDATE`, or `DELETE`.

Examples

This statement locks the `employees` table in row shared mode with the `NOWAIT` option: `LOCK TABLE employees IN ROW SHARE MODE NOWAIT;`

Related Topics

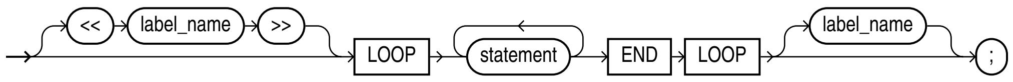
"COMMIT Statement" on page 13-24
"ROLLBACK Statement" on page 13-103

LOOP Statements

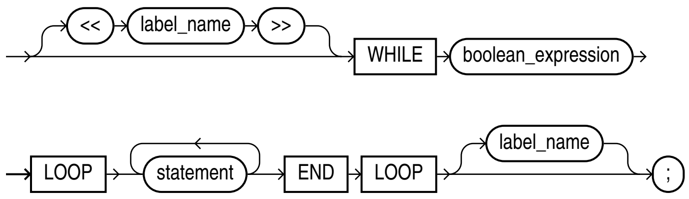
LOOP statements execute a sequence of statements multiple times. The LOOP and END LOOP keywords enclose the statements. PL/SQL provides four kinds of loop statements: basic loop, WHILE loop, FOR loop, and cursor FOR loop. For usage information, see "Controlling Loop Iterations: LOOP and EXIT Statements" on page 4-7.

Syntax

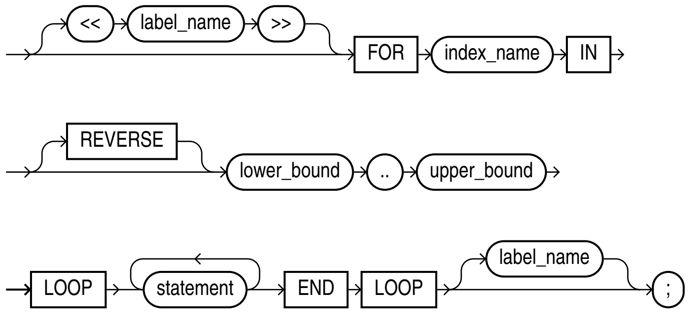
loop statement ::=



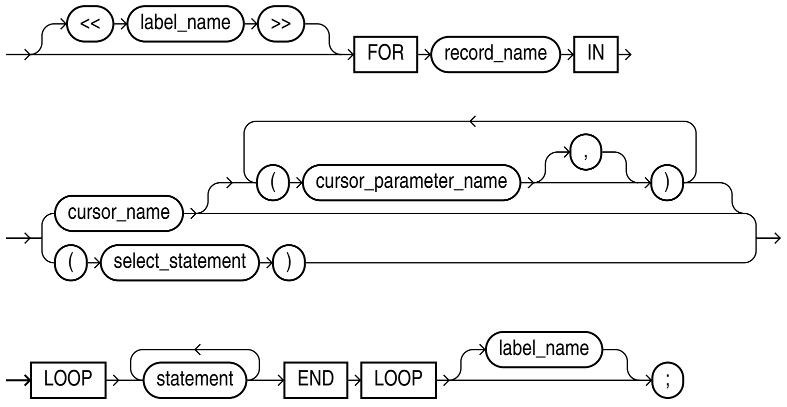
while loop statement ::=



for loop statement ::=



cursor for loop statement ::=



Keyword and Parameter Description

basic_loop_statement

A loop that executes an unlimited number of times. It encloses a sequence of statements between the keywords `LOOP` and `END LOOP`. With each iteration, the sequence of statements is executed, then control resumes at the top of the loop. An `EXIT`, `GOTO`, or `RAISE` statement branches out of the loop. A raised exception also ends the loop.

boolean_expression

An expression that returns the Boolean value `TRUE`, `FALSE`, or `NULL`. It is associated with a sequence of statements, which is executed only if the expression returns `TRUE`. For the syntax of `boolean_expression`, see "Expression Definition" on page 13-45.

cursor_for_loop_statement

Issues a SQL query and loops through the rows in the result set. This is a convenient technique that makes processing a query as simple as reading lines of text in other programming languages.

A cursor `FOR` loop implicitly declares its loop index as a `%ROWTYPE` record, opens a cursor, repeatedly fetches rows of values from the result set into fields in the record, and closes the cursor when all rows have been processed.

cursor_name

An explicit cursor previously declared within the current scope. When the cursor `FOR` loop is entered, `cursor_name` cannot refer to a cursor already opened by an `OPEN` statement or an enclosing cursor `FOR` loop.

cursor_parameter_name

A variable declared as the formal parameter of a cursor. For the syntax of `cursor_parameter_declaration`, see "Cursor Declaration" on page 13-33. A cursor parameter can appear in a query wherever a constant can appear. The formal parameters of a cursor must be `IN` parameters.

for_loop_statement

Numeric `FOR_LOOP` loops iterate over a specified range of integers. The range is part of an iteration scheme, which is enclosed by the keywords `FOR` and `LOOP`.

The range is evaluated when the `FOR` loop is first entered and is never re-evaluated. The loop body is executed once for each integer in the range defined by `lower_bound..upper_bound`. After each iteration, the loop index is incremented.

index_name

An undeclared identifier that names the loop index (sometimes called a loop counter). Its scope is the loop itself; you cannot reference the index outside the loop.

The implicit declaration of `index_name` overrides any other declaration outside the loop. To refer to another variable with the same name, use a label. See Example 4–15, "Using a Label for Referencing Variables Outside a Loop" on page 4-12.

Inside a loop, the index is treated like a constant: it can appear in expressions, but cannot be assigned a value.

label_name

An optional undeclared identifier that labels a loop. `label_name` must be enclosed by double angle brackets and must appear at the beginning of the loop. Optionally, `label_name` (not enclosed in angle brackets) can also appear at the end of the loop.

You can use `label_name` in an `EXIT` statement to exit the loop labelled by `label_name`. You can exit not only the current loop, but any enclosing loop.

You cannot reference the index of a `FOR` loop from a nested `FOR` loop if both indexes have the same name, unless the outer loop is labeled by `label_name` and you use dot notation. See Example 4–16, "Using Labels on Loops for Referencing" on page 4-12.

lower_bound .. upper_bound

Expressions that return numbers. Otherwise, PL/SQL raises the predefined exception `VALUE_ERROR`. The expressions are evaluated only when the loop is first entered. The lower bound need not be 1, it can be a negative integer as in `FOR i IN -5..10`. The loop counter increment (or decrement) must be 1.

Internally, PL/SQL assigns the values of the bounds to temporary `PLS_INTEGER` variables, and, if necessary, rounds the values to the nearest integer. The magnitude range of a `PLS_INTEGER` is -2147483648 to 2147483647, represented in 32 bits. If a bound evaluates to a number outside that range, you get a *numeric overflow* error when PL/SQL attempts the assignment. See "PLS_INTEGER Datatype" on page 3-4.

By default, the loop index is assigned the value of `lower_bound`. If that value is not greater than the value of `upper_bound`, the sequence of statements in the loop is executed, then the index is incremented. If the value of the index is still not greater than the value of `upper_bound`, the sequence of statements is executed again. This process repeats until the value of the index is greater than the value of `upper_bound`. At that point, the loop completes.

record_name

An implicitly declared record. The record has the same structure as a row retrieved by `cursor_name` or `select_statement`.

The record is defined only inside the loop. You cannot refer to its fields outside the loop. The implicit declaration of `record_name` overrides any other declaration outside the loop. You cannot refer to another record with the same name inside the loop unless you qualify the reference using a block label.

Fields in the record store column values from the implicitly fetched row. The fields have the same names and datatypes as their corresponding columns. To access field values, you use dot notation, as follows:

```
record_name.field_name
```

Select-items fetched from the `FOR` loop cursor must have simple names or, if they are expressions, must have aliases. In the following example, `wages` is an alias for the select item `salary+NVL(commission_pct,0)*1000`:

```
CURSOR c1 IS SELECT employee_id,
  salary + NVL(commission_pct,0) * 1000 wages FROM employees ...
```

REVERSE

By default, iteration proceeds upward from the lower bound to the upper bound. If you use the keyword `REVERSE`, iteration proceeds downward from the upper bound to the lower bound. An example follows:

```
BEGIN
```

```
  FOR i IN REVERSE 1..10 LOOP  -- i starts at 10, ends at 1
   DBMS_OUTPUT.PUT_LINE(i); -- statements here execute 10 times
  END LOOP;
END;
/
```

The loop index is assigned the value of `upper_bound`. If that value is not less than the value of `lower_bound`, the sequence of statements in the loop is executed, then the index is decremented. If the value of the index is still not less than the value of `lower_bound`, the sequence of statements is executed again. This process repeats until the value of the index is less than the value of `lower_bound`. At that point, the loop completes.

select_statement

A query associated with an internal cursor unavailable to you. Its syntax is like that of `select_into_statement` without the `INTO` clause. See "SELECT INTO Statement" on page 13-107. PL/SQL automatically declares, opens, fetches from, and closes the internal cursor. Because `select_statement` is not an independent statement, the implicit cursor `SQL` does not apply to it.

while_loop_statement

The `WHILE-LOOP` statement associates a Boolean expression with a sequence of statements enclosed by the keywords `LOOP` and `END LOOP`. Before each iteration of the loop, the expression is evaluated. If the expression returns `TRUE`, the sequence of statements is executed, then control resumes at the top of the loop. If the expression returns `FALSE` or `NULL`, the loop is bypassed and control passes to the next statement.

Usage Notes

You can use the `EXIT WHEN` statement to exit any loop prematurely. If the Boolean expression in the `WHEN` clause returns `TRUE`, the loop is exited immediately.

When you exit a cursor `FOR` loop, the cursor is closed automatically even if you use an `EXIT` or `GOTO` statement to exit the loop prematurely. The cursor is also closed automatically if an exception is raised inside the loop.

Examples

For examples, see the following:

Example 4–18, "Using EXIT With a Label in a LOOP" on page 4-13
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11

Related Topics

"Controlling Loop Iterations: LOOP and EXIT Statements" on page 4-7
"Cursor Declaration" on page 13-33
"EXIT Statement" on page 13-44
"FETCH Statement" on page 13-53
"OPEN Statement" on page 13-80

MERGE Statement

The `MERGE` statement inserts some rows and updates others in a single operation. The decision about whether to update or insert into the target table is based upon a join condition: rows already in the target table that match the join condition are updated; otherwise, a row is inserted using values from a separate subquery.

For a full description and examples of the `MERGE` statement, see *Oracle Database SQL Reference*.

Usage Notes

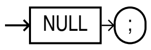
This statement is primarily useful in data warehousing situations where large amounts of data are commonly inserted and updated. If you only need to insert or update a single row, it is more efficient to do that with the regular PL/SQL techniques: try to update the row, and do an insert instead if the update affects zero rows; or try to insert the row, and do an update instead if the insert raises an exception because the table already contains that primary key.

NULL Statement

The NULL statement is a no-op (no operation); it passes control to the next statement without doing anything. In the body of an IF-THEN clause, a loop, or a procedure, the NULL statement serves as a placeholder. For more information, see "Using the NULL Statement" on page 4-15.

Syntax

null statement ::=



Usage Notes

The NULL statement improves readability by making the meaning and action of conditional statements clear. It tells readers that the associated alternative has not been overlooked: you have decided that no action is necessary.

Certain clauses in PL/SQL, such as in an IF statement or an exception handler, must contain at least one executable statement. You can use the NULL statement to make these constructs compile, while not taking any action.

You might not be able to branch to certain places with the GOTO statement because the next statement is END, END IF, and so on, which are not executable statements. In these cases, you can put a NULL statement where you want to branch.

The NULL statement and Boolean value NULL are not related.

Examples

For examples, see the following:

Example 1–12, "Creating a Stored Subprogram" on page 1-13
Example 1–16, "Declaring a Record Type" on page 1-17
Example 4–20, "Using a NULL Statement to Allow a GOTO to a Label" on page 4-14
Example 4–22, "Using the NULL Statement to Show No Action" on page 4-15
Example 4–23, "Using NULL as a Placeholder When Creating a Subprogram" on page 4-16

Related Topics

"Sequential Control: GOTO and NULL Statements" on page 4-13

Object Type Declaration

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. A special kind of method called the constructor creates a new instance of the object type and fills in its attributes.

Object types must be created through SQL and stored in an Oracle database, where they can be shared by many programs. When you define an object type using the `CREATE TYPE` statement, you create an abstract template for some real-world object. The template specifies the attributes and behaviors the object needs in the application environment. For information on the `CREATE TYPE` SQL statement, see *Oracle Database SQL Reference*. For information on the `CREATE TYPE BODY` SQL statement, see *Oracle Database SQL Reference*.

The data structure formed by the set of attributes is public (visible to client programs). However, well-behaved programs do not manipulate it directly. Instead, they use the set of methods provided, so that the data is kept in a proper state.

For more information on object types, see *Oracle Database Application Developer's Guide - Object-Relational Features*. For information on using PL/SQL with object types, see Chapter 12, "Using PL/SQL With Object Types".

Usage Notes

Once an object type is created in your schema, you can use it to declare objects in any PL/SQL block, subprogram, or package. For example, you can use the object type to specify the datatype of an object attribute, table column, PL/SQL variable, bind variable, record field, collection element, formal procedure parameter, or function result.

Like a package, an object type has two parts: a specification and a body. The specification (spec for short) is the interface to your applications; it declares a data structure (set of attributes) along with the operations (methods) needed to manipulate the data. The body fully defines the methods, and so implements the spec.

All the information a client program needs to use the methods is in the spec. Think of the spec as an operational interface and of the body as a black box. You can debug, enhance, or replace the body without changing the spec.

An object type encapsulates data and operations. You can declare attributes and methods in an object type spec, but *not* constants, exceptions, cursors, or types. At least one attribute is required (the maximum is 1000); methods are optional.

In an object type spec, all attributes must be declared before any methods. Only subprograms have an underlying implementation. If an object type spec declares only attributes and/or call specs, the object type body is unnecessary. You cannot declare attributes in the body. All declarations in the object type spec are public (visible outside the object type).

You can refer to an attribute only by name (not by its position in the object type). To access or change the value of an attribute, you use dot notation. Attribute names can be chained, which lets you access the attributes of a nested object type.

In an object type, methods can reference attributes and other methods without a qualifier. In SQL statements, calls to a parameterless method require an empty parameter list. In procedural statements, an empty parameter list is optional unless you chain calls, in which case it is required for all but the last call.

From a SQL statement, if you call a `MEMBER` method on a null instance (that is, `SELF` is null), the method is not invoked and a null is returned. From a procedural statement, if you call a `MEMBER` method on a null instance, PL/SQL raises the predefined exception `SELF_IS_NULL` before the method is invoked.

You can declare a map method or an order method but not both. If you declare either method, you can compare objects in SQL and procedural statements. However, if you declare neither method, you can compare objects only in SQL statements and only for equality or inequality. Two objects of the same type are equal *only if* the values of their corresponding attributes are equal.

Like packaged subprograms, methods of the same kind (functions or procedures) can be overloaded. That is, you can use the same name for different methods if their formal parameters differ in number, order, or datatype family.

Every object type has a default constructor method (constructor for short), which is a system-defined function with the same name as the object type. You use the constructor to initialize and return an instance of that object type. You can also define your own constructor methods that accept different sets of parameters. PL/SQL never calls a constructor implicitly, so you must call it explicitly. Constructor calls are allowed wherever function calls are allowed.

Related Topics

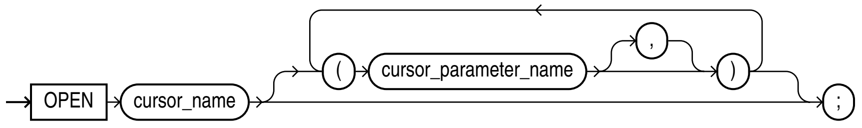
"Function Declaration" on page 13-59
"Package Declaration" on page 13-85
"Procedure Declaration" on page 13-90

OPEN Statement

The OPEN statement executes the query associated with a cursor. It allocates database resources to process the query and identifies the result set -- the rows that match the query conditions. The cursor is positioned before the first row in the result set. For more information, see "Querying Data with PL/SQL" on page 6-14.

Syntax

open statement ::=



Keyword and Parameter Description

cursor_name

An explicit cursor previously declared within the current scope and not currently open.

cursor_parameter_name

A variable declared as the formal parameter of a cursor. (For the syntax of `cursor_parameter_declaration`, see "Cursor Declaration" on page 13-33.) A cursor parameter can appear in a query wherever a constant can appear.

Usage Notes

Generally, PL/SQL parses an explicit cursor only the first time it is opened and parses a SQL statement (creating an implicit cursor) only the first time the statement is executed. All the parsed SQL statements are cached. A SQL statement is reparsed only if it is aged out of the cache by a new SQL statement. Although you must close a cursor before you can reopen it, PL/SQL need not reparse the associated SELECT statement. If you close, then immediately reopen the cursor, a reparse is definitely not needed.

Rows in the result set are not retrieved when the OPEN statement is executed. The FETCH statement retrieves the rows. With a FOR UPDATE cursor, the rows are locked when the cursor is opened.

If formal parameters are declared, actual parameters must be passed to the cursor. The formal parameters of a cursor must be IN parameters; they cannot return values to actual parameters. The values of actual parameters are used when the cursor is opened. The datatypes of the formal and actual parameters must be compatible. The query can also reference PL/SQL variables declared within its scope.

Unless you want to accept default values, each formal parameter in the cursor declaration must have a corresponding actual parameter in the OPEN statement. Formal parameters declared with a default value do not need a corresponding actual parameter. They assume their default values when the OPEN statement is executed.

You can associate the actual parameters in an OPEN statement with the formal parameters in a cursor declaration using positional or named notation.

If a cursor is currently open, you cannot use its name in a cursor `FOR` loop.

Examples

For examples, see the following:

Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"CLOSE Statement" on page 13-16
"Cursor Declaration" on page 13-33
"FETCH Statement" on page 13-53
"LOOP Statements" on page 13-72

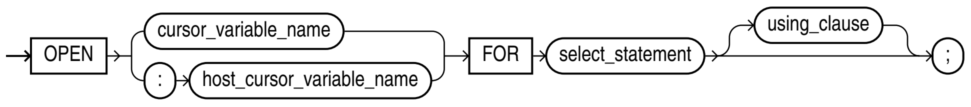
OPEN-FOR Statement

The OPEN-FOR statement executes the query associated with a cursor variable. It allocates database resources to process the query and identifies the result set -- the rows that meet the query conditions. The cursor variable is positioned before the first row in the result set. For more information, see "Using Cursor Variables (REF CURSORs)" on page 6-20.

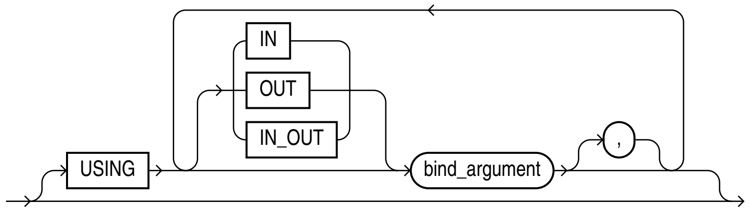
With the optional USING clause, the statement associates a cursor variable with a query, executes the query, identifies the result set, positions the cursor before the first row in the result set, then zeroes the rows-processed count kept by %ROWCOUNT. For more information, see "Building a Dynamic Query with Dynamic SQL" on page 7-7. Because this statement can use bind variables to make the SQL processing more efficient, use the OPEN-FOR-USING statement when building a query where you know the WHERE clauses in advance. Use the OPEN-FOR statement when you need the flexibility to process a dynamic query with an unknown number of WHERE clauses.

Syntax

open for statement ::=



using clause ::=



Keyword and Parameter Description

bind_argument

An expression whose value is passed to the dynamic SELECT statement.

cursor_variable_name

A cursor variable or parameter (without a return type) previously declared within the current scope.

host_cursor_variable_name

A cursor variable previously declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

select_statement

A query associated with cursor_variable, which returns a set of values. The query can reference bind variables and PL/SQL variables, parameters, and functions. The syntax of select_statement is similar to the syntax for select_into_statement defined in "SELECT INTO Statement" on page 13-107, except that the cursor select_statement cannot have an INTO clause. The length of the dynamic string cannot exceed 32767K.

USING clause

This optional clause specifies a list of bind arguments. At run time, bind arguments in the USING clause replace corresponding placeholders in the dynamic SELECT statement.

Usage Notes

You can declare a cursor variable in a PL/SQL host environment such as an OCI or Pro*C program. To open the host cursor variable, you can pass it as a bind variable to an anonymous PL/SQL block. You can reduce network traffic by grouping OPEN-FOR statements. For example, the following PL/SQL block opens five cursor variables in a single round-trip:

```
/* anonymous PL/SQL block in host environment */
BEGIN
  OPEN :emp_cv FOR SELECT * FROM employees;
  OPEN :dept_cv FOR SELECT * FROM departments;
  OPEN :grade_cv FOR SELECT * FROM salgrade;
  OPEN :pay_cv FOR SELECT * FROM payroll;
  OPEN :ins_cv FOR SELECT * FROM insurance;
END;
```

Other OPEN-FOR statements can open the same cursor variable for different queries. You do not need to close a cursor variable before reopening it. When you reopen a cursor variable for a different query, the previous query is lost.

Unlike cursors, cursor variables do not take parameters. Instead, you can pass whole queries (not just parameters) to a cursor variable. Although a PL/SQL stored procedure or function can open a cursor variable and pass it back to a calling subprogram, the calling and called subprograms must be in the same instance. You cannot pass or return cursor variables to procedures and functions called through database links. When you declare a cursor variable as the formal parameter of a subprogram that opens the cursor variable, you must specify the IN OUT mode. That way, the subprogram can pass an open cursor back to the caller.

You use three statements to process a dynamic multi-row query: OPEN-FOR-USING, FETCH, and CLOSE. First, you OPEN a cursor variable FOR a multi-row query. Then, you FETCH rows from the result set. When all the rows are processed, you CLOSE the cursor variable.

The dynamic string can contain any multi-row SELECT statement (without the terminator). The string can also contain placeholders for bind arguments. However, you cannot use bind arguments to pass the names of schema objects to a dynamic SQL statement.

Every placeholder in the dynamic string must be associated with a bind argument in the USING clause. Numeric, character, and string literals are allowed in the USING clause, but Boolean literals (TRUE, FALSE, NULL) are not. To pass nulls to the dynamic string, you must use a workaround. See "Passing Nulls to Dynamic SQL" on page 7-10.

Any bind arguments in the query are evaluated only when the cursor variable is opened. To fetch from the cursor using different bind values, you must reopen the cursor variable with the bind arguments set to their new values.

Dynamic SQL supports all the SQL datatypes. For example, bind arguments can be collections, `LOB`s, instances of an object type, and refs. As a rule, dynamic SQL does not support PL/SQL-specific types. For instance, bind arguments cannot be `BOOLEAN`s or index-by tables.

Examples

For examples, see the following:

Example 6–27, "Passing a REF CURSOR as a Parameter" on page 6-22
Example 6–29, "Stored Procedure to Open a Ref Cursor" on page 6-23
Example 6–30, "Stored Procedure to Open Ref Cursors with Different Queries" on page 6-23
Example 6–31, "Cursor Variable with Different Return Types" on page 6-24
Example 6–32, "Fetching from a Cursor Variable into a Record" on page 6-25
Example 6–33, "Fetching from a Cursor Variable into Collections" on page 6-25
Example 7–9, "Dynamic SQL Fetching into a Record" on page 7-12

Related Topics

"CLOSE Statement" on page 13-16
"Cursor Variables" on page 13-30
"EXECUTE IMMEDIATE Statement" on page 13-41
"FETCH Statement" on page 13-53
"LOOP Statements" on page 13-72

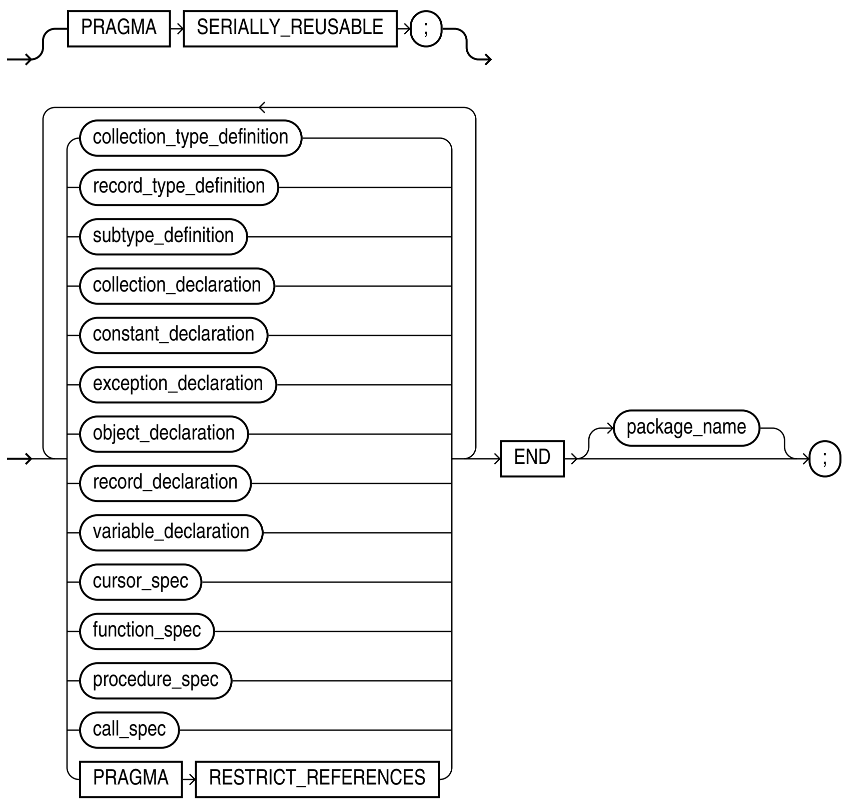
Package Declaration

A package is a schema object that groups logically related PL/SQL types, items, and subprograms. Use packages when writing a set of related subprograms that form an application programming interface (API) that you or others might reuse. Packages have two parts: a specification (spec for short) and a body. For more information, see Chapter 9, "Using PL/SQL Packages". For an example of a package declaration, see Example 9–3 on page 9-6.

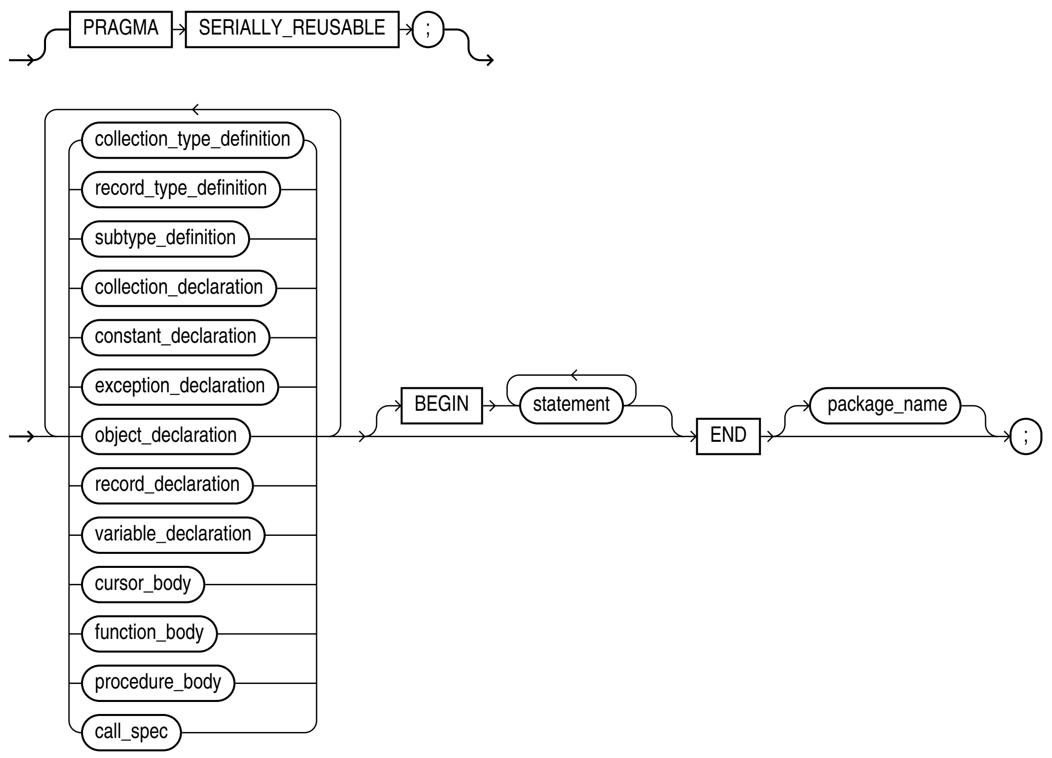
This section discusses the package specification and body options for PL/SQL. For information on the CREATE PACKAGE SQL statement, see *Oracle Database SQL Reference*. For information on the CREATE PACKAGE BODY SQL statement, see *Oracle Database SQL Reference*.

Syntax

package specification ::=



package body ::=



Keyword and Parameter Description

call_spec

Publishes a Java method or external C function in the Oracle data dictionary. It publishes the routine by mapping its name, parameter types, and return type to their SQL counterparts. For more information, see *Oracle Database Java Developer's Guide* and *Oracle Database Application Developer's Guide - Fundamentals*.

collection_declaration

Declares a collection (nested table, index-by table, or varray). For the syntax of `collection_declaration`, see "Collection Definition" on page 13-17.

collection_type_definition

Defines a collection type using the datatype specifier `TABLE` or `VARRAY`.

constant_declaration

Declares a constant. For the syntax of `constant_declaration`, see "Constant and Variable Declaration" on page 13-25.

cursor_body

Defines the underlying implementation of an explicit cursor. For the syntax of `cursor_body`, see "Cursor Declaration" on page 13-33.

cursor_spec

Declares the interface to an explicit cursor. For the syntax of `cursor_spec`, see "Cursor Declaration" on page 13-33.

exception_declaration

Declares an exception. For the syntax of `exception_declaration`, see "Exception Definition" on page 13-39.

function_body

Implements a function. For the syntax of `function_body`, see "Function Declaration" on page 13-59.

function_spec

Declares the interface to a function. For the syntax of `function_spec`, see "Function Declaration" on page 13-59.

object_declaration

Declares an object (instance of an object type). For the syntax of `object_declaration`, see "Object Type Declaration" on page 13-78.

package_name

A package stored in the database. For naming conventions, see "Identifiers" on page 2-3.

pragma_restrict_refs

Pragma `RESTRICT_REFERENCES`, which checks for violations of purity rules. To be callable from SQL statements, a function must obey rules that control side effects. If any SQL statement inside the function body violates a rule, you get an error at run time (when the statement is parsed). For the syntax of the pragma, see "RESTRICT_REFERENCES Pragma" on page 13-98.

The pragma asserts that a function does not read and/or write database tables and/or package variables. For more information about the purity rules and pragma `RESTRICT_REFERENCES`, see *Oracle Database Application Developer's Guide - Fundamentals*.

PRAGMA SERIALLY_REUSABLE

Marks a package as serially reusable, if its state is needed only for the duration of one call to the server (for example, an OCI call to the server or a server-to-server remote procedure call). For more information, see *Oracle Database Application Developer's Guide - Fundamentals*.

procedure_body

Implements a procedure. For the syntax of `procedure_body`, see "Procedure Declaration" on page 13-90.

procedure_spec

Declares the interface to a procedure. For the syntax of `procedure_spec`, see "Procedure Declaration" on page 13-90.

record_declaration

Declares a user-defined record. For the syntax of `record_declaration`, see "Record Definition" on page 13-95.

record_type_definition

Defines a record type using the datatype specifier RECORD or the attribute %ROWTYPE.

schema_name

The schema containing the package. If you omit schema_name, Oracle assumes the package is in your schema.

variable_declaration

Declares a variable. For the syntax of variable_declaration, see "Constant and Variable Declaration" on page 13-25.

Usage Notes

You can use any Oracle tool that supports PL/SQL to create and store packages in an Oracle database. You can issue the CREATE PACKAGE and CREATE PACKAGE BODY statements interactively from SQL*Plus, or from an Oracle Precompiler or OCI host program. However, you cannot define packages in a PL/SQL block or subprogram.

Most packages have a specification and a body. The specification is the interface to your applications; it declares the types, variables, constants, exceptions, cursors, and subprograms available for use. The body fully defines cursors and subprograms, and so implements the spec.

Only subprograms and cursors have an underlying implementation. If a specification declares only types, constants, variables, exceptions, and call specifications, the package body is unnecessary. The body can still be used to initialize items declared in the specification:

```
CREATE OR REPLACE PACKAGE emp_actions AS
--   additional code here ...
   number_hired INTEGER;
END emp_actions;
/
CREATE OR REPLACE PACKAGE BODY emp_actions AS
BEGIN
   number_hired := 0;
END emp_actions;
/
```

You can code and compile a spec without its body. Once the spec has been compiled, stored subprograms that reference the package can be compiled as well. You do not need to define the package bodies fully until you are ready to complete the application. You can debug, enhance, or replace a package body without changing the package spec, which saves you from recompiling subprograms that call the package.

Cursors and subprograms declared in a package spec must be defined in the package body. Other program items declared in the package spec cannot be redeclared in the package body.

To match subprogram specs and bodies, PL/SQL does a token-by-token comparison of their headers. Except for white space, the headers must match word for word. Otherwise, PL/SQL raises an exception.

Variables declared in a package keep their values throughout a session, so you can set the value of a package variable in one procedure, and retrieve the same value in a different procedure.

Examples

For examples, see the following:

Example 1–13, "Creating a Package and Package Body" on page 1-14
Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38
Example 9–3, "Creating the emp_admin Package" on page 9-6
Example 9–4, "Using PUT_LINE in the DBMS_OUTPUT Package" on page 9-9
Example 12–18, "TEAMS Package Using Dynamic SQL for Object Types and Collections" on page 12-11

Related Topics

"Collection Definition" on page 13-17
"Cursor Declaration" on page 13-33
"Exception Definition" on page 13-39
"Function Declaration" on page 13-59
"Procedure Declaration" on page 13-90
"Record Definition" on page 13-95

Procedure Declaration

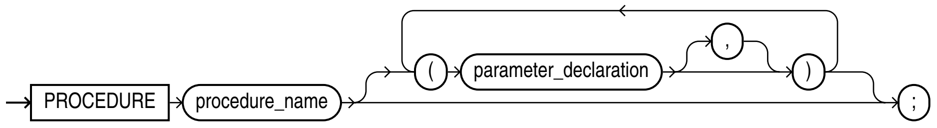
A procedure is a subprogram that can take parameters and be called. Generally, you use a procedure to perform an action. A procedure has two parts: the specification and the body. The specification (spec for short) begins with the keyword `PROCEDURE` and ends with the procedure name or a parameter list. Parameter declarations are optional. Procedures that take no parameters are written without parentheses. The procedure body begins with the keyword `IS` (or `AS`) and ends with the keyword `END` followed by an optional procedure name.

The procedure body has three parts: an optional declarative part, an executable part, and an optional exception-handling part. The declarative part contains declarations of types, cursors, constants, variables, exceptions, and subprograms. These items are local and cease to exist when you exit the procedure. The executable part contains statements that assign values, control execution, and manipulate Oracle data. The exception-handling part contains handlers that deal with exceptions raised during execution. For more information, see "Understanding PL/SQL Procedures" on page 8-3. For an example of a procedure declaration, see Example 9–3 on page 9-6.

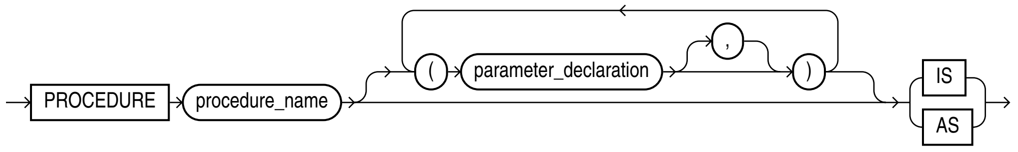
Note that the procedure declaration in a PL/SQL block or package is not the same as creating a procedure in SQL. For information on the `CREATE PROCEDURE` SQL statement, see *Oracle Database SQL Reference*.

Syntax

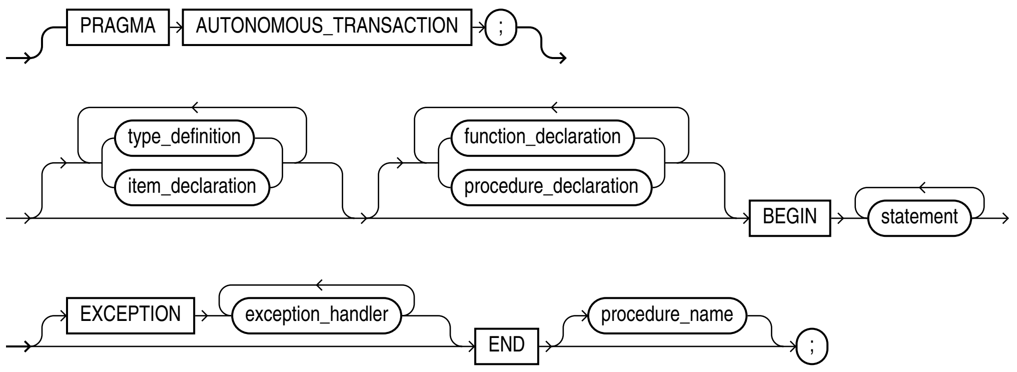
procedure specification ::=



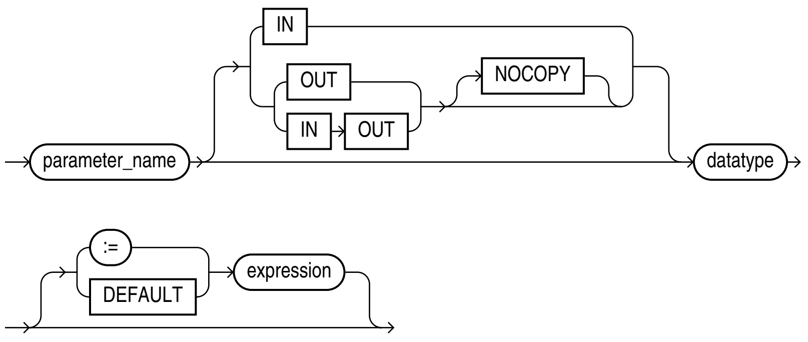
procedure declaration ::=



procedure body ::=



parameter declaration ::=



Keyword and Parameter Description

datatype

A type specifier. For the syntax of `datatype`, see "Constant and Variable Declaration" on page 13-25.

exception_handler

Associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see "Exception Definition" on page 13-39.

expression

A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. When the declaration is elaborated, the value of `expression` is assigned to the parameter. The value and the parameter must have compatible datatypes.

function_declaration

Declares a function. For the syntax of `function_declaration`, see "Function Declaration" on page 13-59.

IN, OUT, IN OUT

Parameter modes that define the behavior of formal parameters. An `IN` parameter passes values to the subprogram being called. An `OUT` parameter returns values to the caller of the subprogram. An `IN OUT` parameter lets passes initial values to the subprogram being called and returns updated values to the caller.

item_declaration

Declares a program object. For the syntax of `item_declaration`, see "Block Declaration" on page 13-8.

NOCOPY

A compiler hint (not directive) that allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference instead of by value (the default). For more information, see "Specifying Subprogram Parameter Modes" on page 8-7.

parameter_name
A formal parameter, which is a variable declared in a procedure spec and referenced in the procedure body.

PRAGMA AUTONOMOUS_TRANSACTION
Marks a function as autonomous. An autonomous transaction is an independent transaction started by the main transaction. Autonomous transactions let you suspend the main transaction, do SQL operations, commit or roll back those operations, then resume the main transaction. For more information, see "Doing Independent Units of Work with Autonomous Transactions" on page 6-37.

procedure_name
A user-defined procedure.

type_definition
Specifies a user-defined datatype. For the syntax of `type_definition`, see "Block Declaration" on page 13-8.

:= | DEFAULT
Initializes `IN` parameters to default values, if they are not specified when the procedure is called.

Usage Notes

A procedure is called as a PL/SQL statement. For example, the procedure `raise_salary` might be called as follows:

```
raise_salary(emp_num, amount);
```

Inside a procedure, an `IN` parameter acts like a constant; you cannot assign it a value. An `OUT` parameter acts like a local variable; you can change its value and reference the value in any way. An `IN OUT` parameter acts like an initialized variable; you can assign it a value, which can be assigned to another variable. For summary information about the parameter modes, see Table 8–1 on page 8-9.

Unlike `OUT` and `IN OUT` parameters, `IN` parameters can be initialized to default values. For more information, see "Using Default Values for Subprogram Parameters" on page 8-9.

Before exiting a procedure, explicitly assign values to all `OUT` formal parameters. An `OUT` actual parameter can have a value before the subprogram is called. However, when you call the subprogram, the value is lost unless you specify the compiler hint `NOCOPY` or the subprogram exits with an unhandled exception.

You can write the procedure spec and body as a unit. Or, you can separate the procedure spec from its body. That way, you can hide implementation details by placing the procedure in a package. You can define procedures in a package body without declaring their specs in the package spec. However, such procedures can be called only from inside the package. At least one statement must appear in the executable part of a procedure. The `NULL` statement meets this requirement.

Examples

For examples, see the following:

Example 1–12, "Creating a Stored Subprogram" on page 1-13
Example 1–13, "Creating a Package and Package Body" on page 1-14

Example 1–14, "Calling a Procedure in a Package" on page 1-15
Example 9–3, "Creating the emp_admin Package" on page 9-6

Related Topics

"Collection Methods" on page 13-20
"Function Declaration" on page 13-59
"Package Declaration" on page 13-85

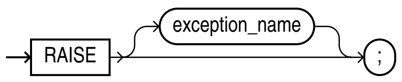
RAISE Statement

The RAISE statement stops normal execution of a PL/SQL block or subprogram and transfers control to an exception handler.

RAISE statements can raise predefined exceptions, such as ZERO_DIVIDE or NO_DATA_FOUND, or user-defined exceptions whose names you decide. For more information, see "Defining Your Own PL/SQL Exceptions" on page 10-5.

Syntax

raise statement ::=



Keyword and Parameter Description

exception_name

A predefined or user-defined exception. For a list of the predefined exceptions, see "Summary of Predefined PL/SQL Exceptions" on page 10-4.

Usage Notes

PL/SQL blocks and subprograms should RAISE an exception only when an error makes it impractical to continue processing. You can code a RAISE statement for a given exception anywhere within the scope of that exception.

When an exception is raised, if PL/SQL cannot find a handler for it in the current block, the exception propagates to successive enclosing blocks, until a handler is found or there are no more blocks to search. If no handler is found, PL/SQL returns an `unhandled exception` error to the host environment.

In an exception handler, you can omit the exception name in a RAISE statement, which raises the current exception again. This technique allows you to take some initial corrective action (perhaps just logging the problem), then pass control to another handler that does more extensive correction. When an exception is reraised, the first block searched is the enclosing block, not the current block.

Examples

For examples, see the following:

Example 1–12, "Creating a Stored Subprogram" on page 1-13
Example 9–3, "Creating the emp_admin Package" on page 9-6
Example 10–3, "Scope of PL/SQL Exceptions" on page 10-6
Example 10–9, "Reraising a PL/SQL Exception" on page 10-12

Related Topics

"Exception Definition" on page 13-39

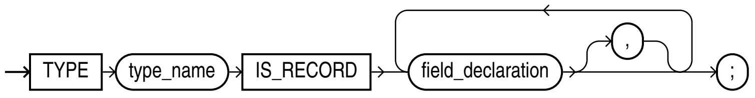
Record Definition

Records are composite variables that can store data values of different types, similar to a `struct` type in C, C++, or Java. For more information, see "Understanding PL/SQL Records" on page 5-5.

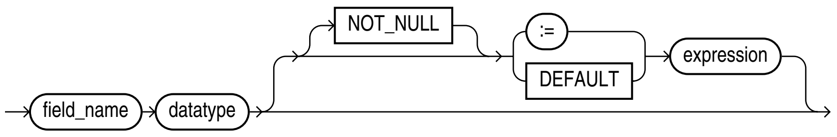
In PL/SQL records are useful for holding data from table rows, or certain columns from table rows. For ease of maintenance, you can declare variables as table%ROWTYPE or cursor%ROWTYPE instead of creating new record types.

Syntax

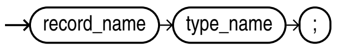
record type definition ::=



record field declaration ::=



record type declaration ::=



Keyword and Parameter Description

datatype

A datatype specifier. For the syntax of `datatype`, see "Constant and Variable Declaration" on page 13-25.

expression

A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. For the syntax of `expression`, see "Expression Definition" on page 13-45. When the declaration is elaborated, the value of `expression` is assigned to the field. The value and the field must have compatible datatypes.

field_name

A field in a user-defined record.

NOT NULL

At run time, trying to assign a null to a field defined as `NOT NULL` raises the predefined exception `VALUE_ERROR`. The constraint `NOT NULL` must be followed by an initialization clause.

record_name

A user-defined record.

type_name

A user-defined record type that was defined using the datatype specifier `RECORD`.

:= | DEFAULT

Initializes fields to default values.

Usage Notes

You can define `RECORD` types and declare user-defined records in the declarative part of any block, subprogram, or package.

A record can be initialized in its declaration. You can use the `%TYPE` attribute to specify the datatype of a field. You can add the `NOT NULL` constraint to any field declaration to prevent the assigning of nulls to that field. Fields declared as `NOT NULL` must be initialized. To reference individual fields in a record, you use dot notation. For example, to reference the `dname` field in the `dept_rec` record, you would use `dept_rec.dname`.

Instead of assigning values separately to each field in a record, you can assign values to all fields at once:

- You can assign one user-defined record to another if they have the same datatype. (Having fields that match exactly is not enough.) You can assign a `%ROWTYPE` record to a user-defined record if their fields match in number and order, and corresponding fields have compatible datatypes.
- You can use the `SELECT` or `FETCH` statement to fetch column values into a record. The columns in the select-list must appear in the same order as the fields in your record.

User-defined records follow the usual scoping and instantiation rules. In a package, they are instantiated when you first reference the package and cease to exist when you end the database session. In a block or subprogram, they are instantiated when you enter the block or subprogram and cease to exist when you exit the block or subprogram.

Like scalar variables, user-defined records can be declared as the formal parameters of procedures and functions. The restrictions that apply to scalar parameters also apply to user-defined records.

You can specify a `RECORD` type in the `RETURN` clause of a function spec. That allows the function to return a user-defined record of the same type. When calling a function that returns a user-defined record, use the following syntax to reference fields in the record:

```
function_name(parameter_list).field_name
```

To reference nested fields, use this syntax:

```
function_name(parameter_list).field_name.nested_field_name
```

If the function takes no parameters, code an empty parameter list. The syntax follows:

```
function_name().field_name
```

Examples

For examples, see the following:

Example 1–16, "Declaring a Record Type" on page 1-17
Example 5–8, "VARRAY of Records" on page 5-9
Example 5–20, "Assigning Values to VARRAYs with Complex Datatypes" on page 5-15
Example 5–21, "Assigning Values to Tables with Complex Datatypes" on page 5-15
Example 5–41, "Declaring and Initializing a Simple Record Type" on page 5-29
Example 5–42, "Declaring and Initializing Record Types" on page 5-29
Example 5–44, "Returning a Record from a Function" on page 5-31
Example 5–45, "Using a Record as Parameter to a Procedure" on page 5-31
Example 5–46, "Declaring a Nested Record" on page 5-31
Example 5–47, "Assigning Default Values to a Record" on page 5-32
Example 5–50, "Inserting a PL/SQL Record Using %ROWTYPE" on page 5-34
Example 5–51, "Updating a Row Using a Record" on page 5-34
Example 5–52, "Using the RETURNING Clause with a Record" on page 5-35
Example 5–53, "Using BULK COLLECT With a SELECT INTO Statement" on page 5-36
Example 6–26, "Cursor Variable Returning a Record Type" on page 6-21
Example 9–3, "Creating the emp_admin Package" on page 9-6

Related Topics

"Collection Definition" on page 13-17
"Function Declaration" on page 13-59
"Package Declaration" on page 13-85
"Procedure Declaration" on page 13-90

RESTRICT_REFERENCES Pragma

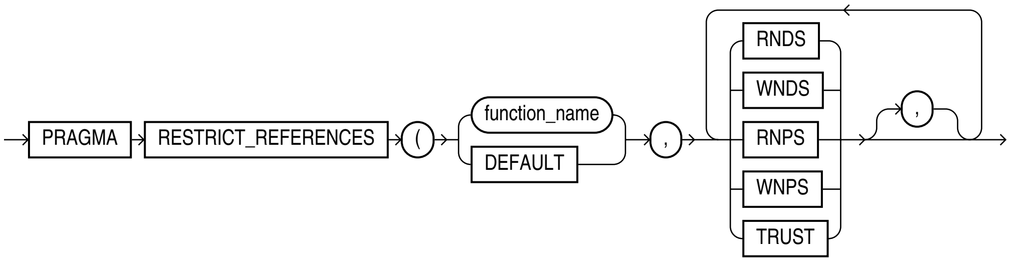
To be callable from SQL statements, a stored function must obey certain purity rules, which control side-effects. See "Controlling Side Effects of PL/SQL Subprograms" on page 8-23. The fewer side-effects a function has, the better it can be optimized within a query, particular when the `PARALLEL_ENABLE` or `DETERMINISTIC` hints are used. The same rules that apply to the function itself also apply to any functions or procedures that it calls.

If any SQL statement inside the function body violates a rule, you get an error at run time (when the statement is parsed). To check for violations of the rules at compile time, you can use the compiler directive `PRAGMA RESTRICT_REFERENCES`. This pragma asserts that a function does not read and/or write database tables and/or package variables. Functions that do any of these read or write operations are difficult to optimize, because any call might produce different results or encounter errors.

For more information, see *Oracle Database Application Developer's Guide - Fundamentals*.

Syntax

restrict_references pragma ::=



Keyword and Parameter Description

DEFAULT

Specifies that the pragma applies to all subprograms in the package spec or object type spec. You can still declare the pragma for individual subprograms. Such pragmas override the default pragma.

function_name

A user-defined function or procedure.

PRAGMA

Signifies that the statement is a compiler directive. Pragmas are processed at compile time, not at run time. They do not affect the meaning of a program; they convey information to the compiler.

RNDS

Asserts that the subprogram reads no database state (does not query database tables).

RNPS
Asserts that the subprogram reads no package state (does not reference the values of packaged variables)

TRUST
Asserts that the subprogram can be trusted not to violate one or more rules. This value is needed for functions written in C or Java that are called from PL/SQL, since PL/SQL cannot verify them at run time.

WNDS
Asserts that the subprogram writes no database state (does not modify tables).

WNPS
Asserts that the subprogram writes no package state (does not change the values of packaged variables).

Usage Notes

You can declare the pragma `RESTRICT_REFERENCES` only in a package spec or object type spec. You can specify up to four constraints (`RNDS`, `RNPS`, `WNDS`, `WNPS`) in any order. To call a function from parallel queries, you must specify all four constraints. No constraint implies another. Typically, this pragma is specified for functions. If a function calls procedures, then specify the pragma for those procedures as well.

When you specify `TRUST`, the function body is not checked for violations of the constraints listed in the pragma. The function is trusted not to violate them. Skipping these checks can improve performance.

If you specify `DEFAULT` instead of a subprogram name, the pragma applies to all subprograms in the package spec or object type spec (including the system-defined constructor for object types). You can still declare the pragma for individual subprograms, overriding the default pragma.

A `RESTRICT_REFERENCES` pragma can apply to only one subprogram declaration. A pragma that references the name of overloaded subprograms always applies to the most recent subprogram declaration.

Examples

For examples, see the following:

Example 6–48, "Calling an Autonomous Function" on page 6-42

Related Topics

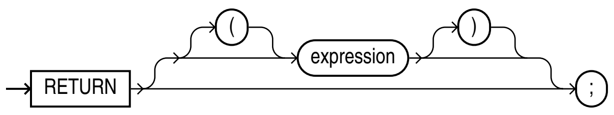
"AUTONOMOUS_TRANSACTION Pragma" on page 13-6
"EXCEPTION_INIT Pragma" on page 13-38
"SERIALLY_REUSABLE Pragma" on page 13-111

RETURN Statement

The RETURN statement immediately completes the execution of a subprogram and returns control to the caller. Execution resumes with the statement following the subprogram call. In a function, the RETURN statement also sets the function identifier to the return value. See "Using the RETURN Statement" on page 8-5.

Syntax

return statement ::=



Keyword and Parameter Description

expression

A combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. When the RETURN statement is executed, the value of expression is assigned to the function identifier.

Usage Notes

The RETURN statement is different than the RETURN clause in a function spec, which specifies the datatype of the return value.

A subprogram can contain several RETURN statements. Executing any of them completes the subprogram immediately. The RETURN statement might not be positioned as the last statement in the subprogram. The RETURN statement can be used in an anonymous block to exit the block and all enclosing blocks, but the RETURN statement cannot contain an expression.

In procedures, a RETURN statement cannot contain an expression. The statement just returns control to the caller before the normal end of the procedure is reached. In functions, a RETURN statement must contain an expression, which is evaluated when the RETURN statement is executed. The resulting value is assigned to the function identifier. In functions, there must be at least one execution path that leads to a RETURN statement. Otherwise, PL/SQL raises an exception at run time.

Examples

For examples, see the following:

Example 1–13, "Creating a Package and Package Body" on page 1-14
Example 2–15, "Using a Subprogram Name for Name Resolution" on page 2-15
Example 5–44, "Returning a Record from a Function" on page 5-31
Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38
Example 6–48, "Calling an Autonomous Function" on page 6-42
Example 9–3, "Creating the emp_admin Package" on page 9-6

Related Topics

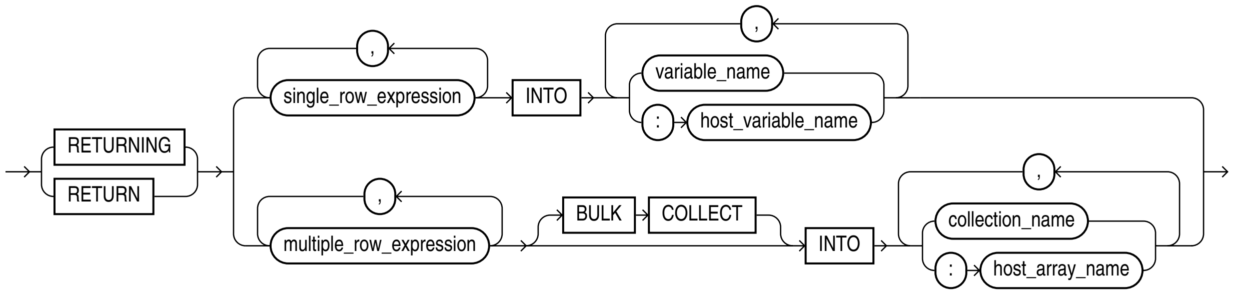
"Function Declaration" on page 13-59

RETURNING INTO Clause

The returning clause specifies the values return from `DELETE`, `EXECUTE IMMEDIATE`, `INSERT`, and `UPDATE` statements. You can retrieve the column values into individual variables or into collections. You cannot use the `RETURNING` clause for remote or parallel deletes. If the statement does not affect any rows, the values of the variables specified in the `RETURNING` clause are undefined.

Syntax

returning clause ::=



Keyword and Parameter Description

BULK COLLECT

Stores result values in one or more collections, for faster queries than loops with `FETCH` statements. For more information, see "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8.

collection_name

A declared collection into which `select_item` values are fetched. For each `select_item`, there must be a corresponding, type-compatible collection in the list.

host_array_name

An array (declared in a PL/SQL host environment and passed to PL/SQL as a bind variable) into which `select_item` values are fetched. For each `select_item`, there must be a corresponding, type-compatible array in the list. Host arrays must be prefixed with a colon.

host_variable_name

A cursor variable declared in a PL/SQL host environment and passed to PL/SQL as a bind variable. The datatype of the host cursor variable is compatible with the return type of any PL/SQL cursor variable. Host variables must be prefixed with a colon.

INTO ...

Used only for single-row queries, this clause specifies the variables or record into which column values are retrieved. For each value retrieved by the query, there must be a corresponding, type-compatible variable or field in the `INTO` clause.

multiple_row_expression
Expression that returns multiple rows of a table.

RETURNING | RETURN
Used only for DML statements that have a RETURNING clause (without a BULK COLLECT clause), this clause specifies the bind variables into which column values are returned. For each value returned by the DML statement, there must be a corresponding, type-compatible variable in the RETURNING INTO clause

single_row_expression
Expression that returns a single row of a table.

variable_name
A variable that stores a selected column value.

Usage

For DML statements that have a `RETURNING` clause, you can place `OUT` arguments in the `RETURNING INTO` clause without specifying the parameter mode, which, by definition, is `OUT`. If you use both the `USING` clause and the `RETURNING INTO` clause, the `USING` clause can contain only `IN` arguments.

At run time, bind arguments replace corresponding placeholders in the dynamic string. Every placeholder must be associated with a bind argument in the `USING` clause and/or `RETURNING INTO` clause. You can use numeric, character, and string literals as bind arguments, but you cannot use Boolean literals (`TRUE`, `FALSE`, and `NULL`). To pass nulls to the dynamic string, you must use a workaround. See "Passing Nulls to Dynamic SQL" on page 7-10.

Dynamic SQL supports all the SQL datatypes. For example, define variables and bind arguments can be collections, `LOB`s, instances of an object type, and refs. Dynamic SQL does not support PL/SQL-specific types. For example, define variables and bind arguments cannot be `BOOLEAN`s or index-by tables. The only exception is that a PL/SQL record can appear in the `INTO` clause.

Examples

For examples, see the following:

Example 5–52, "Using the RETURNING Clause with a Record" on page 5-35
Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 7–5, "Dynamic SQL with RETURNING BULK COLLECT INTO Clause" on page 7-6
Example 7–6, "Dynamic SQL Inside FORALL Statement" on page 7-7
Example 11–15, "Using BULK COLLECT With the RETURNING INTO Clause" on page 11-18
Example 11–16, "Using FORALL With BULK COLLECT" on page 11-19

Related Topics

"DELETE Statement" on page 13-36
"SELECT INTO Statement" on page 13-107
"UPDATE Statement" on page 13-121

ROLLBACK Statement

The ROLLBACK statement is the inverse of the COMMIT statement. It undoes some or all database changes made during the current transaction. For more information, see "Overview of Transaction Processing in PL/SQL" on page 6-30.

The SQL ROLLBACK statement can be embedded as static SQL in PL/SQL. For syntax details on the SQL ROLLBACK statement, see *Oracle Database SQL Reference*.

Usage Notes

All savepoints marked after the savepoint to which you roll back are erased. The savepoint to which you roll back is not erased. For example, if you mark savepoints A, B, C, and D in that order, then roll back to savepoint B, only savepoints C and D are erased.

An implicit savepoint is marked before executing an INSERT, UPDATE, or DELETE statement. If the statement fails, a rollback to this implicit savepoint is done. Normally, just the failed SQL statement is rolled back, not the whole transaction. If the statement raises an unhandled exception, the host environment determines what is rolled back.

Examples

For examples, see the following:

Example 2–14, "Using a Block Label for Name Resolution" on page 2-14
Example 6–37, "Using ROLLBACK" on page 6-31
Example 6–38, "Using SAVEPOINT With ROLLBACK" on page 6-31
Example 6–39, "Reusing a SAVEPOINT With ROLLBACK" on page 6-32

Related Topics

"COMMIT Statement" on page 13-24
"SAVEPOINT Statement" on page 13-106

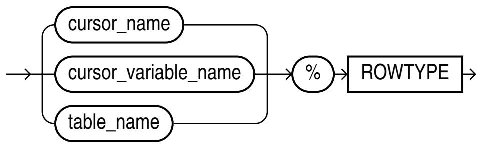
%ROWTYPE Attribute

The `%ROWTYPE` attribute provides a record type that represents a row in a database table. The record can store an entire row of data selected from the table or fetched from a cursor or cursor variable. Variables declared using `%ROWTYPE` are treated like those declared using a datatype name. You can use the `%ROWTYPE` attribute in variable declarations as a datatype specifier.

Fields in a record and corresponding columns in a row have the same names and datatypes. However, fields in a `%ROWTYPE` record do not inherit constraints, such as the `NOT NULL` column or check constraint, or default values. For more information, see "Using the %ROWTYPE Attribute" on page 2-11.

Syntax

%rowtype attribute ::=



Keyword and Parameter Description

cursor_name

An explicit cursor previously declared within the current scope.

cursor_variable_name

A PL/SQL strongly typed cursor variable, previously declared within the current scope.

table_name

A database table or view that must be accessible when the declaration is elaborated.

Usage Notes

Declaring variables as the type *table_name*`%ROWTYPE` is a convenient way to transfer data between database tables and PL/SQL. You create a single variable rather than a separate variable for each column. You do not need to know the name of every column. You refer to the columns using their real names instead of made-up variable names. If columns are later added to or dropped from the table, your code can keep working without changes.

To reference a field in the record, use dot notation (`record_name.field_name`). You can read or write one field at a time this way.

There are two ways to assign values to all fields in a record at once:

- First, PL/SQL allows aggregate assignment between entire records if their declarations refer to the same table or cursor.
- You can assign a list of column values to a record by using the `SELECT` or `FETCH` statement. The column names must appear in the order in which they were

declared. Select-items fetched from a cursor associated with `%ROWTYPE` must have simple names or, if they are expressions, must have aliases.

Examples

For examples, see the following:

Example 1–6, "Using %ROWTYPE with an Explicit Cursor" on page 1-9
Example 2–8, "Using %ROWTYPE With Table Rows" on page 2-11
Example 2–9, "Using the %ROWTYPE Attribute" on page 2-11
Example 2–10, "Assigning Values to a Record With a %ROWTYPE Declaration" on page 2-12
Example 3–11, "Using SUBTYPE With %TYPE and %ROWTYPE" on page 3-20
Example 5–7, "Specifying Collection Element Types with %TYPE and %ROWTYPE" on page 5-9
Example 5–20, "Assigning Values to VARRAYs with Complex Datatypes" on page 5-15
Example 5–42, "Declaring and Initializing Record Types" on page 5-29
Example 6–24, "Cursor Variable Returning a %ROWTYPE Variable" on page 6-21
Example 6–25, "Using the %ROWTYPE Attribute to Provide the Datatype" on page 6-21
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

"Constant and Variable Declaration" on page 13-25
"Cursor Declaration" on page 13-33
"Cursor Variables" on page 13-30
"FETCH Statement" on page 13-53

SAVEPOINT Statement

The SAVEPOINT statement names and marks the current point in the processing of a transaction. With the ROLLBACK TO statement, savepoints undo parts of a transaction instead of the whole transaction. For more information, see "Overview of Transaction Processing in PL/SQL" on page 6-30.

The SQL SAVEPOINT statement can be embedded as static SQL in PL/SQL. For syntax details on the SQL SAVEPOINT statement, see *Oracle Database SQL Reference*.

Usage Notes

A simple rollback or commit erases all savepoints. When you roll back to a savepoint, any savepoints marked after that savepoint are erased. The savepoint to which you roll back remains.

You can reuse savepoint names within a transaction. The savepoint moves from its old position to the current point in the transaction.

If you mark a savepoint within a recursive subprogram, new instances of the SAVEPOINT statement are executed at each level in the recursive descent. You can only roll back to the most recently marked savepoint.

An implicit savepoint is marked before executing an INSERT, UPDATE, or DELETE statement. If the statement fails, a rollback to the implicit savepoint is done. Normally, just the failed SQL statement is rolled back, not the whole transaction; if the statement raises an unhandled exception, the host environment (such as SQL*Plus) determines what is rolled back.

Examples

For examples, see the following:

Example 6–38, "Using SAVEPOINT With ROLLBACK" on page 6-31
Example 6–39, "Reusing a SAVEPOINT With ROLLBACK" on page 6-32

Related Topics

"COMMIT Statement" on page 13-24
"ROLLBACK Statement" on page 13-103

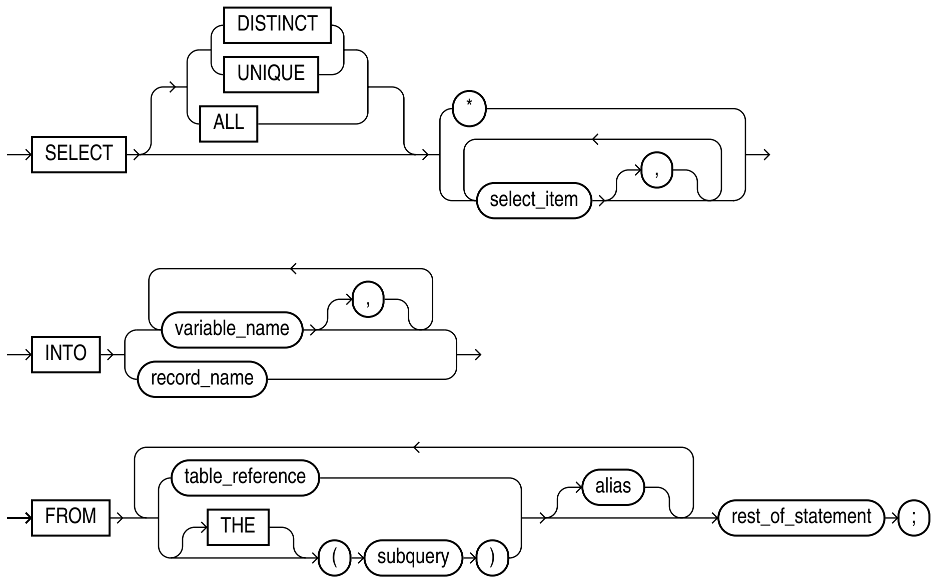
SELECT INTO Statement

The `SELECT INTO` statement retrieves data from one or more database tables, and assigns the selected values to variables or collections. For a full description of the `SELECT` SQL statement, see *Oracle Database SQL Reference*.

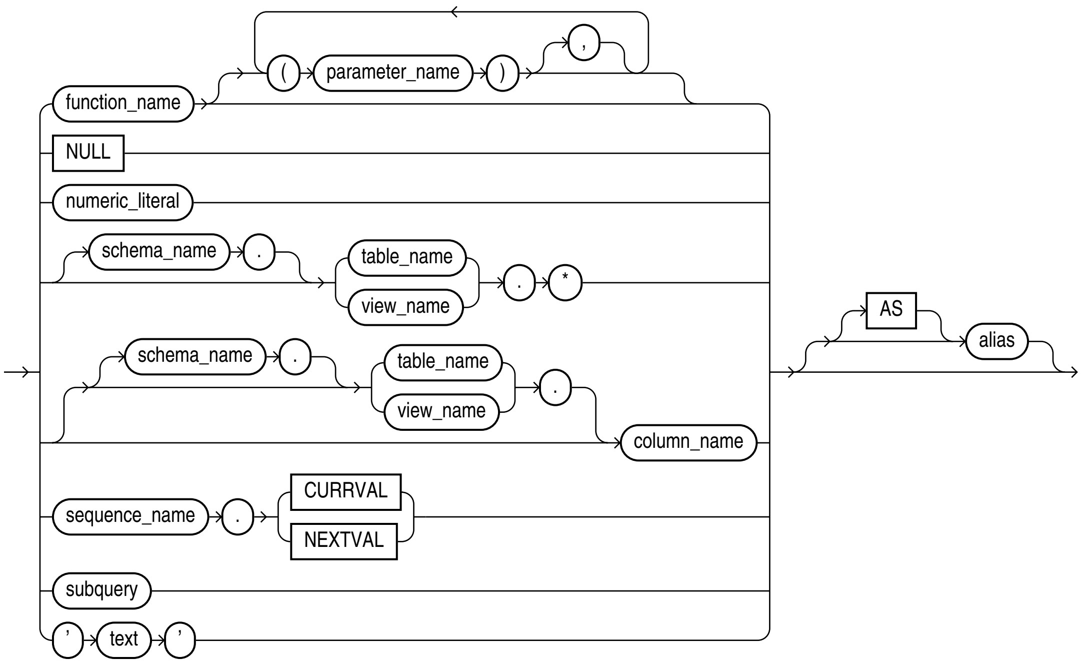
In its default usage (`SELECT ... INTO`), this statement retrieves one or more columns from a single row. In its bulk usage (`SELECT ... BULK COLLECT INTO`), this statement retrieves an entire result set at once.

Syntax

select into statement ::=



select item ::=



Keyword and Parameter Description

alias

Another (usually short) name for the referenced column, table, or view.

BULK COLLECT

Stores result values in one or more collections, for faster queries than loops with `FETCH` statements. For more information, see "Reducing Loop Overhead for DML Statements and Queries with Bulk SQL" on page 11-8.

collection_name

A declared collection into which `select_item` values are fetched. For each `select_item`, there must be a corresponding, type-compatible collection in the list.

function_name

A user-defined function.

host_array_name

An array (declared in a PL/SQL host environment and passed to PL/SQL as a bind variable) into which `select_item` values are fetched. For each `select_item`, there must be a corresponding, type-compatible array in the list. Host arrays must be prefixed with a colon.

numeric_literal

A literal that represents a number or a value implicitly convertible to a number.

parameter_name

A formal parameter of a user-defined function.

record_name
A user-defined or %ROWTYPE record into which rows of values are fetched. For each select_item value returned by the query, there must be a corresponding, type-compatible field in the record.

rest_of_statement
Anything that can follow the FROM clause in a SQL SELECT statement (except the SAMPLE clause).

schema_name
The schema containing the table or view. If you omit schema_name, Oracle assumes the table or view is in your schema.

subquery
A SELECT statement that provides a set of rows for processing. Its syntax is similar to that of select_into_statement without the INTO clause.

table_reference
A table or view that must be accessible when you execute the SELECT statement, and for which you must have SELECT privileges. For the syntax of table_reference, see "DELETE Statement" on page 13-36.

TABLE (subquery2)
The operand of TABLE is a SELECT statement that returns a single column value, which must be a nested table or a varray. Operator TABLE informs Oracle that the value is a collection, not a scalar value.

variable_name
A previously declared variable into which a select_item value is fetched. For each select_item value returned by the query, there must be a corresponding, type-compatible variable in the list.

Usage Notes
By default, a SELECT INTO statement must return only one row. Otherwise, PL/SQL raises the predefined exception TOO_MANY_ROWS and the values of the variables in the INTO clause are undefined. Make sure your WHERE clause is specific enough to only match one row

If no rows are returned, PL/SQL raises NO_DATA_FOUND. You can guard against this exception by selecting the result of an aggregate function, such as COUNT(*) or AVG(), where practical. These functions are guaranteed to return a single value, even if no rows match the condition.

A SELECT ... BULK COLLECT INTO statement can return multiple rows. You must set up collection variables to hold the results. You can declare associative arrays or nested tables that grow as needed to hold the entire result set.

The implicit cursor SQL and its attributes %NOTFOUND, %FOUND, %ROWCOUNT, and %ISOPEN provide information about the execution of a SELECT INTO statement.

Examples
Example 13–4 shows various ways to use the SELECT INTO statement.

Example 13–4 Using the SELECT INTO Statement

```
DECLARE
  deptid        employees.department_id%TYPE;
  jobid         employees.job_id%TYPE;
  emp_rec       employees%ROWTYPE;
  TYPE emp_tab IS TABLE OF employees%ROWTYPE INDEX BY PLS_INTEGER;
  all_emps      emp_tab;
BEGIN
  SELECT department_id, job_id INTO deptid, jobid
     FROM employees WHERE employee_id = 140;
  IF SQL%FOUND THEN
    DBMS_OUTPUT.PUT_LINE('Dept Id: ' || deptid || ', Job Id: ' || jobid);
  END IF;
  SELECT * INTO emp_rec FROM employees WHERE employee_id = 105;
  SELECT * BULK COLLECT INTO all_emps FROM employees;
  DBMS_OUTPUT.PUT_LINE('Number of rows: ' || SQL%ROWCOUNT);
END;
/
```

For examples, see the following:

Example 1–3, "Assigning Values to Variables by SELECTing INTO" on page 1-6
Example 1–4, "Assigning Values to Variables as Parameters of a Subprogram" on page 1-7
Example 1–9, "Using WHILE-LOOP for Control" on page 1-11
Example 5–51, "Updating a Row Using a Record" on page 5-34
Example 5–52, "Using the RETURNING Clause with a Record" on page 5-35
Example 6–5, "Using CURRVAL and NEXTVAL" on page 6-4
Example 6–37, "Using ROLLBACK" on page 6-31
Example 6–38, "Using SAVEPOINT With ROLLBACK" on page 6-31
Example 6–43, "Declaring an Autonomous Function in a Package" on page 6-38
Example 7–1, "Examples of Dynamic SQL" on page 7-3
Example 7–2, "Dynamic SQL Procedure that Accepts Table Name and WHERE Clause" on page 7-4

Related Topics

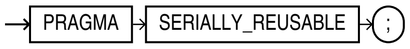
"Assignment Statement" on page 13-3
"FETCH Statement" on page 13-53
"%ROWTYPE Attribute" on page 13-104

SERIALLY_REUSABLE Pragma

The pragma `SERIALLY_REUSABLE` indicates that the package state is needed only for the duration of one call to the server. An example could be an OCI call to the database or a stored procedure call through a database link. After this call, the storage for the package variables can be reused, reducing the memory overhead for long-running sessions. For more information, see *Oracle Database Application Developer's Guide - Fundamentals*.

Syntax

pragma serially_resuable ::=



Keyword and Parameter Description

PRAGMA

Signifies that the statement is a pragma (compiler directive). Pragmas are processed at compile time, not at run time. They do not affect the meaning of a program; they simply convey information to the compiler.

Usage Notes

This pragma is appropriate for packages that declare large temporary work areas that are used once and not needed during subsequent database calls in the same session.

You can mark a bodiless package as serially reusable. If a package has a spec and body, you must mark both. You cannot mark only the body.

The global memory for serially reusable packages is pooled in the System Global Area (SGA), not allocated to individual users in the User Global Area (UGA). That way, the package work area can be reused. When the call to the server ends, the memory is returned to the pool. Each time the package is reused, its public variables are initialized to their default values or to `NULL`.

Serially reusable packages cannot be accessed from database triggers or other PL/SQL subprograms that are called from SQL statements. If you try, Oracle generates an error.

Examples

Example 13–5 creates a serially reusable package.

Example 13–5 Creating a Serially Reusable Package

```
CREATE PACKAGE pkg1 IS
   PRAGMA SERIALLY_REUSABLE;
   num NUMBER := 0;
   PROCEDURE init_pkg_state(n NUMBER);
   PROCEDURE print_pkg_state;
END pkg1;
/
CREATE PACKAGE BODY pkg1 IS
   PRAGMA SERIALLY_REUSABLE;
   PROCEDURE init_pkg_state (n NUMBER) IS
   BEGIN
      pkg1.num := n;
   END;
   PROCEDURE print_pkg_state IS
   BEGIN
      DBMS_OUTPUT.PUT_LINE('Num: ' || pkg1.num);
   END;
END pkg1;
/
```

Related Topics

"AUTONOMOUS_TRANSACTION Pragma" on page 13-6
"EXCEPTION_INIT Pragma" on page 13-38
"RESTRICT_REFERENCES Pragma" on page 13-98

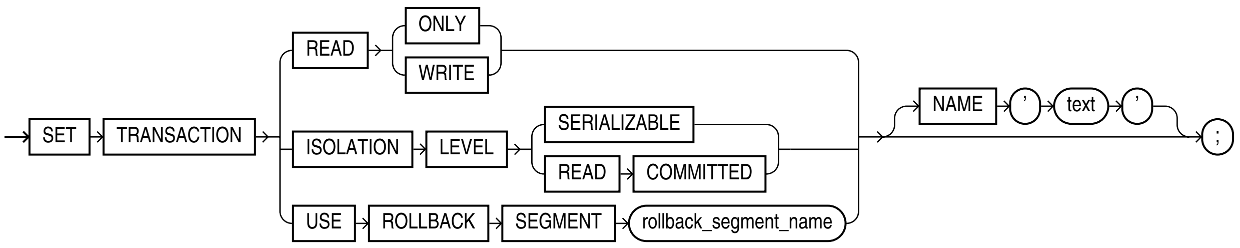
SET TRANSACTION Statement

The SET TRANSACTION statement begins a read-only or read-write transaction, establishes an isolation level, or assigns the current transaction to a specified rollback segment. Read-only transactions are useful for running multiple queries against one or more tables while other users update the same tables. For more information, see "Setting Transaction Properties with SET TRANSACTION" on page 6-33.

For additional information on the SET TRANSACTION SQL statement, see *Oracle Database SQL Reference*.

Syntax

set transaction ::=



Keyword and Parameter Description

READ ONLY

Establishes the current transaction as read-only, so that subsequent queries see only changes committed before the transaction began. The use of READ ONLY does not affect other users or transactions.

READ WRITE

Establishes the current transaction as read-write. The use of READ WRITE does not affect other users or transactions. If the transaction executes a data manipulation statement, Oracle assigns the transaction to a rollback segment.

ISOLATION LEVEL

Specifies how to handle transactions that modify the database.

SERIALIZABLE: If a serializable transaction tries to execute a SQL data manipulation statement that modifies any table already modified by an uncommitted transaction, the statement fails.

To enable SERIALIZABLE mode, your DBA must set the Oracle initialization parameter COMPATIBLE to 7.3.0 or higher.

READ COMMITTED: If a transaction includes SQL data manipulation statements that require row locks held by another transaction, the statement waits until the row locks are released.

USE ROLLBACK SEGMENT

Assigns the current transaction to the specified rollback segment and establishes the transaction as read-write. You cannot use this parameter with the READ ONLY parameter in the same transaction because read-only transactions do not generate rollback information.

NAME

Specifies a name or comment text for the transaction. This is better than using the `COMMIT COMMENT` feature because the name is available while the transaction is running, making it easier to monitor long-running and in-doubt transactions.

Usage Notes

The `SET TRANSACTION` statement must be the first SQL statement in the transaction and can appear only once in the transaction.

Examples

For examples, see the following:

Example 6–40, "Using SET TRANSACTION to Begin a Read-only Transaction" on page 6-33

Related Topics

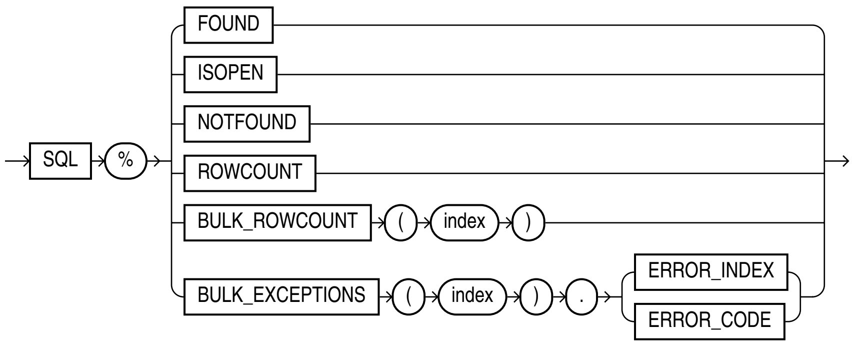
"COMMIT Statement" on page 13-24
"ROLLBACK Statement" on page 13-103
"SAVEPOINT Statement" on page 13-106

SQL Cursor

Oracle implicitly opens a cursor to process each SQL statement not associated with an explicit cursor. In PL/SQL, you can refer to the most recent implicit cursor as the `SQL` cursor, which always has the attributes `%FOUND`, `%ISOPEN`, `%NOTFOUND`, and `%ROWCOUNT`. They provide information about the execution of data manipulation statements. The `SQL` cursor has additional attributes, `%BULK_ROWCOUNT` and `%BULK_EXCEPTIONS`, designed for use with the `FORALL` statement. For more information, see "Querying Data with PL/SQL" on page 6-14.

Syntax

sql cursor ::=



Keyword and Parameter Description

%BULK_ROWCOUNT

A composite attribute designed for use with the `FORALL` statement. This attribute acts like an index-by table. Its *i*th element stores the number of rows processed by the *i*th execution of an `UPDATE` or `DELETE` statement. If the *i*th execution affects no rows, `%BULK_ROWCOUNT(i)` returns zero.

%BULK_EXCEPTIONS

An associative array that stores information about any exceptions encountered by a `FORALL` statement that uses the `SAVE EXCEPTIONS` clause. You must loop through its elements to determine where the exceptions occurred and what they were. For each index value `i` between 1 and `SQL%BULK_EXCEPTIONS.COUNT`, `SQL%BULK_EXCEPTIONS(i).ERROR_INDEX` specifies which iteration of the `FORALL` loop caused an exception. `SQL%BULK_EXCEPTIONS(i).ERROR_CODE` specifies the Oracle error code that corresponds to the exception.

%FOUND

Returns `TRUE` if an `INSERT`, `UPDATE`, or `DELETE` statement affected one or more rows or a `SELECT INTO` statement returned one or more rows. Otherwise, it returns `FALSE`.

%ISOPEN

Always returns `FALSE`, because Oracle closes the `SQL` cursor automatically after executing its associated SQL statement.

%NOTFOUND

The logical opposite of `%FOUND`. It returns `TRUE` if an `INSERT`, `UPDATE`, or `DELETE` statement affected no rows, or a `SELECT INTO` statement returned no rows. Otherwise, it returns `FALSE`.

%ROWCOUNT

Returns the number of rows affected by an `INSERT`, `UPDATE`, or `DELETE` statement, or returned by a `SELECT INTO` statement.

SQL

The name of the Oracle implicit cursor.

Usage Notes

You can use cursor attributes in procedural statements but not in SQL statements. Before Oracle opens the `SQL` cursor automatically, the implicit cursor attributes return `NULL`. The values of cursor attributes always refer to the most recently executed SQL statement, wherever that statement appears. It might be in a different scope. If you want to save an attribute value for later use, assign it to a variable immediately.

If a `SELECT INTO` statement fails to return a row, PL/SQL raises the predefined exception `NO_DATA_FOUND`, whether you check `SQL%NOTFOUND` on the next line or not. A `SELECT INTO` statement that calls a SQL aggregate function never raises `NO_DATA_FOUND`, because those functions always return a value or a `NULL`. In such cases, `SQL%NOTFOUND` returns `FALSE`. `%BULK_ROWCOUNT` is not maintained for bulk inserts because that would be redundant as a typical insert affects only one row. See "Counting Rows Affected by FORALL with the %BULK_ROWCOUNT Attribute" on page 11-12.

You can use the scalar attributes `%FOUND`, `%NOTFOUND`, and `%ROWCOUNT` with bulk binds. For example, `%ROWCOUNT` returns the total number of rows processed by all executions of the SQL statement. Although `%FOUND` and `%NOTFOUND` refer only to the last execution of the SQL statement, you can use `%BULK_ROWCOUNT` to infer their values for individual executions. For example, when `%BULK_ROWCOUNT(i)` is zero, `%FOUND` and `%NOTFOUND` are `FALSE` and `TRUE`, respectively.

Examples

For examples, see the following:

Example 6–7, "Using SQL%FOUND" on page 6-7
Example 6–8, "Using SQL%ROWCOUNT" on page 6-7
Example 6–10, "Fetching With a Cursor" on page 6-10
Example 6–14, "Using %FOUND" on page 6-12
Example 6–15, "Using %ISOPEN" on page 6-12
Example 6–16, "Using %NOTFOUND" on page 6-13
Example 6–17, "Using %ROWCOUNT" on page 6-13
Example 11–7, "Using %BULK_ROWCOUNT With the FORALL Statement" on page 11-13
Example 13–4, "Using the SELECT INTO Statement" on page 13-110

Related Topics

"Cursor Declaration" on page 13-33
"Cursor Attributes" on page 13-28
"FORALL Statement" on page 13-56

SQLCODE Function

The function SQLCODE returns the number code of the most recent exception.

For internal exceptions, SQLCODE returns the number of the associated Oracle error. The number that SQLCODE returns is negative unless the Oracle error is *no data found*, in which case SQLCODE returns +100. For user-defined exceptions, SQLCODE returns +1, or a value you assign if the exception is associated with an Oracle error number through pragma EXCEPTION_INIT.

Syntax

sqlcode function ::=

Usage Notes

SQLCODE is only useful in an exception handler. Outside a handler, SQLCODE always returns 0. SQLCODE is especially useful in the OTHERS exception handler, because it lets you identify which internal exception was raised. You cannot use SQLCODE directly in a SQL statement. Assign the value of SQLCODE to a local variable first.

When using pragma RESTRICT_REFERENCES to assert the purity of a stored function, you cannot specify the constraints WNPS and RNPS if the function calls SQLCODE.

Examples

Example 13–6 shows the use of SQLCODE and SQLERRM.

Example 13–6 Using SQLCODE and SQLERRM

```
DECLARE
   name employees.last_name%TYPE;
   v_code NUMBER;
   v_errm VARCHAR2(64);
BEGIN
   SELECT last_name INTO name FROM employees WHERE employee_id = 1000;
   EXCEPTION
      WHEN OTHERS THEN
         v_code := SQLCODE;
         v_errm := SUBSTR(SQLERRM, 1 , 64);
         DBMS_OUTPUT.PUT_LINE('The error code is ' || v_code || '- ' || v_errm);
END;
/
```

For examples, see the following:

Example 10–11, "Displaying SQLCODE and SQLERRM" on page 10-14

Related Topics

"Exception Definition" on page 13-39
"SQLERRM Function" on page 13-118
"Retrieving the Error Code and Error Message: SQLCODE and SQLERRM" on page 10-14

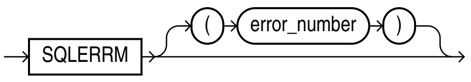
SQLERRM Function

The function SQLERRM returns the error message associated with its error-number argument. If the argument is omitted, it returns the error message associated with the current value of SQLCODE. SQLERRM with no argument is useful only in an exception handler. Outside a handler, SQLERRM with no argument always returns the `normal, successful completion` message. For internal exceptions, SQLERRM returns the message associated with the Oracle error that occurred. The message begins with the Oracle error code.

For user-defined exceptions, SQLERRM returns the message user-defined exception, unless you used the pragma EXCEPTION_INIT to associate the exception with an Oracle error number, in which case SQLERRM returns the corresponding error message. For more information, see "Retrieving the Error Code and Error Message: SQLCODE and SQLERRM" on page 10-14.

Syntax

sqlerrm function ::=



Keyword and Parameter Description

error_number

A valid Oracle error number. For a list of Oracle errors (ones prefixed by ORA-), see *Oracle Database Error Messages*.

Usage Notes

SQLERRM is especially useful in the OTHERS exception handler, where it lets you identify which internal exception was raised. The error number passed to SQLERRM should be negative. Passing a zero to SQLERRM always returns the `ORA-0000: normal, successful completion` message. Passing a positive number to SQLERRM always returns the `User-Defined Exception` message unless you pass `+100`, in which case SQLERRM returns the `ORA-01403: no data found` message.

You cannot use SQLERRM directly in a SQL statement. Assign the value of SQLERRM to a local variable first, as shown in Example 13–6 on page 13-117.

When using pragma RESTRICT_REFERENCES to assert the purity of a stored function, you cannot specify the constraints WNPS and RNPS if the function calls SQLERRM.

Examples

For examples, see the following:

Example 10–11, "Displaying SQLCODE and SQLERRM" on page 10-14
Example 13–6, "Using SQLCODE and SQLERRM" on page 13-117

Related Topics

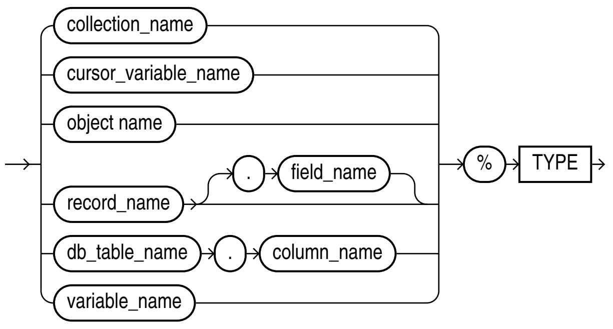
"Exception Definition" on page 13-39
"SQLCODE Function" on page 13-117

%TYPE Attribute

The %TYPE attribute lets use the datatype of a field, record, nested table, database column, or variable in your own declarations, rather than hardcoding the type names. You can use the %TYPE attribute as a datatype specifier when declaring constants, variables, fields, and parameters. If the types that you reference change, your declarations are automatically updated. This technique saves you from making code changes when, for example, the length of a VARCHAR2 column is increased. Note that column constraints, such as the NOT NULL and check constraint, or default values are not inherited by items declared using %TYPE. For more information, see "Using the %TYPE Attribute" on page 2-10.

Syntax

%type attribute ::=



Keyword and Parameter Description

collection_name

A nested table, index-by table, or varray previously declared within the current scope.

cursor_variable_name

A PL/SQL cursor variable previously declared within the current scope. Only the value of another cursor variable can be assigned to a cursor variable.

db_table_name.column_name

A table and column that must be accessible when the declaration is elaborated.

object_name

An instance of an object type, previously declared within the current scope.

record_name

A user-defined or %ROWTYPE record, previously declared within the current scope.

record_name.field_name

A field in a user-defined or %ROWTYPE record, previously declared within the current scope.

variable_name
A variable, previously declared in the same scope.

Usage Notes

The %TYPE attribute is particularly useful when declaring variables, fields, and parameters that refer to database columns. Your code can keep working even when the lengths or types of the columns change.

Examples

For examples, see the following:

Example 1–15, "Using a PL/SQL Collection Type" on page 1-16
Example 2–6, "Using %TYPE With the Datatype of a Variable" on page 2-10
Example 2–7, "Using %TYPE With Table Columns" on page 2-10
Example 2–15, "Using a Subprogram Name for Name Resolution" on page 2-15
Example 2–10, "Assigning Values to a Record With a %ROWTYPE Declaration" on page 2-12
Example 3–11, "Using SUBTYPE With %TYPE and %ROWTYPE" on page 3-20
Example 5–5, "Declaring a Procedure Parameter as a Nested Table" on page 5-8
Example 5–7, "Specifying Collection Element Types with %TYPE and %ROWTYPE" on page 5-9
Example 5–42, "Declaring and Initializing Record Types" on page 5-29
Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 6–13, "Fetching Bulk Data With a Cursor" on page 6-11
Example 13–1, "Declaring and Assigning Values to Variables" on page 13-5

Related Topics

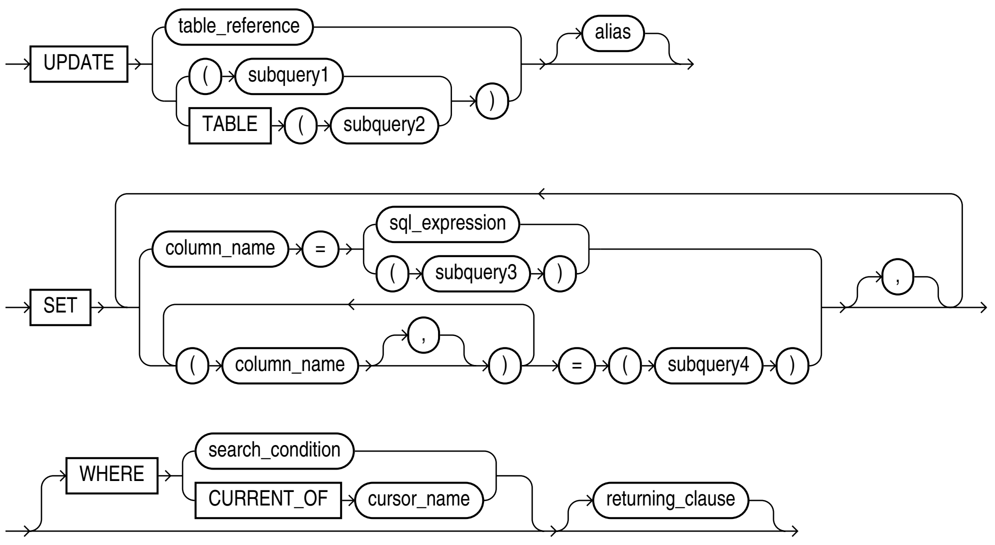
"Constant and Variable Declaration" on page 13-25
"%ROWTYPE Attribute" on page 13-104

UPDATE Statement

The UPDATE statement changes the values of specified columns in one or more rows in a table or view. For a full description of the UPDATE SQL statement, see *Oracle Database SQL Reference*.

Syntax

update statement ::=



Keyword and Parameter Description

alias

Another (usually short) name for the referenced table or view, typically used in the WHERE clause.

column_name

The column (or one of the columns) to be updated. It must be the name of a column in the referenced table or view. A column name cannot be repeated in the column_name list. Column names need not appear in the UPDATE statement in the same order that they appear in the table or view.

returning_clause

Returns values from updated rows, eliminating the need to SELECT the rows afterward. You can retrieve the column values into variables or host variables, or into collections or host arrays. You cannot use the RETURNING clause for remote or parallel updates. If the statement does not affect any rows, the values of the variables specified in the RETURNING clause are undefined. For the syntax of returning_clause, see "RETURNING INTO Clause" on page 13-101.

SET column_name = sql_expression

This clause assigns the value of sql_expression to the column identified by column_name. If sql_expression contains references to columns in the table being updated, the references are resolved in the context of the current row. The old column values are used on the right side of the equal sign.

SET column_name = (subquery3)

Assigns the value retrieved from the database by `subquery3` to the column identified by `column_name`. The subquery must return exactly one row and one column.

SET (column_name, column_name, ...) = (subquery4)

Assigns the values retrieved from the database by `subquery4` to the columns in the `column_name` list. The subquery must return exactly one row that includes all the columns listed. The column values returned by the subquery are assigned to the columns in the column list in order. The first value is assigned to the first column in the list, the second value is assigned to the second column in the list, and so on.

sql_expression

Any valid SQL expression. For more information, see *Oracle Database SQL Reference*.

subquery

A `SELECT` statement that provides a set of rows for processing. Its syntax is like that of `select_into_statement` without the `INTO` clause. See "SELECT INTO Statement" on page 13-107.

table_reference

A table or view that must be accessible when you execute the `UPDATE` statement, and for which you must have `UPDATE` privileges. For the syntax of `table_reference`, see "DELETE Statement" on page 13-36.

TABLE (subquery2)

The operand of `TABLE` is a `SELECT` statement that returns a single column value, which must be a nested table or a varray. Operator `TABLE` informs Oracle that the value is a collection, not a scalar value.

WHERE CURRENT OF cursor_name

Refers to the latest row processed by the `FETCH` statement associated with the specified cursor. The cursor must be `FOR UPDATE` and must be open and positioned on a row. If the cursor is not open, the `CURRENT OF` clause causes an error. If the cursor is open, but no rows have been fetched or the last fetch returned no rows, PL/SQL raises the predefined exception `NO_DATA_FOUND`.

WHERE search_condition

Chooses which rows to update in the database table. Only rows that meet the search condition are updated. If you omit this clause, all rows in the table are updated.

Usage Notes

You can use the `UPDATE WHERE CURRENT OF` statement after a fetch from an open cursor (including fetches done by a cursor `FOR` loop), provided the associated query is `FOR UPDATE`. This statement updates the row that was just fetched.

The implicit cursor `SQL` and the cursor attributes `%NOTFOUND`, `%FOUND`, `%ROWCOUNT`, and `%ISOPEN` let you access useful information about the execution of an `UPDATE` statement.

Examples

Example 13–7 creates a table with correct employee IDs but garbled names. Then it runs an UPDATE statement with a correlated query, to retrieve the correct names from the EMPLOYEES table and fix the names in the new table.

Example 13–7 Using UPDATE With a Subquery

```
-- Create a table with all the right IDs, but messed-up names
CREATE TABLE employee_temp AS
  SELECT employee_id, UPPER(first_name) first_name,
    TRANSLATE(last_name,'aeiou','12345') last_name
    FROM employees;
BEGIN
-- Display the first 5 names to show they're messed up
   FOR person IN (SELECT * FROM employee_temp WHERE ROWNUM < 6)
   LOOP
      DBMS_OUTPUT.PUT_LINE(person.first_name || ' ' || person.last_name);
   END LOOP;
   UPDATE employee_temp SET (first_name, last_name) =
      (SELECT first_name, last_name FROM employees
         WHERE employee_id = employee_temp.employee_id);
   DBMS_OUTPUT.PUT_LINE('*** Updated ' || SQL%ROWCOUNT || ' rows. ***');
-- Display the first 5 names to show they've been fixed up
   FOR person IN (SELECT * FROM employee_temp WHERE ROWNUM < 6)
   LOOP
      DBMS_OUTPUT.PUT_LINE(person.first_name || ' ' || person.last_name);
   END LOOP;
END;
/
```

For examples, see the following:

Example 1–12, "Creating a Stored Subprogram" on page 1-13
Example 4–1, "Using a Simple IF-THEN Statement" on page 4-2
Example 5–51, "Updating a Row Using a Record" on page 5-34
Example 5–52, "Using the RETURNING Clause with a Record" on page 5-35
Example 6–1, "Data Manipulation With PL/SQL" on page 6-1
Example 6–5, "Using CURRVAL and NEXTVAL" on page 6-4
Example 6–6, "Using ROWNUM" on page 6-5
Example 6–38, "Using SAVEPOINT With ROLLBACK" on page 6-31
Example 6–41, "Using CURRENT OF to Update the Latest Row Fetched From a Cursor" on page 6-35
Example 7–1, "Examples of Dynamic SQL" on page 7-3
Example 7–5, "Dynamic SQL with RETURNING BULK COLLECT INTO Clause" on page 7-6
Example 7–6, "Dynamic SQL Inside FORALL Statement" on page 7-7
Example 11–6, "Using Rollbacks With FORALL" on page 11-12
Example 11–9, "Bulk Operation That Continues Despite Exceptions" on page 11-15

Related Topics

"Data Manipulation" on page 6-1
"DELETE Statement" on page 13-36
"FETCH Statement" on page 13-53
"INSERT Statement" on page 13-66

A

Obfuscating PL/SQL Source Code

This appendix describes how to use the standalone `wrap` utility and subprograms of the `DBMS_DDL` package to obfuscate, or wrap, PL/SQL source code. When you obfuscate (hide) PL/SQL units, you can deliver PL/SQL applications without exposing your source code and implementation details.

This appendix contains these topics:

See Also: For information on the `DBMS_DDL` package, see *Oracle Database PL/SQL Packages and Types Reference*

What is Obfuscation?

Obfuscation, or wrapping, of a PL/SQL unit is the process of hiding the PL/SQL source code. Wrapping can be done with the `wrap` utility and `DBMS_DDL` subprograms. The `wrap` utility is run from the command line and processes an input SQL file, such as a SQL*Plus installation script. The `DBMS_DDL` subprograms wrap a single PL/SQL unit, such as a single `CREATE PROCEDURE` command, that has been generated dynamically.

The advantages of obfuscating, or hiding, the source code of PL/SQL units with the `wrap` utility or wrap subprograms of the `DBMS_DDL` package are:

- It is difficult for other developers to misuse your application, or business competitors to see your algorithms.
- Your source code is not visible through the `USER_SOURCE`, `ALL_SOURCE`, or `DBA_SOURCE` data dictionary views.
- SQL*Plus can process the obfuscated source files.
- The Import and Export utilities accept wrapped files. You can back up or move wrapped procedures.

Tips When Obfuscating PL/SQL Units

When obfuscating (wrapping) PL/SQL units note the following:

- When wrapping a package or object type, wrap only the body, not the specification. This allows other developers see the information they need to use the package or type, but they cannot see its implementation.

- PL/SQL source inside wrapped files cannot be edited. To change wrapped PL/SQL code, edit the original source file and wrap it again. You can either hold off on wrapping your code until it is ready for shipment to end-users, or include the wrapping operation as part of your build environment.
- To be sure that all the important parts of your source code are obfuscated, view the wrapped file in a text editor before distributing it.

Limitations of Obfuscation

The following are limitations when obfuscating PL/SQL source code:

- Although wrapping a compilation unit helps to hide the algorithm and makes reverse-engineering difficult, Oracle Corporation does not recommend it as a secure method for hiding passwords or table names. Obfuscating a PL/SQL unit prevents most users from examining the source code, but might not stop all attempts.
- The wrapping does not obfuscate the source code for triggers. To hide the workings of a trigger, you can write a one-line trigger that calls a wrapped procedure.
- Wrapping only detects tokenization errors, such as a runaway string, when obfuscating PL/SQL code. Wrapping does not detect syntax or semantic errors, such as tables or views that do not exist. Those errors are detected during PL/SQL compilation or when executing the output file in SQL*Plus.
- Obfuscated PL/SQL program units cannot be imported into a database of a previous (lower) release. Wrapped compilation units are upward-compatible between Oracle releases, but are not downward-compatible. For example, you can load files processed by the V8.1.5 `wrap` utility into a V8.1.6 Oracle database, but you cannot load files processed by the V8.1.6 `wrap` utility into a V8.1.5 Oracle database.

Limitations of the wrap Utility

- Because the source code is parsed by the PL/SQL compiler, not by SQL*Plus, you cannot include substitution variables using the SQL*Plus `DEFINE` notation inside the PL/SQL code. You can use substitution variables in other SQL statements that are not obfuscated.
- Most of the comments are removed in wrapped files. See "Input and Output Files for the PL/SQL wrap Utility" on page A-3.

Limitations of the DBMS_DDL wrap Function

- If you invoke `DBMS_SQL.PARSE` (when using an overload where the statement formal has datatype `VARCHAR2A` or `VARCHAR2S` for text which exceeds 32767 bytes) on the output of `DBMS_DDL.WRAP`, then you need to set the `LFFLG` parameter to `FALSE`. Otherwise `DBMS_SQL.PARSE` adds newlines to the wrapped unit which corrupts the unit.

Obfuscating PL/SQL Code With the wrap Utility

The `wrap` utility processes an input SQL file and obfuscates only the PL/SQL units in the file, such as a package specification, package body, function, procedure, type specification, or type body. It does not obfuscate PL/SQL content in anonymous blocks or triggers or non-PL/SQL code.

To run the wrap utility, enter the `wrap` command at your operating system prompt using the following syntax:

```
wrap iname=input_file [oname=output_file]
```

Do not use any spaces around the equal signs.

`input_file` is the name of a file containing SQL statements, that you typically run using SQL*Plus. If you omit the file extension, an extension of `.sql` is assumed. For example, the following commands are equivalent:

```
wrap iname=/mydir/myfile
wrap iname=/mydir/myfile.sql
```

You can also specify a different file extension:

```
wrap iname=/mydir/myfile.src
```

`output_file` is the name of the obfuscated file that is created. The `oname` option is optional, because the output file name defaults to that of the input file and its extension defaults to `.plb`. For example, the following commands are equivalent:

```
wrap iname=/mydir/myfile
wrap iname=/mydir/myfile.sql oname=/mydir/myfile.plb
```

You can use the option `oname` to specify a different file name and extension:

```
wrap iname=/mydir/myfile oname=/yourdir/yourfile.out
```

Input and Output Files for the PL/SQL wrap Utility

The input file can contain any combination of SQL statements. Most statements are passed through unchanged. `CREATE` statements that define subprograms, packages, or object types are obfuscated; their bodies are replaced by a scrambled form that the PL/SQL compiler understands.

The following CREATE statements are obfuscated:

```
CREATE [OR REPLACE] FUNCTION function_name
CREATE [OR REPLACE] PROCEDURE procedure_name
CREATE [OR REPLACE] PACKAGE package_name
CREATE [OR REPLACE] PACKAGE BODY package_name
CREATE [OR REPLACE] TYPE type_name AS OBJECT
CREATE [OR REPLACE] TYPE type_name UNDER type_name
CREATE [OR REPLACE] TYPE BODY type_name
```

The `CREATE [OR REPLACE] TRIGGER` statement, and `[DECLARE] BEGIN..END` anonymous blocks, are not obfuscated. All other SQL statements are passed unchanged to the output file.

All comment lines in the unit being wrapped are deleted, except for those in a `CREATE OR REPLACE` header and C-style comments (delimited by `/* */`).

The output file is a text file, which you can run as a script in SQL*Plus to set up your PL/SQL procedures, functions, and packages. Run a wrapped file as follows:

```
SQL> @wrapped_file_name.plb;
```

Running the wrap Utility

For example, assume that the `wrap_test.sql` file contains the following:

```
CREATE PROCEDURE wraptest IS
  TYPE emp_tab IS TABLE OF employees%ROWTYPE INDEX BY PLS_INTEGER;
  all_emps      emp_tab;
BEGIN
  SELECT * BULK COLLECT INTO all_emps FROM employees;
  FOR i IN 1..10 LOOP
    DBMS_OUTPUT.PUT_LINE('Emp Id: ' || all_emps(i).employee_id);
  END LOOP;
END;
/
```

To wrap the file, run the following from the operating system prompt:

```
wrap iname=wrap_test.sql
```

The output of the `wrap` utility is similar to the following:

```
PL/SQL Wrapper: Release 10.2.0.0.0 on Tue Apr 26 16:47:39 2005
Copyright (c) 1993, 2005, Oracle.  All rights reserved.
Processing wrap_test.sql to wrap_test.plb
```

If you view the contents of the `wrap_test.plb` text file, the first line is `CREATE PROCEDURE wraptest wrapped` and the rest of the file contents is hidden.

You can run `wrap_test.plb` in SQL*Plus to execute the SQL statements in the file:

```
SQL> @wrap_test.plb
```

After the `wrap_test.plb` is run, you can execute the procedure that was created:

```
SQL> CALL wraptest();
```

Obfuscating PL/QL Code With DBMS_DDL Subprograms

The `DBMS_DDL` package contains procedures for obfuscating a single PL/SQL unit, such as a package specification, package body, function, procedure, type specification, or type body. These overloaded subprograms provide a mechanism for obfuscating dynamically generated PL/SQL program units that are created in a database.

The `DBMS_DDL` package contains the `WRAP` function and the `CREATE_WRAPPED` procedure. The `CREATE_WRAPPED` both wraps the text and creates the PL/SQL unit. When calling the wrap procedures, use the fully-qualified package name, `SYS.DBMS_DDL`, to avoid any naming conflicts and the possibility that someone might create a local package called `DBMS_DDL` or define the `DBMS_DDL` public synonym. The input `CREATE OR REPLACE` statement executes with the privileges of the user who invokes `DBMS_DDL.WRAP()` or `DBMS_DDL.CREATE_WRAPPED()`.

The `DBMS_DDL` package also provides the `MALFORMED_WRAP_INPUT` exception (ORA-24230) which is raised if the input to the wrap procedures is not a valid PL/SQL unit.

Using the DBMS_DDL create_wrapped Procedure

Example A–1 illustrates how `CREATE_WRAPPED` can be used to dynamically create and wrap a package specification and a package body in a database.

Example A–1 Using the create_wrapped Procedure to Wrap a Package

```
DECLARE
-- the package_text variable contains the text to create the package spec and body
  package_text VARCHAR2(32767);
  FUNCTION generate_spec (pkgname VARCHAR2) RETURN VARCHAR2 AS
  BEGIN
     RETURN 'CREATE PACKAGE ' || pkgname || ' AS
       PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER);
       PROCEDURE fire_employee (emp_id NUMBER);
       END ' || pkgname || ';';
  END generate_spec;
  FUNCTION generate_body (pkgname VARCHAR2) RETURN VARCHAR2 AS
  BEGIN
     RETURN 'CREATE PACKAGE BODY ' || pkgname || ' AS
       PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER) IS
       BEGIN
         UPDATE employees SET salary = salary + amount WHERE employee_id = emp_id;
       END raise_salary;
       PROCEDURE fire_employee (emp_id NUMBER) IS
       BEGIN
         DELETE FROM employees WHERE employee_id = emp_id;
       END fire_employee;
       END ' || pkgname || ';';
  END generate_body;

BEGIN
  package_text := generate_spec('emp_actions'); -- generate package spec
  SYS.DBMS_DDL.CREATE_WRAPPED(package_text);  -- create and wrap the package spec
  package_text := generate_body('emp_actions'); -- generate package body
  SYS.DBMS_DDL.CREATE_WRAPPED(package_text); -- create and wrap the package body
END;
/

-- call a procedure from the wrapped package
CALL emp_actions.raise_salary(120, 100);
```

When you check the `*_SOURCE` views, the source is wrapped, or hidden, so that others cannot view the code details. For example:

```
SELECT text FROM USER_SOURCE WHERE name = 'EMP_ACTIONS';
```

The resulting output appears similar to:

```
TEXT
------------------------------------------------------------
PACKAGE emp_actions wrapped
a000000
1f
abcd
...
```

B

How PL/SQL Resolves Identifier Names

This appendix explains how PL/SQL resolves references to names in potentially ambiguous SQL and procedural statements.

This appendix contains these topics:

- What Is Name Resolution?
- Examples of Qualified Names and Dot Notation
- Differences in Name Resolution Between PL/SQL and SQL
- Understanding Capture
- Avoiding Inner Capture in DML Statements
- Qualifying References to Object Attributes and Methods

What Is Name Resolution?

During compilation, the PL/SQL compiler determines which objects are associated with each name in a PL/SQL subprogram. A name might refer to a local variable, a table, a package, a procedure, a schema, and so on. When a subprogram is recompiled, that association might change if objects have been created or deleted.

A declaration or definition in an inner scope can hide another in an outer scope. In Example B–1, the declaration of variable `client` hides the definition of datatype `Client` because PL/SQL names are not case sensitive:

Example B–1 Resolving Global and Local Variable Names

```
BEGIN
   <<block1>>
   DECLARE
      TYPE Client IS RECORD ( first_name VARCHAR2(20), last_name VARCHAR2(25) );
      TYPE Customer IS RECORD ( first_name VARCHAR2(20), last_name VARCHAR2(25) );
   BEGIN
      DECLARE
         client Customer; -- hides definition of type Client in outer scope
      -- lead1  Client;   -- not allowed; Client resolves to the variable client
         lead2  block1.Client; -- OK; refers to type Client
      BEGIN
         NULL; -- no processing, just an example of name resolution
      END;
   END;
END;
/
```

You can refer to datatype `Client` by qualifying the reference with block label `block1`.

In the following set of `CREATE TYPE` statements, the second statement generates a warning. Creating an attribute named `manager` hides the type named `manager`, so the declaration of the second attribute does not execute correctly.

```
CREATE TYPE manager AS OBJECT (dept NUMBER);
/
CREATE TYPE person AS OBJECT (manager NUMBER, mgr manager) -- raises a warning;
/
```

Examples of Qualified Names and Dot Notation

During name resolution, the compiler can encounter various forms of references including simple unqualified names, dot-separated chains of identifiers, indexed components of a collection, and so on. This is shown in Example B–2.

Example B–2 Using the Dot Notation to Qualify Names

```
CREATE OR REPLACE PACKAGE pkg1 AS
   m NUMBER;
   TYPE t1 IS RECORD (a NUMBER);
   v1 t1;
   TYPE t2 IS TABLE OF t1 INDEX BY PLS_INTEGER;
   v2 t2;
   FUNCTION f1 (p1 NUMBER) RETURN t1;
   FUNCTION f2 (q1 NUMBER) RETURN t2;
END pkg1;
/

CREATE OR REPLACE PACKAGE BODY pkg1 AS
   FUNCTION f1 (p1 NUMBER) RETURN t1 IS
      n NUMBER;
   BEGIN
-- (1) unqualified name
      n := m;
-- (2) dot-separated chain of identifiers (package name used as scope
--  qualifier followed by variable name)
      n := pkg1.m;
-- (3) dot-separated chain of identifiers (package name used as scope
--  qualifier followed by function name also used as scope qualifier
--  followed by parameter name)
      n := pkg1.f1.p1;
-- (4) dot-separated chain of identifiers (variable name followed by
--  component selector)
      n := v1.a;
-- (5) dot-separated chain of identifiers (package name used as scope
--  qualifier followed by variable name followed by component selector)
      n := pkg1.v1.a;
-- (6) indexed name followed by component selector
      n := v2(10).a;
-- (7) function call followed by component selector
      n := f1(10).a;
-- (8) function call followed by indexing followed by component selector
      n := f2(10)(10).a;
-- (9) function call (which is a dot-separated chain of identifiers,
-- including schema name used as scope qualifier followed by package
-- name used as scope qualifier followed by function name)
-- followed by component selector of the returned result followed
-- by indexing followed by component selector
      n := hr.pkg1.f2(10)(10).a;
-- (10) variable name followed by component selector
      v1.a := p1;
     RETURN v1;
   END f1;

   FUNCTION f2 (q1 NUMBER) RETURN t2 IS
   v_t1 t1;
   v_t2 t2;
   BEGIN
     v_t1.a := q1;
     v_t2(1) := v_t1;
     RETURN v_t2;
   END f2;
END pkg1;
/
```

Note that an outside reference to a private variable declared in a function body is not legal. For example, an outside reference to the variable `n` declared in function `f1`, such as `hr.pkg1.f1.n` from function `f2`, raises an error. See "Private Versus Public Items in Packages" on page 9-8.

Additional Examples of How to Specify Names With the Dot Notation

Dot notation is used for identifying record fields, object attributes, and items inside packages or other schemas. When you combine these items, you might need to use expressions with multiple levels of dots, where it is not always clear what each dot refers to. Here are some of the combinations:

Field or Attribute of a Function Return Value

```
func_name().field_name
func_name().attribute_name
```

Schema Object Owned by Another Schema

```
schema_name.table_name
schema_name.procedure_name()
schema_name.type_name.member_name()
```

Packaged Object Owned by Another User

```
schema_name.package_name.procedure_name()
schema_name.package_name.record_name.field_name
```

Record Containing an Object Type

```
record_name.field_name.attribute_name
record_name.field_name.member_name()
```

Differences in Name Resolution Between PL/SQL and SQL

The name resolution rules for PL/SQL and SQL are similar. You can avoid the few differences if you follow the capture avoidance rules. For compatibility, the SQL rules are more permissive than the PL/SQL rules. SQL rules, which are mostly context sensitive, recognize as legal more situations and DML statements than the PL/SQL rules.

- PL/SQL uses the same name-resolution rules as SQL when the PL/SQL compiler processes a SQL statement, such as a DML statement. For example, for a name such as `HR.JOBS`, SQL matches objects in the `HR` schema first, then packages, types, tables, and views in the current schema.
- PL/SQL uses a different order to resolve names in PL/SQL statements such as assignments and procedure calls. In the case of a name `HR.JOBS`, PL/SQL searches first for packages, types, tables, and views named `HR` in the current schema, then for objects in the `HR` schema.

For information on SQL naming rules, see *Oracle Database SQL Reference*.

Understanding Capture

When a declaration or type definition in another scope prevents the compiler from resolving a reference correctly, that declaration or definition is said to capture the reference. Usually this is the result of migration or schema evolution. There are three kinds of capture: inner, same-scope, and outer. Inner and same-scope capture apply only in SQL scope.

Inner Capture

An inner capture occurs when a name in an inner scope no longer refers to an entity in an outer scope:

- The name might now resolve to an entity in an inner scope.
- The program might cause an error, if some part of the identifier is captured in an inner scope and the complete reference cannot be resolved.

If the reference points to a different but valid name, you might not know why the program is acting differently.

In the following example, the reference to `col2` in the inner `SELECT` statement binds to column `col2` in table `tab1` because table `tab2` has no column named `col2`:

```
CREATE TABLE tab1 (col1 NUMBER, col2 NUMBER);
INSERT INTO tab1 VALUES (100, 10);
CREATE TABLE tab2 (col1 NUMBER);
INSERT INTO tab2 VALUES (100);

CREATE OR REPLACE PROCEDURE proc AS
   CURSOR c1 IS SELECT * FROM tab1
      WHERE EXISTS (SELECT * FROM tab2 WHERE col2 = 10);
BEGIN
   NULL;
END;
/
```

In the preceding example, if you add a column named `col2` to table `tab2`:

```
ALTER TABLE tab2 ADD (col2 NUMBER);
```

then procedure `proc` is invalidated and recompiled automatically upon next use. However, upon recompilation, the `col2` in the inner `SELECT` statement binds to column `col2` in table `tab2` because `tab2` is in the inner scope. Thus, the reference to `col2` is captured by the addition of column `col2` to table `tab2`.

Using collections and object types can cause more inner capture situations. In the following example, the reference to `hr.tab2.a` resolves to attribute `a` of column tab2 in table tab1 through table alias hr, which is visible in the outer scope of the query:

```
CREATE TYPE type1 AS OBJECT (a NUMBER);
/
CREATE TABLE tab1 (tab2 type1);
INSERT INTO tab1 VALUES ( type1(10) );
CREATE TABLE tab2 (x NUMBER);
INSERT INTO tab2 VALUES ( 10 );

-- in the following, alias tab1 with same name as schema name, which
-- is not a good practice but is used here for illustration purpose
-- note lack of alias in second SELECT
SELECT * FROM tab1 hr
   WHERE EXISTS (SELECT * FROM hr.tab2 WHERE x = hr.tab2.a);
```

In the preceding example, you might add a column named a to table hr.tab2, which appears in the inner subquery. When the query is processed, an inner capture occurs because the reference to hr.tab2.a resolves to column a of table tab2 in schema hr. You can avoid inner captures by following the rules given in "Avoiding Inner Capture in DML Statements" on page B-5. According to those rules, you should revise the query as follows:

```
SELECT * FROM hr.tab1 p1
   WHERE EXISTS (SELECT * FROM hr.tab2 p2 WHERE p2.x = p1.tab2.a);
```

Same-Scope Capture

In SQL scope, a same-scope capture occurs when a column is added to one of two tables used in a join, so that the same column name exists in both tables. Previously, you could refer to that column name in a join query. To avoid an error, now you must qualify the column name with the table name.

Outer Capture

An outer capture occurs when a name in an inner scope, which once resolved to an entity in an inner scope, is resolved to an entity in an outer scope. SQL and PL/SQL are designed to prevent outer captures. You do not need to take any action to avoid this condition.

Avoiding Inner Capture in DML Statements

You can avoid inner capture in DML statements by following these rules:

- Specify an alias for each table in the DML statement.
- Keep table aliases unique throughout the DML statement.
- Avoid table aliases that match schema names used in the query.
- Qualify each column reference with the table alias.

Qualifying a reference with schema_name.table_name does not prevent inner capture if the statement refers to tables with columns of a user-defined object type.

Qualifying References to Object Attributes and Methods

Columns of a user-defined object type allow for more inner capture situations. To minimize problems, the name-resolution algorithm includes the following rules for the use of table aliases.

References to Attributes and Methods

All references to attributes and methods must be qualified by a table alias. When referencing a table, if you reference the attributes or methods of an object stored in that table, the table name must be accompanied by an alias. As the following examples show, column-qualified references to an attribute or method are not allowed if they are prefixed with a table name:

```
CREATE TYPE t1 AS OBJECT (x NUMBER);
/
CREATE TABLE tb1 (col1 t1);

BEGIN
-- following inserts are allowed without an alias
-- because there is no column list
  INSERT INTO tb1 VALUES ( t1(10) );
  INSERT INTO tb1 VALUES ( t1(20) );
  INSERT INTO tb1 VALUES ( t1(30) );
END;
/
BEGIN
  UPDATE tb1 SET col1.x = 10 WHERE col1.x = 20; -- error, not allowed
END;
/
BEGIN
  UPDATE tb1 SET tb1.col1.x = 10 WHERE tb1.col1.x = 20; -- not allowed
END;
/
BEGIN
  UPDATE hr.tb1 SET hr.tb1.col1.x = 10 WHERE hr.tb1.col1.x = 20; -- not allowed
END;
/
BEGIN -- following allowed with table alias
  UPDATE hr.tb1 t set t.col1.x = 10 WHERE t.col1.x = 20;
END;
/
DECLARE
  y NUMBER;
BEGIN -- following allowed with table alias
  SELECT t.col1.x INTO y FROM tb1 t WHERE t.col1.x = 30;
END;
/
BEGIN
  DELETE FROM tb1 WHERE tb1.col1.x = 10; -- not allowed
END;
/
BEGIN -- following allowed with table alias
  DELETE FROM tb1 t WHERE t.col1.x = 10;
END;
/
```

References to Row Expressions

Row expressions must resolve as references to table aliases. You can pass row expressions to operators `REF` and `VALUE`, and you can use row expressions in the `SET` clause of an `UPDATE` statement. Some examples follow:

```
CREATE TYPE t1 AS OBJECT (x number);
/
CREATE TABLE ot1 OF t1;

BEGIN
-- following inserts are allowed without an alias
-- because there is no column list
  INSERT INTO ot1 VALUES ( t1(10) );
  INSERT INTO ot1 VALUES ( 20 );
  INSERT INTO ot1 VALUES ( 30 );
END;
/
BEGIN
  UPDATE ot1 SET VALUE(ot1.x) = t1(20) WHERE VALUE(ot1.x) = t1(10); -- not allowed
END;
/
BEGIN -- following allowed with table alias
  UPDATE ot1 o SET o = (t1(20)) WHERE o.x = 10;
END;
/
DECLARE
  n_ref REF t1;
BEGIN -- following allowed with table alias
  SELECT REF(o) INTO n_ref FROM ot1 o WHERE VALUE(o) = t1(30);
END;
/
DECLARE
  n t1;
BEGIN -- following allowed with table alias
  SELECT VALUE(o) INTO n FROM ot1 o WHERE VALUE(o) = t1(30);
END;
/
DECLARE
  n NUMBER;
BEGIN -- following allowed with table alias
  SELECT o.x INTO n FROM ot1 o WHERE o.x = 30;
END;
/
BEGIN
  DELETE FROM ot1 WHERE VALUE(ot1) = (t1(10)); -- not allowed
END;
/
BEGIN -- folowing allowed with table alias
  DELETE FROM ot1 o WHERE VALUE(o) = (t1(20));
END;
/
```

C

PL/SQL Program Limits

This appendix discusses the program limits that are imposed by the PL/SQL language. PL/SQL is based on the programming language Ada. As a result, PL/SQL uses a variant of Descriptive Intermediate Attributed Notation for Ada (DIANA), a tree-structured intermediate language. It is defined using a meta-notation called Interface Definition Language (IDL). DIANA is used internally by compilers and other tools.

At compile time, PL/SQL source code is translated into machine-readable m-code. Both the DIANA and m-code for a procedure or package are stored in the database. At run time, they are loaded into the shared memory pool. The DIANA is used to compile dependent procedures; the m-code is simply executed.

In the shared memory pool, a package spec, object type spec, standalone subprogram, or anonymous block is limited to 67108864 (2**26) DIANA nodes which correspond to tokens such as identifiers, keywords, operators, and so on. This allows for ~6,000,000 lines of code unless you exceed limits imposed by the PL/SQL compiler, some of which are given in Table C–1.

Table C–1 PL/SQL Compiler Limits

Item	Limit
bind variables passed to a program unit	32768
exception handlers in a program unit	65536
fields in a record	65536
levels of block nesting	255
levels of record nesting	32
levels of subquery nesting	254
levels of label nesting	98
levels of nested collections	no predefined limit
magnitude of a `BINARY_INTEGER` value	-2147483648..2147483647
magnitude of a `PLS_INTEGER` value	-2147483648..2147483647
number of formal parameters in an explicit cursor, function, or procedure	65536
objects referenced by a program unit	65536
precision of a `FLOAT` value (binary digits)	126
precision of a `NUMBER` value (decimal digits)	38
precision of a `REAL` value (binary digits)	63

Table C–1 (Cont.) PL/SQL Compiler Limits

Item	Limit
size of an identifier (characters)	30
size of a string literal (bytes)	32767
size of a CHAR value (bytes)	32767
size of a LONG value (bytes)	32760
size of a LONG RAW value (bytes)	32760
size of a RAW value (bytes)	32767
size of a VARCHAR2 value (bytes)	32767
size of an NCHAR value (bytes)	32767
size of an NVARCHAR2 value (bytes)	32767
size of a BFILE value (bytes)	4G * value of DB_BLOCK_SIZE parameter
size of a BLOB value (bytes)	4G * value of DB_BLOCK_SIZE parameter
size of a CLOB value (bytes)	4G * value of DB_BLOCK_SIZE parameter
size of an NCLOB value (bytes)	4G * value of DB_BLOCK_SIZE parameter

To estimate how much memory a program unit requires, you can query the data dictionary view `user_object_size`. The column `parsed_size` returns the size (in bytes) of the "flattened" DIANA. For example:

```
SQL> SELECT * FROM user_object_size WHERE name = 'PKG1';

NAME TYPE        SOURCE_SIZE  PARSED_SIZE  CODE_SIZE  ERROR_SIZE
----------------------------------------------------------------
PKG1 PACKAGE              46          165        119           0
PKG1 PACKAGE BODY         82            0        139           0
```

Unfortunately, you cannot estimate the number of DIANA nodes from the parsed size. Two program units with the same parsed size might require 1500 and 2000 DIANA nodes, respectively because, for example, the second unit contains more complex SQL statements.

When a PL/SQL block, subprogram, package, or object type exceeds a size limit, you get an error such as `PLS-00123: program too large`. Typically, this problem occurs with packages or anonymous blocks. With a package, the best solution is to divide it into smaller packages. With an anonymous block, the best solution is to redefine it as a group of subprograms, which can be stored in the database.

For additional information about the limits on datatypes, see Chapter 3, "PL/SQL Datatypes". For limits on collection subscripts, see "Referencing Collection Elements" on page 5-11.

D

PL/SQL Reserved Words and Keywords

The words listed in this appendix are reserved by PL/SQL. You should not use them to name program objects such as constants, variables, cursors, schema objects such as columns, tables, or indexes.

These words reserved by PL/SQL are classified as keywords or reserved words. See Table D–1 and Table D–2. Reserved words can never be used as identifiers. Keywords can be used as identifiers, but this is not recommended.

Some of these words are also reserved by SQL. For a list of the Oracle database reserved words, see *Oracle Database SQL Reference*. You can generate a list of all keywords and reserved words with the `V$RESERVED_WORDS` view, described in *Oracle Database Reference*.

Table D–1 lists the PL/SQL reserved words.

Table D–1 PL/SQL Reserved Words

Begins with:	Reserved Words
A	ALL, ALTER, AND, ANY, ARRAY, ARROW, AS, ASC, AT
B	BEGIN, BETWEEN, BY
C	CASE, CHECK, CLUSTERS, CLUSTER, COLAUTH, COLUMNS, COMPRESS, CONNECT, CRASH, CREATE, CURRENT
D	DECIMAL, DECLARE, DEFAULT, DELETE, DESC, DISTINCT, DROP
E	ELSE, END, EXCEPTION, EXCLUSIVE, EXISTS
F	FETCH, FORM, FOR, FROM
G	GOTO, GRANT, GROUP
H	HAVING
I	IDENTIFIED, IF, IN, INDEXES, INDEX, INSERT, INTERSECT, INTO, IS
L	LIKE, LOCK
M	MINUS, MODE
N	NOCOMPRESS, NOT, NOWAIT, NULL
O	OF, ON, OPTION, OR, ORDER,OVERLAPS
P	PRIOR, PROCEDURE, PUBLIC
R	RANGE, RECORD, RESOURCE, REVOKE
S	SELECT, SHARE, SIZE, SQL, START, SUBTYPE
T	TABAUTH, TABLE, THEN, TO, TYPE
U	UNION, UNIQUE, UPDATE, USE
V	VALUES, VIEW, VIEWS
W	WHEN, WHERE, WITH

Table D–2 lists the PL/SQL keywords.

Table D–2 PL/SQL Keywords

Begins with:	Keywords
A	A, ADD, AGENT, AGGREGATE, ARRAY, ATTRIBUTE, AUTHID, AVG
B	BFILE_BASE, BINARY, BLOB_BASE, BLOCK, BODY, BOTH, BOUND, BULK, BYTE
C	C, CALL, CALLING, CASCADE, CHAR, CHAR_BASE, CHARACTER, CHARSETFORM, CHARSETID, CHARSET, CLOB_BASE, CLOSE, COLLECT, COMMENT, COMMIT, COMMITTED, COMPILED, CONSTANT, CONSTRUCTOR, CONTEXT, CONVERT, COUNT, CURSOR, CUSTOMDATUM
D	DANGLING, DATA, DATE, DATE_BASE, DAY, DEFINE, DETERMINISTIC, DOUBLE, DURATION
E	ELEMENT, ELSIF, EMPTY, ESCAPE, EXCEPT, EXCEPTIONS, EXECUTE, EXIT, EXTERNAL
F	FINAL, FIXED, FLOAT, FORALL, FORCE, FUNCTION
G	GENERAL
H	HASH, HEAP, HIDDEN, HOUR
I	IMMEDIATE, INCLUDING, INDICATOR, INDICES, INFINITE, INSTANTIABLE, INT, INTERFACE, INTERVAL, INVALIDATE, ISOLATION
J	JAVA
L	LANGUAGE, LARGE, LEADING, LENGTH, LEVEL, LIBRARY, LIKE2, LIKE4, LIKEC, LIMIT, LIMITED, LOCAL, LONG, LOOP
M	MAP, MAX, MAXLEN, MEMBER, MERGE, MIN, MINUTE, MOD, MODIFY, MONTH, MULTISET
N	NAME, NAN, NATIONAL, NATIVE, NCHAR, NEW, NOCOPY, NUMBER_BASE
O	OBJECT, OCICOLL, OCIDATETIME, OCIDATE, OCIDURATION, OCIINTERVAL, OCILOBLOCATOR, OCINUMBER, OCIRAW, OCIREFCURSOR, OCIREF, OCIROWID, OCISTRING, OCITYPE, ONLY, OPAQUE, OPEN, OPERATOR, ORACLE, ORADATA, ORGANIZATION, ORLANY, ORLVARY, OTHERS, OUT, OVERRIDING
P	PACKAGE, PARALLEL_ENABLE, PARAMETER, PARAMETERS, PARTITION, PASCAL, PIPE, PIPELINED, PRAGMA, PRECISION, PRIVATE
R	RAISE, RANGE, RAW, READ, RECORD, REF, REFERENCE, REM, REMAINDER, RENAME, RESULT, RETURN, RETURNING, REVERSE, ROLLBACK, ROW
S	SAMPLE, SAVE, SAVEPOINT, SB1, SB2, SB4, SECOND, SEGMENT, SELF, SEPARATE, SEQUENCE, SERIALIZABLE, SET, SHORT, SIZE_T, SOME, SPARSE, SQLCODE, SQLDATA, SQLNAME, SQLSTATE, STANDARD, STATIC, STDDEV, STORED, STRING, STRUCT, STYLE, SUBMULTISET, SUBPARTITION, SUBSTITUTABLE, SUBTYPE, SUM, SYNONYM
T	TDO, THE, TIME, TIMESTAMP, TIMEZONE_ABBR, TIMEZONE_HOUR, TIMEZONE_MINUTE, TIMEZONE_REGION, TRAILING, TRANSAC, TRANSACTIONAL, TRUSTED, TYPE
U	UB1, UB2, UB4, UNDER, UNSIGNED, UNTRUSTED, USE, USING
V	VALIST, VALUE, VARIABLE, VARIANCE, VARRAY, VARYING, VOID
W	WHILE, WORK, WRAPPED, WRITE
Y	YEAR
Z	ZONE

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