

PL/SQL

User's Guide and Reference

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E PL/SQL Program Limits

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Preface

PL/SQL, Oracle's procedural extension of SQL, is an advanced fourth-generation programming language (4GL). It offers modern features such as data encapsulation, overloading, collection types, exception handling, and information hiding. PL/SQL also offers seamless SQL access, tight integration with the Oracle server and tools, portability, and security.

This guide explains all the concepts behind PL/SQL and illustrates every facet of the language. Good programming style is stressed throughout and supported by numerous examples. Using this guide, you learn PL/SQL quickly and efficiently.

This preface contains these topics:

- [Audience](#)
- [Organization](#)
- [Related Documentation](#)
- [Conventions](#)
- [Sample Database Tables](#)
- [Documentation Accessibility](#)

Audience

Anyone developing PL/SQL-based applications for Oracle will benefit from reading this guide. Written especially for programmers, this comprehensive treatment of PL/SQL will also be of value to systems analysts, project managers, and others interested in database applications. To use this guide effectively, you need a working knowledge of Oracle, SQL, and a 3GL such as Ada, C, or COBOL.

You will not find installation instructions or system-specific information in this guide. For that kind of information, see the Oracle installation or user's guide for your system.

Organization

The *PL/SQL User's Guide and Reference* contains:

Chapter 1, "Overview of PL/SQL"

This chapter surveys the main features of PL/SQL and points out the advantages they offer. It also acquaints you with the basic concepts behind PL/SQL and the general appearance of PL/SQL programs.

Chapter 2, "Fundamentals of PL/SQL"

This chapter focuses on the small-scale aspects of PL/SQL. It discusses lexical units, scalar datatypes, user-defined subtypes, data conversion, expressions, assignments, block structure, declarations, and scope.

Chapter 3, "PL/SQL Datatypes"

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

Chapter 4, "PL/SQL Control Structures"

This chapter shows you how to structure the flow of control through a PL/SQL program. It describes conditional, iterative, and sequential control. You learn how to apply simple but powerful control structures such as `IF-THEN-ELSE`, `CASE`, and `WHILE-LOOP`.

Chapter 5, "PL/SQL Collections and Records"

This chapter focuses on the composite datatypes `TABLE`, `VARRAY`, and `RECORD`. You learn how to reference and manipulate whole collections of data, and how to treat related but dissimilar data as a logical unit. You also learn how to improve performance by bulk-binding collections.

Chapter 6, "Interaction Between PL/SQL and Oracle"

This chapter shows you how PL/SQL supports the SQL commands, functions, and operators that let you manipulate Oracle data. You also learn how to manage cursors, process transactions, and safeguard your database.

Chapter 7, "Handling PL/SQL Errors"

This chapter provides an in-depth discussion of error reporting and recovery. You learn how to detect and handle errors using PL/SQL exceptions.

Chapter 8, "PL/SQL Subprograms"

This chapter shows you how to write and use subprograms. It discusses procedures, functions, forward declarations, actual and formal parameters, positional and named notation, parameter modes, the NOCOPY compiler hint, parameter default values, aliasing, overloading, invoker rights, and recursion.

Chapter 9, "PL/SQL Packages"

This chapter shows you how to bundle related PL/SQL types, items, and subprograms into a package. Once written, your general-purpose package is compiled, then stored in an Oracle database, where its contents can be shared by many applications.

Chapter 10, "PL/SQL Object Types"

This chapter introduces you to object-oriented programming based on object types, which provide abstract templates for real-world objects. You learn how to define object types and manipulate objects.

Chapter 11, "Native Dynamic SQL"

This chapter shows you how to use dynamic SQL, an advanced programming technique that makes your applications more flexible and versatile. You learn two simple ways to write programs that can build and process SQL statements "on the fly" at run time.

Chapter 12, "Tuning PL/SQL Applications"

This chapter shows you how to tune PL/SQL-based applications. You learn how to make small adjustments that improve performance.

Chapter 13, "PL/SQL Language Elements"

This chapter uses syntax diagrams to show how commands, parameters, and other language elements are sequenced to form PL/SQL statements. Also, it provides usage notes and short examples to help you become fluent in PL/SQL quickly.

Appendix A, "Sample PL/SQL Programs"

This appendix provides several PL/SQL programs to guide you in writing your own. The sample programs illustrate important concepts and features.

Appendix B, "CHAR versus VARCHAR2 Semantics"

This appendix explains the subtle but important semantic differences between the CHAR and VARCHAR2 base types.

Appendix C, "PL/SQL Wrap Utility"

This appendix shows you how to run the Wrap Utility, a standalone programming utility that enables you to deliver PL/SQL applications without exposing your source code.

Appendix D, "PL/SQL Name Resolution"

This appendix explains how PL/SQL resolves references to names in potentially ambiguous SQL and procedural statements.

Appendix E, "PL/SQL Program Limits"

This appendix helps you deal with the program limits imposed by the PL/SQL compilation and run-time system.

Appendix F, "PL/SQL Reserved Words"

This appendix lists those words reserved for use by PL/SQL.

Related Documentation

For more information, see these Oracle resources:

Various aspects of PL/SQL programming, in particular details for triggers and stored procedures, are covered in *Oracle9i Application Developer's Guide - Fundamentals*

For extensive information on object-oriented programming using both PL/SQL and SQL features, see *Oracle9i Application Developer's Guide - Object-Relational Features*

For information about programming with large objects (LOBs), see *Oracle9i Application Developer's Guide - Large Objects (LOBs)*

For SQL information, see the *Oracle9i SQL Reference* and *Oracle9i Database Administrator's Guide*. For basic Oracle concepts, see *Oracle9i Database Concepts*.

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

<http://technet.oracle.com/membership/index.htm>

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

<http://technet.oracle.com/docs/index.htm>

or to the documentation search engine at:

<http://tahiti.oracle.com/>

This search engine has a number of features that you might find useful, such as searching for examples, looking up SQL and PL/SQL syntax, and formatting large numbers of search results into a "virtual book".

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 .
<i>Italics</i>	Italic typeface indicates book titles or emphasis.	<i>Oracle9i Database Concepts</i> Ensure that the recovery catalog and target database do <i>not</i> 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, RMAN 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 executables, filenames, directory names, and sample user-supplied elements. Such elements include computer and database names, net service names, and connect identifiers, as well as 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 open 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 monospace (fixed-width font) <i>italic</i>	Lowercase monospace italic font represents placeholders or variables.	You can specify the <i>parallel_clause</i> . Run <i>Uold_release</i> .SQL where <i>old_release</i> 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
[]	Brackets enclose one or more optional items. Do not enter the brackets.	DECIMAL (<i>digits</i> [, <i>precision</i>])
{ }	Braces enclose two or more items, one of which is required. Do not enter the braces.	{ENABLE DISABLE}
	A vertical bar represents a choice of two or more options within brackets or braces. Enter one of the options. Do not enter the vertical bar.	{ENABLE DISABLE} [COMPRESS NOCOMPRESS]
...	Horizontal ellipsis points indicate either: <ul style="list-style-type: none"> That we have omitted parts of the code that are not directly related to the example That you can repeat a portion of the code 	CREATE TABLE ... AS <i>subquery</i> ; SELECT <i>col1</i> , <i>col2</i> , ... , <i>coln</i> FROM employees;
.	Vertical ellipsis points indicate that we have omitted several lines of code not directly related to the example.	
Other notation	You must enter symbols other than brackets, braces, vertical bars, and ellipsis points as shown.	acctbal NUMBER(11,2); acct CONSTANT NUMBER(4) := 3;
<i>Italics</i>	Italicized text indicates placeholders or variables for which you must supply particular values.	CONNECT SYSTEM/ <i>system_password</i> DB_NAME = <i>database_name</i>
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. However, because these terms are not case sensitive, you can enter them in lowercase.	SELECT last_name, employee_id FROM employees; SELECT * FROM USER_TABLES; DROP TABLE hr.employees;

Convention	Meaning	Example
lowercase	Lowercase typeface indicates programmatic elements that you supply. For example, lowercase indicates names of tables, columns, or files. Note: Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.	<pre>SELECT last_name, employee_id FROM employees; sqlplus hr/hr CREATE USER mjones IDENTIFIED BY ty3MU9;</pre>
--	A double hyphen begins a single-line comment, which extends to the end of a line.	--
/* */	A slash-asterisk and an asterisk-slash delimit a multi-line comment, which can span multiple lines.	/* */

Sample Database Tables

Most programming examples in this guide use two sample database tables named `dept` and `emp`. Their definitions follow:

```
CREATE TABLE dept (
    deptno NUMBER(2) NOT NULL,
    dname  VARCHAR2(14),
    loc    VARCHAR2(13));

CREATE TABLE emp (
    empno    NUMBER(4) NOT NULL,
    ename    VARCHAR2(10),
    job      VARCHAR2(9),
    mgr      NUMBER(4),
    hiredate DATE,
    sal      NUMBER(7,2),
    comm     NUMBER(7,2),
    deptno   NUMBER(2));
```

Sample Data

Respectively, the `dept` and `emp` tables contain the following rows of data:

```
DEPTNO  DNAME          LOC
-----  -
10      ACCOUNTING    NEW YORK
20      RESEARCH      DALLAS
30      SALES         CHICAGO
```

EMPNO	ENAME	JOB	MGR	HIREDATE	SAL	COMM	DEPTNO
7369	SMITH	CLERK	7902	17-DEC-80	800		20
7499	ALLEN	SALESMAN	7698	20-FEB-81	1600	300	30
7521	WARD	SALESMAN	7698	22-FEB-81	1250	500	30
7566	JONES	MANAGER	7839	02-APR-81	2975		20
7654	MARTIN	SALESMAN	7698	28-SEP-81	1250	1400	30
7698	BLAKE	MANAGER	7839	01-MAY-81	2850		30
7782	CLARK	MANAGER	7839	09-JUN-81	2450		10
7788	SCOTT	ANALYST	7566	19-APR-87	3000		20
7839	KING	PRESIDENT		17-NOV-81	5000		10
7844	TURNER	SALESMAN	7698	08-SEP-81	1500		30
7876	ADAMS	CLERK	7788	23-MAY-87	1100		20
7900	JAMES	CLERK	7698	03-DEC-81	950		30
7902	FORD	ANALYST	7566	03-DEC-81	3000		20
7934	MILLER	CLERK	7782	23-JAN-82	1300		10

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<http://www.oracle.com/accessibility/>

JAWS, a Windows screen reader, 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, JAWS may not always read a line of text that consists solely of a bracket or brace.

What's New in PL/SQL?

This section describes new features of PL/SQL release 9.0.1 and provides pointers to additional information.

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

- [Oracle9i New Features in PL/SQL](#)

Oracle9i New Features in PL/SQL

- **Integration of SQL and PL/SQL parsers**

PL/SQL now supports the complete range of syntax for SQL statements, such as INSERT, UPDATE, DELETE, and so on. If you received errors for valid SQL syntax in PL/SQL programs before, those statements should now work.

See Also: Because of more consistent error-checking, you might find that some invalid code is now found at compile time instead of producing an error at runtime, or vice versa. You might need to change the source code as part of the migration procedure. See *Oracle9i Database Migration* for details on the complete migration procedure.

- **CASE statements and expressions**

CASE statements and expressions are a shorthand way of representing IF/THEN choices with multiple alternatives.

See Also:

- ["CASE Expressions"](#) on page 2-31
- ["CASE Statement"](#) on page 4-5
- ["CASE Statement"](#) on page 13-18

- **Inheritance and Dynamic Method Dispatch**

Types can be declared in a supertype/subtype hierarchy, with subtypes inheriting attributes and methods from their supertypes. The subtypes can also add new attributes and methods, and override existing methods. A call to an object method executes the appropriate version of the method, based on the type of the object.

See Also:

- ["Overview of PL/SQL Type Inheritance"](#) on page 10-14
- ["How Overloading Works with Inheritance"](#) on page 8-28

- **Type Evolution**

Attributes and methods can be added to and dropped from object types, without the need to re-create the types and corresponding data. This feature lets

the type hierarchy adapt to changes in the application, rather than being planned out entirely in advance.

See Also: ["Changing Attributes and Methods of an Existing Object Type \(Type Evolution\)"](#) on page 10-12

- **New Date/Time Types**

The new datatype `TIMESTAMP` records time values including fractional seconds. New datatypes `TIMESTAMP WITH TIME ZONE` and `TIMESTAMP WITH LOCAL TIME ZONE` allow you to adjust date and time values to account for time zone differences. You can specify whether the time zone observes daylight savings time, to account for anomalies when clocks shift forward or backward. New datatypes `INTERVAL DAY TO SECOND` and `INTERVAL YEAR TO MONTH` represent differences between two date and time values, simplifying date arithmetic.

See Also:

- ["Datetime and Interval Types"](#) on page 3-15
- ["Datetime and Interval Arithmetic"](#) on page 3-20
- ["Datetime Literals"](#) on page 2-9

- **Native Compilation of PL/SQL Code**

Improve performance by compiling Oracle-supplied and user-written stored procedures into native executables, using typical C development tools. This setting is saved so that the procedure is compiled the same way if it is later invalidated.

See Also: ["Compiling PL/SQL Code for Native Execution"](#) on page 12-14

- **Improved Globalization and National Language Support**

Data can be stored in Unicode format using fixed-width or variable-width character sets. String handling and storage declarations can be specified using byte lengths, or character lengths where the number of bytes is computed for you. You can set up the entire database to use the same length semantics for strings, or specify the settings for individual procedures; this setting is remembered if a procedure is invalidated.

See Also:

- ["Character Types"](#) on page 3-5
- ["National Character Types"](#) on page 3-10

■ **Table Functions and Cursor Expressions**

You can query a set of returned rows like a table. Result sets can be passed from one function to another, letting you set up a sequence of transformations with no table to hold intermediate results. Rows of the result set can be returned a few at a time, reducing the memory overhead for producing large result sets within a function.

See Also:

- ["Accepting and Returning Multiple Rows with Table Functions"](#) on page 8-30
- ["Using Cursor Expressions"](#) on page 6-41

■ **Multilevel Collections**

You can nest the collection types, for example to create a `VARRAY` of PL/SQL tables, a `VARRAY` of `VARRAY`s, or a PL/SQL table of PL/SQL tables. You can model complex data structures such as multidimensional arrays in a natural way.

See Also: ["Using Multilevel Collections"](#) on page 5-21

■ **Better Integration for LOB Datatypes**

You can operate on LOB types much like other similar types. You can use character functions on `CLOB` and `NCLOB` types. You can treat `BLOB` types as `RAW`s. Conversions between LOBs and other types are much simpler, particularly when converting from `LONG` to LOB types.

See Also: ["LOB Types"](#) on page 3-13

■ **Enhancements to Bulk Operations**

You can now perform bulk SQL operations, such as bulk fetches, using native dynamic SQL (the `EXECUTE IMMEDIATE` statement). You can perform bulk insert or update operations that continue despite errors on some rows, then examine the problems after the operation is complete.

See Also:

- ["Reducing Loop Overhead for Collections with Bulk Binds"](#) on page 5-32
- ["Using Bulk Dynamic SQL"](#) on page 11-12
- ["EXECUTE IMMEDIATE Statement"](#) on page 13-66

- **MERGE Statement**

This specialized statement combines insert and update into a single operation. It is intended for data warehousing applications that perform particular patterns of inserts and updates.

See Also:

- ["MERGE Statement"](#) on page 13-117 for a brief discussion and example
- *Oracle9i SQL Reference* for detailed information



Overview of PL/SQL

The limits of my language mean the limits of my world. —Ludwig Wittgenstein

This chapter surveys the main features of PL/SQL and points out the advantages they offer. It also acquaints you with the basic concepts behind PL/SQL and the general appearance of PL/SQL programs. You see how PL/SQL bridges the gap between database technology and procedural programming languages.

This chapter discusses the following topics:

[Understanding the Main Features of PL/SQL](#)

[PL/SQL Architecture](#)

[Advantages of PL/SQL](#)

See Also: Access additional information and code samples for PL/SQL on the Oracle Technical Network, at http://otn.oracle.com/tech/pl_sql/.

Understanding the Main Features of PL/SQL

A good way to get acquainted with PL/SQL is to look at a sample program. The program below processes an order for a tennis racket. First, it declares a variable of type `NUMBER` to store the quantity of tennis rackets on hand. Then, it retrieves the quantity on hand from a database table named `inventory`. If the quantity is greater than zero, the program updates the table and inserts a purchase record into another table named `purchase_record`. Otherwise, the program inserts an out-of-stock record into the `purchase_record` table.

```
-- available online in file 'exampl'
DECLARE
    qty_on_hand  NUMBER(5);
BEGIN
    SELECT quantity INTO qty_on_hand FROM inventory
        WHERE product = 'TENNIS RACKET'
        FOR UPDATE OF quantity;
    IF qty_on_hand > 0 THEN -- check quantity
        UPDATE inventory SET quantity = quantity - 1
            WHERE product = 'TENNIS RACKET';
        INSERT INTO purchase_record
            VALUES ('Tennis racket purchased', SYSDATE);
    ELSE
        INSERT INTO purchase_record
            VALUES ('Out of tennis rackets', SYSDATE);
    END IF;
    COMMIT;
END;
```

With PL/SQL, you can use SQL statements to manipulate Oracle data and flow-of-control statements to process the data. Moreover, you can declare constants and variables, define procedures and functions, and trap runtime errors. Thus, PL/SQL combines the data manipulating power of SQL with the data processing power of procedural languages.

Block Structure

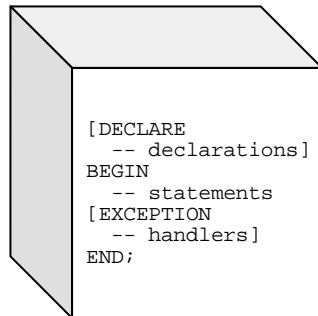
PL/SQL is a *block-structured* language. That is, the basic units (procedures, functions, and anonymous blocks) that make up a PL/SQL program are logical blocks, which can contain any number of nested sub-blocks. Typically, each logical block corresponds to a problem or subproblem to be solved. Thus, PL/SQL supports the divide-and-conquer approach to problem solving called *stepwise refinement*.

A block (or sub-block) lets you group logically related declarations and statements. That way, you can place declarations close to where they are used. The declarations are local to the block and cease to exist when the block completes.

As [Figure 1-1](#) shows, a PL/SQL block has three parts: a declarative part, an executable part, and an exception-handling part. (In PL/SQL, a warning or error condition is called an *exception*.) Only the executable part is required.

The order of the parts is logical. First comes the declarative part, in which items can be declared. Once declared, items can be manipulated in the executable part. Exceptions raised during execution can be dealt with in the exception-handling part.

Figure 1-1 Block Structure



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

Variables and Constants

PL/SQL lets you declare constants and variables, then use them in SQL and procedural statements anywhere an expression can be used. However, forward references are not allowed. So, you must declare a constant or variable *before* referencing it in other statements, including other declarative statements.

Declaring Variables

Variables can have any SQL datatype, such as CHAR, DATE, or NUMBER, or any PL/SQL datatype, such as BOOLEAN or BINARY_INTEGER. For example, assume that you want to declare a variable named `part_no` to hold 4-digit numbers and a variable named `in_stock` to hold the Boolean value TRUE or FALSE. You declare these variables as follows:

```
part_no  NUMBER(4);
in_stock BOOLEAN;
```

You can also declare nested tables, variable-size arrays (varrays for short), and records using the TABLE, VARRAY, and RECORD composite datatypes.

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. You place the variable to the left of the operator and an expression (which can include function calls) to the right. A few examples follow:

```
tax := price * tax_rate;
valid_id := FALSE;
bonus := current_salary * 0.10;
wages := gross_pay(emp_id, st_hrs, ot_hrs) - deductions;
```

The second way to assign values to a variable is by selecting (or fetching) database values into it. In the example below, you have Oracle compute a 10% bonus when you select the salary of an employee. Now, you can use the variable `bonus` in another computation or insert its value into a database table.

```
SELECT sal * 0.10 INTO bonus FROM emp WHERE empno = emp_id;
```

The third way to assign values to a variable is by passing it as an OUT or IN OUT parameter to a subprogram. As the following example shows, an IN OUT parameter lets you pass initial values to the subprogram being called and return updated values to the caller:

```
DECLARE
    my_sal REAL(7,2);
    PROCEDURE adjust_salary (emp_id INT, salary IN OUT REAL) IS ...
BEGIN
    SELECT AVG(sal) INTO my_sal FROM emp;
    adjust_salary(7788, my_sal); -- assigns a new value to my_sal
```


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. Thereafter, no more assignments to the constant are allowed. In the following example, you declare a constant named `credit_limit`:

```
credit_limit CONSTANT REAL := 5000.00;
```

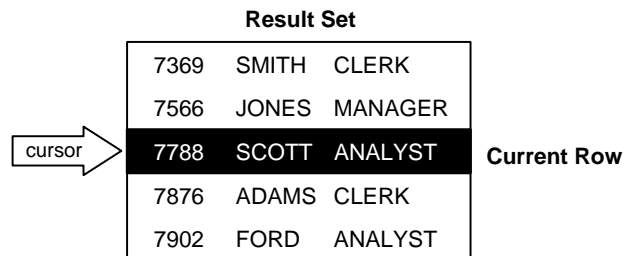
Cursors

Oracle uses work areas to execute SQL statements and store processing information. A PL/SQL construct called a *cursor* lets you name a work area and access its stored information. There are two kinds of cursors: *implicit* and *explicit*. PL/SQL implicitly declares a cursor for all SQL data manipulation statements, including queries that return only one row. For queries that return more than one row, you can explicitly declare a cursor to process the rows individually. An example follows:

```
DECLARE
  CURSOR c1 IS
    SELECT empno, ename, job FROM emp WHERE deptno = 20;
```

The set of rows returned by a multi-row query is called the *result set*. Its size is the number of rows that meet your search criteria. As [Figure 1-2](#) shows, an explicit cursor "points" to the *current row* in the result set. This allows your program to process the rows one at a time.

Figure 1-2 Query Processing



Multi-row query processing is somewhat like file processing. For example, a COBOL program opens a file, processes records, then closes the file. Likewise, a PL/SQL program opens a cursor, processes rows returned by a query, then closes the cursor. Just as a file pointer marks the current position in an open file, a cursor marks the current position in a result set.

You use the `OPEN`, `FETCH`, and `CLOSE` statements to control a cursor. The `OPEN` statement executes the query associated with the cursor, identifies the result set, and positions the cursor before the first row. The `FETCH` statement retrieves the current row and advances the cursor to the next row. When the last row has been processed, the `CLOSE` statement disables the cursor.

Cursor FOR Loops

In most situations that require an explicit cursor, you can simplify coding by using a cursor `FOR` loop instead of the `OPEN`, `FETCH`, and `CLOSE` statements. A cursor `FOR` loop implicitly declares its loop index as a record that represents a row fetched from the database. Next, it opens a cursor, repeatedly fetches rows of values from the result set into fields in the record, then closes the cursor when all rows have been processed. In the following example, the cursor `FOR` loop implicitly declares `emp_rec` as a record:

```
DECLARE
    CURSOR c1 IS
        SELECT ename, sal, hiredate, deptno FROM emp;
    ...
BEGIN
    FOR emp_rec IN c1 LOOP
        ...
        salary_total := salary_total + emp_rec.sal;
    END LOOP;
```

To reference individual fields in the record, you use *dot notation*, in which a dot (.) serves as the component selector.

Cursor Variables

Like a cursor, a cursor variable points to the current row in the result set of a multi-row query. But, unlike a cursor, a cursor variable can be opened for any type-compatible query. It is not tied to a specific query. Cursor variables are true PL/SQL variables, to which you can assign new values and which you can pass to subprograms stored in an Oracle database. This gives you more flexibility and a convenient way to centralize data retrieval.

Typically, you open a cursor variable by passing it to a stored procedure that declares a cursor variable as one of its formal parameters. The following procedure opens the cursor variable `generic_cv` for the chosen query:

```
PROCEDURE open_cv (generic_cv IN OUT GenericCurTyp, choice NUMBER) IS
BEGIN
    IF choice = 1 THEN
        OPEN generic_cv FOR SELECT * FROM emp;
    ELSIF choice = 2 THEN
        OPEN generic_cv FOR SELECT * FROM dept;
    ELSIF choice = 3 THEN
        OPEN generic_cv FOR SELECT * FROM salgrade;
    END IF;
    . . .
END;
```

Attributes

PL/SQL variables and cursors have *attributes*, which are properties that let you reference the datatype and structure of an item without repeating its definition. Database columns and tables have similar attributes, which you can use to ease maintenance. A percent sign (%) serves as the attribute indicator.

%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 `title` in a table named `books`. To declare a variable named `my_title` that has the same datatype as column `title`, use dot notation and the `%TYPE` attribute, as follows:

```
my_title books.title%TYPE;
```

Declaring `my_title` with `%TYPE` has two advantages. First, you need not know the exact datatype of `title`. Second, if you change the database definition of `title` (make it a longer character string for example), the datatype of `my_title` changes accordingly at run time.

%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.

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

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

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

```
my_deptno := dept_rec.deptno;
```

If you declare a cursor that retrieves the last name, salary, hire date, and job title of an employee, you can use `%ROWTYPE` to declare a record that stores the same information, as follows:

```
DECLARE
    CURSOR c1 IS
        SELECT ename, sal, hiredate, job FROM emp;
    emp_rec c1%ROWTYPE; -- declare record variable that represents
                        -- a row fetched from the emp table
```

When you execute the statement

```
FETCH c1 INTO emp_rec;
```

the value in the `ename` column of the `emp` table is assigned to the `ename` field of `emp_rec`, the value in the `sal` column is assigned to the `sal` field, and so on.

[Figure 1-3](#) shows how the result might appear.

Figure 1-3 `%ROWTYPE` Record

emp_rec	
<code>emp_rec.ename</code>	JAMES
<code>emp_rec.sal</code>	950.00
<code>emp_rec.hiredate</code>	03-DEC-95
<code>emp_rec.job</code>	CLERK

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. Collectively, these statements can handle any situation.

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; the ELSE clause defines what to do if the condition is false or null.

Consider the program below, which processes a bank transaction. Before allowing you to withdraw \$500 from account 3, it makes sure the account has sufficient funds to cover the withdrawal. If the funds are available, the program debits the account. Otherwise, the program inserts a record into an audit table.

```
-- available online in file 'examp2'
DECLARE
  acct_balance NUMBER(11,2);
  acct          CONSTANT NUMBER(4) := 3;
  debit_amt     CONSTANT NUMBER(5,2) := 500.00;
BEGIN
  SELECT bal INTO acct_balance FROM accounts
     WHERE account_id = acct
     FOR UPDATE OF bal;
  IF acct_balance >= debit_amt THEN
    UPDATE accounts SET bal = bal - debit_amt
       WHERE account_id = acct;
  ELSE
    INSERT INTO temp VALUES
      (acct, acct_balance, 'Insufficient funds');
    -- insert account, current balance, and message
  END IF;
  COMMIT;
END;
```

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 (which might be an entire PL/SQL block) for each case.

```
-- This CASE statement performs different actions based
-- on a set of conditional tests.
CASE
  WHEN shape = 'square' THEN area := side * side;
  WHEN shape = 'circle' THEN
    BEGIN
      area := pi * (radius * radius);
      DBMS_OUTPUT.PUT_LINE('Value is not exact because pi is
irrational. ');
    END;
  WHEN shape = 'rectangle' THEN area := length * width;
  ELSE
    BEGIN
      DBMS_OUTPUT.PUT_LINE('No formula to calculate area of a ' ||
shape);
      RAISE PROGRAM_ERROR;
    END;
END CASE;
```

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. For example, the following loop inserts 500 numbers and their square roots into a database table:

```
FOR num IN 1..500 LOOP
  INSERT INTO roots VALUES (num, SQRT(num));
END LOOP;
```

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 the following example, you find the first employee who has a salary over \$2500 and is higher in the chain of command than employee 7499:

```
-- available online in file 'examp3'
DECLARE
    salary            emp.sal%TYPE := 0;
    mgr_num           emp.mgr%TYPE;
    last_name         emp.ename%TYPE;
    starting_empno    emp.empno%TYPE := 7499;
BEGIN
    SELECT mgr INTO mgr_num FROM emp
        WHERE empno = starting_empno;
    WHILE salary <= 2500 LOOP
        SELECT sal, mgr, ename INTO salary, mgr_num, last_name
            FROM emp WHERE empno = mgr_num;
    END LOOP;
    INSERT INTO temp VALUES (NULL, salary, last_name);
    COMMIT;
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        INSERT INTO temp VALUES (NULL, NULL, 'Not found');
        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 the following example, the loop completes when the value of `total` exceeds 25,000:

```
LOOP
    ...
    total := total + salary;
    EXIT WHEN total > 25000; -- exit loop if condition is true
END LOOP;
-- control resumes here
```

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 the following example shows:

```
IF rating > 90 THEN
    GOTO calc_raise; -- branch to label
END IF;
...
<<calc_raise>>
IF job_title = 'SALESMAN' THEN -- control resumes here
    amount := commission * 0.25;
ELSE
    amount := salary * 0.10;
END IF;
```

Modularity

Modularity lets you break an application down into manageable, well-defined modules. Through successive refinement, you can reduce a complex problem to a set of simple problems that have easy-to-implement solutions. PL/SQL meets this need with *program units*, which include blocks, subprograms, and packages.

Subprograms

PL/SQL has two types of subprograms called *procedures* and *functions*, which can take parameters and be invoked (called). As the following example shows, 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:

```
PROCEDURE award_bonus (emp_id NUMBER) IS
    bonus          REAL;
    comm_missing EXCEPTION;
BEGIN -- executable part starts here
    SELECT comm * 0.15 INTO bonus FROM emp WHERE empno = emp_id;
    IF bonus IS NULL THEN
        RAISE comm_missing;
    ELSE
        UPDATE payroll SET pay = pay + bonus WHERE empno = emp_id;
    END IF;
EXCEPTION -- exception-handling part starts here
    WHEN comm_missing THEN
        ...
END award_bonus;
```


When called, this procedure accepts an employee number. It uses the number to select the employee's commission from a database table and, at the same time, compute a 15% bonus. Then, it checks the bonus amount. If the bonus is null, an exception is raised; otherwise, the employee's payroll record is updated.

Packages

PL/SQL lets you bundle logically related types, variables, cursors, and subprograms into a *package*. Each package is easy to understand and the interfaces between packages are simple, clear, and well defined. This aids application development.

Packages usually have two parts: a specification and a body. The *specification* is the interface to your applications; it declares the types, constants, variables, exceptions, cursors, and subprograms available for use. The *body* defines cursors and subprograms and so implements the specification.

In the following example, you package two employment procedures:

```
CREATE PACKAGE emp_actions AS -- package specification
    PROCEDURE hire_employee (empno NUMBER, ename CHAR, ...);
    PROCEDURE fire_employee (emp_id NUMBER);
END emp_actions;

CREATE PACKAGE BODY emp_actions AS -- package body
    PROCEDURE hire_employee (empno NUMBER, ename CHAR, ...) IS
    BEGIN
        INSERT INTO emp VALUES (empno, ename, ...);
    END hire_employee;
    PROCEDURE fire_employee (emp_id NUMBER) IS
    BEGIN
        DELETE FROM emp WHERE empno = emp_id;
    END fire_employee;
END emp_actions;
```

Only the declarations in the package specification are visible and accessible to applications. Implementation details in the package body are hidden and inaccessible.

Packages can be compiled and stored in an Oracle database, where their contents can be shared by many applications. When you call a packaged subprogram for the first time, the whole package is loaded into memory. So, subsequent calls to related subprograms in the package require no disk I/O. Thus, packages can enhance productivity and improve performance.

Data Abstraction

Data abstraction lets you extract the essential properties of data while ignoring unnecessary details. Once you design a data structure, you can forget the details and focus on designing algorithms that manipulate the data structure.

Collections

The collection types `TABLE` and `VARRAY` allow you to declare index-by tables, nested tables, and variable-size arrays (varrays for short). A 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.

To reference an element, use standard subscripting syntax. For example, the following call references the fifth element in the nested table (of type `Staff`) returned by function `new_hires`:

```
DECLARE
    TYPE Staff IS TABLE OF Employee;
    staffer Employee;
    FUNCTION new_hires (hiredate DATE) RETURN Staff IS
    BEGIN ... END;
BEGIN
    staffer := new_hires('10-NOV-98')(5);
    ...
END;
```

Collections work like the arrays found in most third-generation programming languages. Also, collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms.

Records

You can use the `%ROWTYPE` attribute to declare a record that represents a row in a table or a row fetched from a cursor. But, with a user-defined record, you can declare fields of your own.

Records contain uniquely named fields, which can have different datatypes. Suppose you have various data about an employee such as name, salary, and hire date. These items are dissimilar in type but logically related. A record containing a field for each item lets you treat the data as a logical unit.

Consider the following example:

```
DECLARE
```

```

TYPE TimeRec IS RECORD (hours SMALLINT, minutes SMALLINT);
TYPE MeetingTyp IS RECORD (
    date_held DATE,
    duration TimeRec, -- nested record
    location VARCHAR2(20),
    purpose VARCHAR2(50));

```

Notice that you can nest records. That is, a record can be a component of another record.

Object Types

In PL/SQL, object-oriented programming is based on 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 called *attributes*. The functions and procedures that characterize the behavior of the object type are called *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.

When you define an object type using the `CREATE TYPE` statement (in SQL*Plus for example), you create an abstract template for some real-world object. As the following example of a bank account shows, the template specifies only those attributes and behaviors the object will need in the application environment:

```

CREATE TYPE Bank_Account AS OBJECT (
    acct_number INTEGER(5),
    balance REAL,
    status VARCHAR2(10),
    MEMBER PROCEDURE open (amount IN REAL),
    MEMBER PROCEDURE verify_acct (num IN INTEGER),
    MEMBER PROCEDURE close (num IN INTEGER, amount OUT REAL),
    MEMBER PROCEDURE deposit (num IN INTEGER, amount IN REAL),
    MEMBER PROCEDURE withdraw (num IN INTEGER, amount IN REAL),
    MEMBER FUNCTION curr_bal (num IN INTEGER) RETURN REAL
);

```

At run time, when the data structure is filled with values, you have created an instance of an abstract bank account. You can create as many instances (called *objects*) as you need. Each object has the number, balance, and status of an actual bank account.

Information Hiding

With information hiding, you see only the details that are relevant at a given level of algorithm and data structure design. Information hiding keeps high-level design decisions separate from low-level design details, which are more likely to change.

Algorithms

You implement information hiding for algorithms through *top-down design*. Once you define the purpose and interface specifications of a low-level procedure, you can ignore the implementation details. They are hidden at higher levels. For example, the implementation of a procedure named `raise_salary` is hidden. All you need to know is that the procedure will increase a specific employee's salary by a given amount. Any changes to the definition of `raise_salary` are transparent to calling applications.

Data Structures

You implement information hiding for data structures through *data encapsulation*. By developing a set of utility subprograms for a data structure, you insulate it from users and other developers. That way, other developers know how to use the subprograms that operate on the data structure but not how the structure is represented.

With PL/SQL packages, you can specify whether subprograms are public or private. Thus, packages enforce data encapsulation by letting you put subprogram definitions in a black box. A private definition is hidden and inaccessible. Only the package, not your application, is affected if the definition changes. This simplifies maintenance and enhancement.

Error Handling

PL/SQL makes it easy to detect and process predefined and user-defined error conditions called *exceptions*. 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. To handle raised exceptions, you write separate routines called *exception handlers*.

Predefined exceptions are raised implicitly by the runtime system. For example, if you try to divide a number by zero, PL/SQL raises the predefined exception `ZERO_DIVIDE` automatically. You must raise user-defined exceptions explicitly with the `RAISE` statement.

You can define exceptions of your own in the declarative part of any PL/SQL block or subprogram. In the executable part, you check for the condition that needs special attention. If you find that the condition exists, you execute a `RAISE` statement. In the example below, you compute the bonus earned by a salesperson. The bonus is based on salary and commission. So, if the commission is null, you raise the exception `comm_missing`.

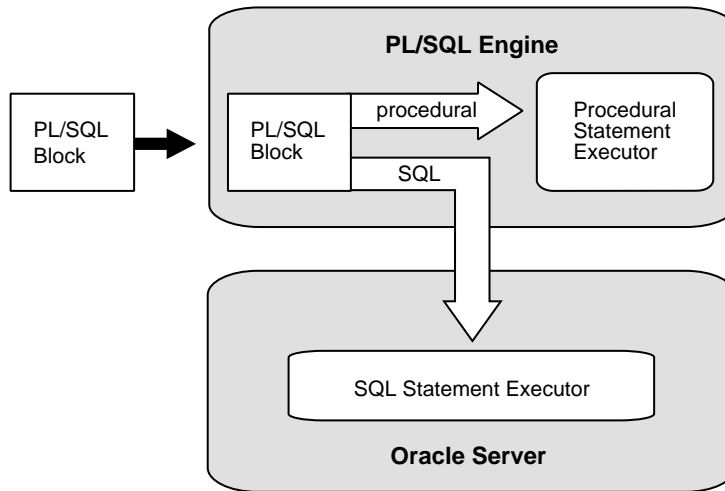
```
DECLARE
    ...
    comm_missing EXCEPTION; -- declare exception
BEGIN
    ...
    IF commission IS NULL THEN
        RAISE comm_missing; -- raise exception
    END IF;
    bonus := (salary * 0.10) + (commission * 0.15);
EXCEPTION
    WHEN comm_missing THEN ... -- process the exception
```

PL/SQL Architecture

The PL/SQL compilation and run-time system is a technology, not an independent product. Think of this technology as 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 or Oracle Reports. So, PL/SQL can reside in two environments:

- The Oracle database server
- Oracle tools

These two environments are independent. PL/SQL is bundled with the Oracle server but might be unavailable in some tools. In either environment, the PL/SQL engine accepts as input any valid PL/SQL block or subprogram. [Figure 1-4](#) shows the PL/SQL engine processing an anonymous block. The engine executes procedural statements but sends SQL statements to the SQL Statement Executor in the Oracle server.

Figure 1–4 PL/SQL Engine

In the Oracle Database Server

Application development tools that lack a local PL/SQL engine must rely on Oracle to process PL/SQL blocks and subprograms. When it contains the PL/SQL engine, an Oracle server can process PL/SQL blocks and subprograms as well as single SQL statements. The Oracle server passes the blocks and subprograms to its local PL/SQL engine.

Anonymous Blocks

Anonymous PL/SQL blocks can be embedded in an Oracle Precompiler or OCI program. At run time, the program, lacking a local PL/SQL engine, sends these blocks to the Oracle server, where they are compiled and executed. Likewise, interactive tools such as SQL*Plus and Enterprise Manager, lacking a local PL/SQL engine, must send anonymous blocks to Oracle.

Stored Subprograms

Subprograms can be compiled separately and stored permanently in an Oracle database, ready to be executed. A subprogram explicitly `CREATED` using an Oracle tool is called a *stored* subprogram. Once compiled and stored in the data dictionary, it is a schema object, which can be referenced by any number of applications connected to that database.

Stored subprograms defined within a package are called *packaged* subprograms. Those defined independently are called *standalone* subprograms. Those defined within another subprogram or within a PL/SQL block are called *local* subprograms, which cannot be referenced by other applications and exist only for the convenience of the enclosing block.

Stored subprograms offer higher productivity, better performance, memory savings, application integrity, and tighter security. For example, by designing applications around a library of stored procedures and functions, you can avoid redundant coding and increase your productivity.

You can call stored subprograms from a database trigger, another stored subprogram, an Oracle Precompiler application, an OCI application, or interactively from SQL*Plus or Enterprise Manager. For example, you might call the standalone procedure `create_dept` from SQL*Plus as follows:

```
SQL> CALL create_dept('FINANCE', 'NEW YORK');
```

Subprograms are stored in parsed, compiled form. So, when called, they are loaded and passed to the PL/SQL engine immediately. Also, they take advantage of shared memory. So, only one copy of a subprogram need be loaded into memory for execution by multiple users.

Database Triggers

A database trigger is a stored subprogram associated with a database table, view, or event. For instance, you can have Oracle fire a trigger automatically before or after an INSERT, UPDATE, or DELETE statement affects a table. One of the many uses for database triggers is to audit data modifications. For example, the following *table-level* trigger fires whenever salaries in the `emp` table are updated:

```
CREATE TRIGGER audit_sal
  AFTER UPDATE OF sal ON emp
  FOR EACH ROW
BEGIN
  INSERT INTO emp_audit VALUES ...
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, see *Oracle9i Application Developer's Guide - Fundamentals*.

In Oracle Tools

When it contains the PL/SQL engine, an application development tool can process PL/SQL blocks and subprograms. The tool passes the blocks to its local PL/SQL engine. The engine executes all procedural statements at the application site and sends only SQL statements to Oracle. Thus, most of the work is done at the application site, not at the server site.

Furthermore, if the block contains no SQL statements, the engine executes the entire block at the application site. This is useful if your application can benefit from conditional and iterative control.

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

Advantages of PL/SQL

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

- Support for SQL
- Support for object-oriented programming
- Better performance
- Higher productivity
- Full portability
- Tight integration with Oracle
- Tight security

Support for 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.

SQL is non-procedural, meaning that you can state what you want done without stating how to do it. Oracle determines the best way to carry out your request. There is no necessary connection between consecutive statements because Oracle executes SQL statements one at a time.

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. So, you can manipulate Oracle data flexibly and safely. Also, PL/SQL fully supports SQL datatypes. That reduces the need to convert data passed between your applications and the database.

PL/SQL also supports dynamic SQL, an advanced 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 "on the fly" at run time.

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.

In addition, object types allow for realistic data modeling. Complex real-world entities and relationships map directly into object types. That helps your programs better reflect the world they are trying to simulate.

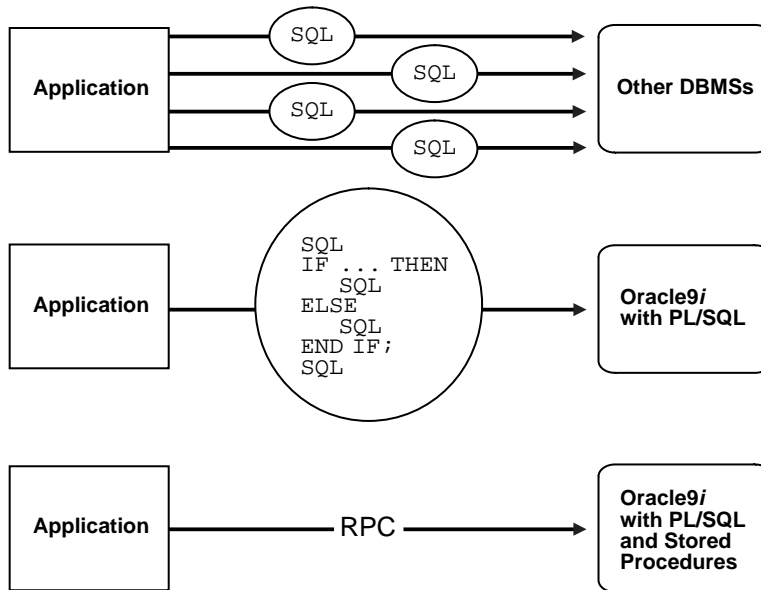
Better Performance

Without PL/SQL, Oracle must process SQL statements one at a time. Each SQL statement results in another call to Oracle and higher performance overhead. In a networked environment, the overhead can become significant. Every time a SQL statement is issued, it must be sent over the network, creating more traffic.

However, with PL/SQL, an entire block of statements can be sent to Oracle at one time. This can drastically reduce communication between your application and Oracle. As [Figure 1-5](#) shows, if your application is database intensive, you can use PL/SQL blocks and subprograms to group SQL statements before sending them to Oracle for execution.

PL/SQL stored procedures are compiled once and stored in executable form, so procedure calls are quick and efficient. Also, stored procedures, which execute in the server, can be invoked over slow network connections with a single call. That reduces network traffic and improves round-trip response times. Executable code is automatically cached and shared among users. That lowers memory requirements and invocation overhead.

Figure 1–5 PL/SQL Boosts Performance



PL/SQL also improves performance by adding procedural processing power to Oracle tools. Using PL/SQL, a tool can do any computation quickly and efficiently without calling on the Oracle server. This saves time and reduces network traffic.

Higher Productivity

PL/SQL adds functionality to non-procedural tools such as Oracle Forms and Oracle Reports. With PL/SQL in these tools, you can use familiar procedural constructs to build applications. For example, you can use an entire PL/SQL block in an Oracle Forms trigger. You need not use multiple trigger steps, macros, or user exits. Thus, PL/SQL increases productivity by putting better tools in your hands.

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

Full Portability

Applications written in PL/SQL are portable to any operating system and platform on which Oracle runs. In other words, PL/SQL programs can run anywhere Oracle can run; you need not tailor them to each new environment. That means you can write portable program libraries, which can be reused in different environments.

Tight Integration with SQL

The PL/SQL and SQL languages are tightly integrated. PL/SQL supports all the SQL datatypes and the non-value `NULL`. That allows you to manipulate Oracle data easily and efficiently. It also helps you to write high-performance code.

The `%TYPE` and `%ROWTYPE` attributes further integrate PL/SQL with SQL. For example, you can use the `%TYPE` attribute to declare variables, basing the declarations on the definitions of database columns. If a definition changes, the variable declaration changes accordingly the next time you compile or run your program. The new definition takes effect without any effort on your part. This provides data independence, reduces maintenance costs, and allows programs to adapt as the database changes to meet new business needs.

Tight Security

PL/SQL stored procedures enable you to partition application logic between the client and server. That way, you can prevent client applications from manipulating sensitive Oracle data. Database triggers written in PL/SQL can disable application updates selectively and do content-based auditing of user inserts.

Furthermore, you can restrict access to Oracle data by allowing users to manipulate it only through stored procedures that execute with their definer's privileges. For example, you can grant users access to a procedure that updates a table, but not grant them access to the table itself.

Fundamentals of PL/SQL

There are six essentials in painting. The first is called spirit; the second, rhythm; the third, thought; the fourth, scenery; the fifth, the brush; and the last is the ink. —Ching Hao

The previous chapter provided an overview of PL/SQL. This chapter focuses on the small-scale aspects of the language. Like every other programming language, PL/SQL has a character set, reserved words, punctuation, datatypes, rigid syntax, and fixed rules of usage and statement formation. You use these basic elements of PL/SQL to represent real-world objects and operations.

This chapter discusses the following topics:

- Character Set
- Lexical Units
- Declarations
- Naming Conventions
- Scope and Visibility
- Assignments
- Expressions and Comparisons
- Built-In Functions

Character Set

You write a PL/SQL program as lines of text using a specific set of characters. The PL/SQL character set includes

- the upper- and lower-case letters A .. Z and a .. z
- the numerals 0 .. 9
- the symbols () + - * / < > = ! ~ ^ ; : . ' @ % , " # \$ & _ | { } ? []
- tabs, spaces, and carriage returns

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

Lexical Units

A line of PL/SQL text contains groups of characters known as *lexical units*, which can be classified as follows:

- 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
```

However, you cannot embed spaces in 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
```

To show structure, you can divide lines using carriage returns and indent lines using spaces or tabs. Compare these `IF` statements for readability:

```
IF x>y THEN max:=x;ELSE max:=y;END IF; | 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. Simple symbols consist of one character. A list follows:

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

Compound symbols consist of two characters. A list follows:

Symbol	Meaning
<code>:=</code>	assignment operator
<code>=></code>	association operator
<code> </code>	concatenation operator
<code>**</code>	exponentiation operator
<code><<</code>	label delimiter (begin)
<code>>></code>	label delimiter (end)
<code>/*</code>	multi-line comment delimiter (begin)
<code>*/</code>	multi-line comment delimiter (end)
<code>..</code>	range operator
<code><></code>	relational operator
<code>!=</code>	relational operator
<code>~=</code>	relational operator
<code>^=</code>	relational operator
<code><=</code>	relational operator
<code>>=</code>	relational operator
<code>--</code>	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      -- not allowed because of ampersand
debit-amount    -- not allowed because of hyphen
on/off          -- not allowed because of slash
user id         -- not allowed because of space
```

The next examples show that 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. So, if the only difference between identifiers is the case of corresponding letters, PL/SQL considers the identifiers to be the same, as the following example shows:

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

The size of an identifier cannot exceed 30 characters. But, 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. So, 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 and so should not be redefined. For example, the words `BEGIN` and `END`, which bracket the executable part of a block or subprogram, are reserved. As the next example shows, if you try to redefine a reserved word, you get a compilation error:

```
DECLARE
    end BOOLEAN; -- not allowed; causes compilation error
```

However, you can embed reserved words in an identifier, as the following example shows:

```
DECLARE
    end_of_game BOOLEAN; -- allowed
```

Often, reserved words are written in upper case to promote readability. However, like other PL/SQL identifiers, reserved words can be written in lower or mixed case. For a list of reserved words, see [Appendix F](#).

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.

Some PL/SQL reserved words are not reserved by SQL. For example, you can use the PL/SQL reserved word `TYPE` in a `CREATE TABLE` statement to name a database column. But, if a SQL statement in your program refers to that column, you get a compilation error, as the following example shows:

```
SELECT acct, type, bal INTO ... -- causes compilation error
```

To prevent the error, enclose the uppercase column name in double quotes, as follows:

```
SELECT acct, "TYPE", bal INTO ...
```

The column name cannot appear in lower or mixed case (unless it was defined that way in the `CREATE TABLE` statement). For example, the following statement is invalid:

```
SELECT acct, "type", bal INTO ... -- causes compilation error
```

Alternatively, you can create a view that renames the troublesome column, then use the view instead of the base table in SQL statements.

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.

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.

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 must be 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
```

As the following example shows, if the value of a numeric literal falls outside the range 1E-130 .. 10E125, you get a compilation error:

```
DECLARE
  n NUMBER;
BEGIN
  n := 10E127; -- causes a 'numeric overflow or underflow' error
```

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.

Several examples follow:

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

All string literals except the null string (') have datatype CHAR.

Given that apostrophes (single quotes) delimit string literals, how do you represent an apostrophe within a string? As the next example shows, you write two single quotes, which is not the same as writing a double quote:

```
'Don''t leave without saving your work.'
```

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

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

Boolean Literals

Boolean literals are the predefined values TRUE, FALSE, and NULL (which 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:

```
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 *Oracle9i SQL Reference*. For examples of performing date/time arithmetic, see *Oracle9i 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:

```
-- begin processing
SELECT sal INTO salary FROM emp -- get current salary
    WHERE empno = emp_id;
bonus := salary * 0.15; -- compute bonus amount
```

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 "comment-out" the line:

```
-- DELETE FROM emp WHERE comm IS NULL;
```

Multi-line Comments

Multi-line comments begin with a slash-asterisk (/*), end with an asterisk-slash (* /), and can span multiple lines. Some examples follow:

```
BEGIN
    ...
    /* Compute a 15% bonus for top-rated employees. */
    IF rating > 90 THEN
```

```

        bonus := salary * 0.15 /* bonus is based on salary */
ELSE
    bonus := 0;
END IF;
...
/* The following line computes the area of a
   circle using pi, which is the ratio between
   the circumference and diameter. */
area := pi * radius**2;
END;

```

You can use multi-line comment delimiters to comment-out whole sections of code, as the following example shows:

```

/*
LOOP
    FETCH c1 INTO emp_rec;
    EXIT WHEN c1%NOTFOUND;
...
END LOOP;
*/

```

Restrictions on Comments

You cannot nest comments. Also, you cannot use single-line comments in a PL/SQL block that will be processed dynamically 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. So, use multi-line comments 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.

A couple of examples follow:

```

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:

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

By default, variables are initialized to `NULL`. So, these declarations are equivalent:

```
birthday DATE;
birthday DATE := NULL;
```

In the declaration of a constant, the keyword `CONSTANT` must precede the type specifier, as the following example shows:

```
credit_limit CONSTANT REAL := 5000.00;
```

This declaration names a constant of type `REAL` and assigns an initial (also final) value of 5000 to the constant. A constant must be initialized in its declaration. Otherwise, you get a compilation error when the declaration is elaborated. (The processing of a declaration by the PL/SQL compiler is called *elaboration*.)

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. A couple of examples follow:

```
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, as the following example shows:

```
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. For example, the following declaration is not allowed:

```
acct_id INTEGER(5) NOT NULL; -- not allowed; not initialized
```

PL/SQL provide subtypes NATURALN and POSITIVEN that are predefined as NOT NULL. For instance, the following declarations are equivalent:

```
emp_count NATURAL NOT NULL := 0;
emp_count NATURALN := 0;
```

In NATURALN and POSITIVEN declarations, the type specifier must be followed by an initialization clause. Otherwise, you get a compilation error. For example, the following declaration is not allowed:

```
line_items POSITIVEN; -- not allowed; not initialized
```

Using %TYPE

The %TYPE attribute provides the datatype of a variable or database column. In the following example, %TYPE provides the datatype of a variable:

```
credit REAL(7,2);
debit credit%TYPE;
```

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 REAL(7,2) variable. The next example shows that a %TYPE declaration can include an initialization clause:

```
balance          NUMBER(7,2);
minimum_balance balance%TYPE := 10.00;
```

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

```
my_dname scott.dept.dname%TYPE;
```

Using `%TYPE` to declare `my_dname` has two advantages. First, you need not know the exact datatype of `dname`. Second, if the database definition of `dname` changes, the datatype of `my_dname` changes accordingly at run time.

However, `%TYPE` variables do not inherit the `NOT NULL` column constraint. In the next example, even though the database column `empno` is defined as `NOT NULL`, you can assign a null to the variable `my_empno`:

```
DECLARE
    my_empno emp.empno%TYPE;
    ...
BEGIN
    my_empno := NULL; -- this works
```

Using %ROWTYPE

The `%ROWTYPE` attribute provides a record type that represents a row in a table (or view). The record can store an entire row of data selected from the table or fetched from a cursor or strongly typed cursor variable. In the example below, you declare two records. The first record stores a row selected from the `emp` table. The second record stores a row fetched from cursor `c1`.

```
DECLARE
    emp_rec emp%ROWTYPE;
    CURSOR c1 IS SELECT deptno, dname, loc FROM dept;
    dept_rec c1%ROWTYPE;
```

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 the `NOT NULL` column constraint.

In the following example, you select column values into record `emp_rec`:

```
BEGIN
    SELECT * INTO emp_rec FROM emp WHERE ...
```

The column values returned by the `SELECT` statement are stored in fields. To reference a field, you use dot notation. For example, you might reference the `deptno` field as follows:

```
IF emp_rec.deptno = 20 THEN ...
```

Also, you can assign the value of an expression to a specific field, as the following examples show:

```
emp_rec.ename := 'JOHNSON';
emp_rec.sal := emp_rec.sal * 1.15;
```

In the final example, you use `%ROWTYPE` to define a packaged cursor:

```
CREATE PACKAGE emp_actions AS
    CURSOR c1 RETURN emp%ROWTYPE; -- declare cursor specification
    ...
END emp_actions;

CREATE PACKAGE BODY emp_actions AS
    CURSOR c1 RETURN emp%ROWTYPE IS -- define cursor body
        SELECT * FROM emp WHERE sal > 3000;
    ...
END emp_actions;
```

Aggregate Assignment

A `%ROWTYPE` declaration cannot include an initialization clause. However, 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. For example, the following assignment is allowed:

```
DECLARE
    dept_rec1 dept%ROWTYPE;
    dept_rec2 dept%ROWTYPE;
    CURSOR c1 IS SELECT deptno, dname, loc FROM dept;
    dept_rec3 c1%ROWTYPE;
BEGIN
    ...
    dept_rec1 := dept_rec2;
```

However, because `dept_rec2` is based on a table and `dept_rec3` is based on a cursor, the following assignment is not allowed:

```
dept_rec2 := dept_rec3; -- not allowed
```

Second, you can assign a list of column values to a record by using the `SELECT` or `FETCH` statement, as the example below 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 dept%ROWTYPE;
    ...
BEGIN
    SELECT * INTO dept_rec FROM dept WHERE deptno = 30;
    ...
END;
```

However, you cannot assign a list of column values to a record by using an assignment statement. So, the following syntax is not allowed:

```
record_name := (value1, value2, value3, ...); -- not allowed
```

Using Aliases

Select-list items fetched from a cursor associated with `%ROWTYPE` must have simple names or, if they are expressions, must have aliases. In the following example, you use an alias called `wages`:

```
-- available online in file 'examp4'
DECLARE
    CURSOR my_cursor IS
        SELECT sal + NVL(comm, 0) wages, ename FROM emp;
    my_rec my_cursor%ROWTYPE;
BEGIN
    OPEN my_cursor;
    LOOP
        FETCH my_cursor INTO my_rec;
        EXIT WHEN my_cursor%NOTFOUND;
        IF my_rec.wages > 2000 THEN
            INSERT INTO temp VALUES (NULL, my_rec.wages, my_rec.ename);
        END IF;
    END LOOP;
    CLOSE my_cursor;
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. For example, the following declaration of `maxi` is not allowed:

```
maxi INTEGER := 2 * mini; -- not allowed
mini INTEGER := 15;
```

However, PL/SQL does allow the forward declaration of subprograms. For more information, see ["Declaring PL/SQL Subprograms"](#) on page 8-10.

Some languages allow you to declare a list of variables that have the same datatype. PL/SQL does *not* allow this. For example, the following declaration is not allowed:

```
i, j, k SMALLINT; -- not allowed
```

You must declare each variable separately:

```
i SMALLINT;
j SMALLINT;
k SMALLINT;
```

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, and packages. 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. So, even if their datatypes differ, variables and parameters cannot share the same name. In the following example, the second declaration is not allowed:

```
DECLARE
    valid_id BOOLEAN;
    valid_id VARCHAR2(5); -- not allowed duplicate identifier
```

For the scoping rules that apply to identifiers, see "[Scope and Visibility](#)" on page 2-19.

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:

```
DECLARE
    zip_code INTEGER;
    Zip_Code INTEGER; -- same as zip_code
```

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, the following `DELETE` statement removes all employees from the `emp` table, not just 'KING', because Oracle assumes that both `ename` in the `WHERE` clause refer to the database column:

```
DECLARE
    ename VARCHAR2(10) := 'KING';
BEGIN
    DELETE FROM emp WHERE ename = ename;
    ...
```

In such cases, to avoid ambiguity, prefix the names of local variables and formal parameters with `my_`, as follows:

```
DECLARE
    my_ename VARCHAR2(10);
```

Or, use a block label to qualify references, as in

```
<<main>>
DECLARE
    ename VARCHAR2(10) := 'KING';
BEGIN
    DELETE FROM emp WHERE ename = main.ename;
    ...
```

The next example shows that you can use a subprogram name to qualify references to local variables and formal parameters:

```
FUNCTION bonus (deptno IN NUMBER, ...) RETURN REAL IS
    job CHAR(10);
BEGIN
    SELECT ... WHERE deptno = bonus.deptno AND job = bonus.job;
    ...
```

For a full discussion of name resolution, see [Appendix D](#).

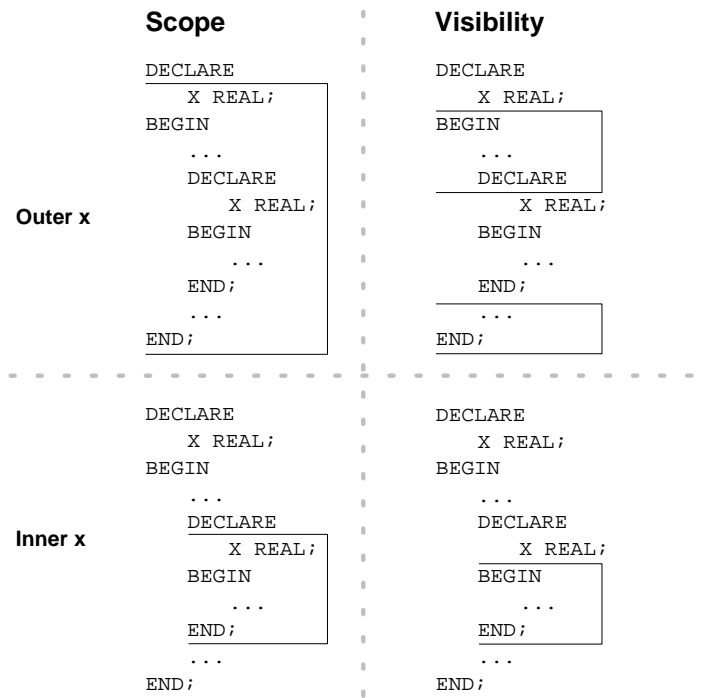
Scope and Visibility

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



The example below 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.

```

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

```



```

DECLARE
    d REAL;
BEGIN
    -- 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 the following example shows:

```

<<outer>>
DECLARE
    birthdate DATE;
BEGIN
    DECLARE
        birthdate DATE;
    BEGIN
        ...
        IF birthdate = outer.birthdate THEN ...
    END;
    ...
END;

```

As the next example shows, the qualifier can also be the name of an enclosing subprogram:

```

PROCEDURE check_credit (...) IS
    rating NUMBER;
    FUNCTION valid (...) RETURN BOOLEAN IS
        rating NUMBER;
    BEGIN
        ...
        IF check_credit.rating < 3 THEN ...
    END;
BEGIN
    ...
END;

```

However, within the same scope, a label and a subprogram cannot have the same name.

Assignments

Variables and constants are initialized every time a block or subprogram is entered. By default, variables are initialized to `NULL`. So, unless you expressly initialize a variable, its value is undefined, as the following example shows:

```
DECLARE
    count INTEGER;
    ...
BEGIN
    count := count + 1; -- assigns a null to count
```

The expression on the right of the assignment operator yields `NULL` because `count` is null. To avoid unexpected results, never reference a variable before you assign it a value.

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

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

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.

Boolean Values

Only the values `TRUE`, `FALSE`, and `NULL` can be assigned to a Boolean variable. For example, given the declaration

```
DECLARE
    done BOOLEAN;
```

the following statements are allowed:

```
BEGIN
    done := FALSE;
    WHILE NOT done LOOP
        ...
    END LOOP;
```

When applied to an expression, the relational operators return a Boolean value. So, the following assignment is allowed:

```
done := (count > 500);
```

Database Values

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. An example follows:

```
DECLARE
  emp_id    emp.empno%TYPE;
  emp_name  emp.ename%TYPE;
  wages     NUMBER(7,2);
BEGIN
  -- assign a value to emp_id here
  SELECT ename, sal + comm
     INTO emp_name, wages FROM emp
    WHERE empno = emp_id;
  ...
END;
```

However, you cannot select column values into a Boolean variable.

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* (finds the current value of) an expression by combining the values of the operands in ways specified by the operators. This always yields a single value and datatype. PL/SQL determines the datatype 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 2-1](#) shows the default order of operations from first to last (top to bottom).

Table 2-1 *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 example below, 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 2-2](#). AND and OR are binary operators; NOT is a unary operator.

Table 2-2 Logic Truth Table

x	y	x AND y	x OR y	NOT x
TRUE	TRUE	TRUE	TRUE	FALSE
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. It follows that if you apply the NOT operator to a null, the result is also indeterminate. Be careful. Nulls can cause unexpected results; see "[Handling Null Values in Comparisons and Conditional Statements](#)" on page 2-33.

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 following `OR` expression:

```
DECLARE
    ...
    on_hand INTEGER;
    on_order INTEGER;
BEGIN
    ..
    IF (on_hand = 0) OR ((on_order / on_hand) < 5) THEN
        ...
    END IF;
END;
```

When the value of `on_hand` is zero, the left operand yields `TRUE`, so PL/SQL need not evaluate the right operand. If PL/SQL were to evaluate both operands before applying the `OR` operator, the right operand would cause a *division by zero* error. In any case, it is a poor programming practice to rely on short-circuit evaluation.

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. Here are a couple of examples:

```
IF quantity_on_hand > 0 THEN
    UPDATE inventory SET quantity = quantity - 1
        WHERE part_number = item_number;
ELSE
    ...
END IF;
```

Relational Operators

The relational operators allow you to compare arbitrarily complex expressions. The following list gives the meaning of each operator:

Operator	Meaning
=	equal to
<>, !=, ~=, ^=	not equal to
<	less than
>	greater than
<=	less than or equal to
>=	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`. So, test for **nullity** (the state of being 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 `ename` is `'JOHNSON'`, the following expression is true:

```
ename LIKE 'J%SON'
```

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 statement does *not* delete rows in which the `ename` column is null:

```
DELETE FROM emp WHERE ename IN (NULL, 'KING', 'FORD');
```

Furthermore, expressions of the form

```
value NOT IN set
```

yield `FALSE` if the set contains a null. For example, instead of deleting rows in which the `ename` column is not null and not `'KING'`, the following statement deletes no rows:

```
DELETE FROM emp WHERE ename NOT IN (NULL, 'KING');
```

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.

There are semantic differences between the `CHAR` and `VARCHAR2` base types that come into play when you compare character values. For more information, see [Appendix B](#).

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 "[Character Types](#)" on page 3-5.

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. So, for example, the following `IF` condition might not yield `TRUE`:

```
count := 1;  
IF count = 1.0 THEN  
    ...  
END IF;
```

- 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. So, comparisons with the Boolean values `TRUE` and `FALSE` are redundant. For example, assuming the variable `done` is of type `BOOLEAN`, the `WHILE` statement

```
WHILE NOT (done = TRUE) LOOP  
    ...  
END LOOP;
```

can be simplified as follows:

```
WHILE NOT done LOOP  
    ...  
END LOOP;
```

- Using CLOB values with comparison operators, or functions such as LIKE and BETWEEN, can result in creation of temporary LOBs. You might need to make sure your temporary tablespace is large enough to handle these temporary LOBs. For details, see the "Modeling and Design" chapter in *Oracle9i Application Developer's Guide - Large Objects (LOBs)*.

CASE Expressions

A CASE expression selects a result and returns it. To select the result, the CASE expression uses a **selector**, an expression whose value is used to select one of several alternatives. A CASE expression has the following form:

```
CASE selector
  WHEN expression1 THEN result1
  WHEN expression2 THEN result2
  ...
  WHEN expressionN THEN resultN
  [ELSE resultN+1]
END;
```

The selector is followed by one or more WHEN clauses, which are checked sequentially. The value of the selector determines which clause is executed. The first WHEN clause that matches the value of the selector determines the result value, and subsequent WHEN clauses are not evaluated. An example follows:

```
DECLARE
  grade CHAR(1);
  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;
  ...
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.

An alternative to the CASE expression is the CASE statement, where each WHEN clause can be an entire PL/SQL block. For details, see "[CASE Statement](#)" on page 4-5.

Searched CASE Expression

PL/SQL also provides a *searched* CASE expression, which has the form:

```
CASE
  WHEN search_condition1 THEN result1
  WHEN search_condition2 THEN result2
  ...
  WHEN search_conditionN THEN resultN
  [ELSE resultN+1]
END;
```

A searched CASE expression has no selector. Each WHEN clause contains a search condition that yields a Boolean value, which lets you test different variables or multiple conditions in a single WHEN clause. An example follows:

```
DECLARE
  grade CHAR(1);
  appraisal VARCHAR2(20);
BEGIN
  ...
  appraisal :=
    CASE
      WHEN grade = 'A' THEN 'Excellent'
      WHEN grade = 'B' THEN 'Very Good'
      WHEN grade = 'C' THEN 'Good'
      WHEN grade = 'D' THEN 'Fair'
      WHEN grade = 'F' THEN 'Poor'
      ELSE 'No such grade'
    END;
  ...
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 the example below, 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.

```
x := 5;
y := NULL;
...
IF x != y THEN -- yields NULL, not TRUE
    sequence_of_statements; -- not executed
END IF;
```

In the next 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.

```
a := NULL;
b := NULL;
...
IF a = b THEN -- yields NULL, not TRUE
    sequence_of_statements; -- not executed
END IF;
```

NOT Operator

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

<pre>IF x > y THEN high := x; ELSE high := y; END IF;</pre>	<pre>IF NOT x > y THEN high := y; ELSE high := x; END IF;</pre>
--	--

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`.

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:

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

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

```
IF my_string IS NULL THEN ...
```

Concatenation Operator

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

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

returns the following value:

```
'applesauce'
```

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 the following example, if the column `rating` is null, `DECODE` returns the value 1000:

```
SELECT DECODE(rating, NULL, 1000, 'C', 2000, 'B', 4000, 'A', 5000)
```

```
INTO credit_limit FROM accts WHERE acctno = my_acctno;
```

The function `NVL` returns the value of its second argument if its first argument is null. In the example below, if `hire_date` is null, `NVL` returns the value of `SYSDATE`. Otherwise, `NVL` returns the value of `hire_date`:

```
start_date := NVL(hire_date, SYSDATE);
```

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 instance, after the assignment

```
new_string := REPLACE(old_string, NULL, my_string);
```

the values of `old_string` and `new_string` are the same.

If its third argument is null, `REPLACE` returns its first argument with every occurrence of its second argument removed. For example, after the assignments

```
syllabified_name := 'Gold-i-locks';
name := REPLACE(syllabified_name, '-', NULL);
```

the value of `name` is 'goldilocks'

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

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 2–3 shows the functions in each category. For descriptions of the error-reporting functions, see [Chapter 13](#). For descriptions of the other functions, see *Oracle9i 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 2–3 Built-In Functions

Error	Number	Character	Conversion	Date	Obj Ref	Misc
SQLCODE	ABS	ASCII	CHARTOROWID	ADD_MONTHS	DEREF	BFILENAME
SQLERRM	ACOS	CHR	CONVERT	CURRENT_DATE	REF	DECODE
	ASIN	CONCAT	HEXTORAW	CURRENT_TIMESTAMP	VALUE	DUMP
	ATAN	INITCAP	RAWTOHEX	DBTIMEZONE		EMPTY_BLOB
	ATAN2	INSTR	ROWIDTOCHAR	EXTRACT		EMPTY_CLOB
	BITAND	INSTRB	TO_BLOB	FROM_TZ		GREATEST
	CEIL	LENGTH	TO_CHAR	LAST_DAY		LEAST
	COS	LENGTHB	TO_CLOB	LOCALTIMESTAMP		NLS_CHARSET_DECL_LEN
	COSH	LOWER	TO_DATE	MONTHS_BETWEEN		NLS_CHARSET_ID
	EXP	LPAD	TO_MULTI_BYTE	NEW_TIME		NLS_CHARSET_NAME
	FLOOR	LTRIM	TO_NCLOB	NEXT_DAY		NVL
	LN	NLS_INITCAP	TO_NUMBER	NUMTODSINTERVAL		SYS_CONTEXT
	LOG	NLS_LOWER	TO_SINGLE_BYTE	NUMTOYMINTERVAL		SYS_GUID
	MOD	NLSSORT		ROUND		UID
	POWER	NLS_UPPER		SESSIONTIMEZONE		USER
	ROUND	REPLACE		SYSDATE		USERENV
	SIGN	RPAD		SYSTIMESTAMP		VSIZE
	SIN	RTRIM		TO_DSINTERVAL		
	SINH	SOUNDEX		TO_TIMESTAMP		
	SQRT	SUBSTR		TO_TIMESTAMP_LTZ		
	TAN	SUBSTRB		TO_TIMESTAMP_TZ		
	TANH	TRANSLATE		TO_YMINTERVAL		
	TRUNC	TRIM		TZ_OFFSET		
		UPPER		TRUNC		

PL/SQL Datatypes

Like—but oh how different! —William Wordsworth

Every constant, variable, and parameter has a *datatype* (or *type*), which specifies a storage format, constraints, and valid range of values. PL/SQL provides a variety of predefined datatypes. For instance, you can choose from integer, floating point, character, Boolean, date, collection, reference, and LOB types. In addition, PL/SQL 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 discusses the following topics:

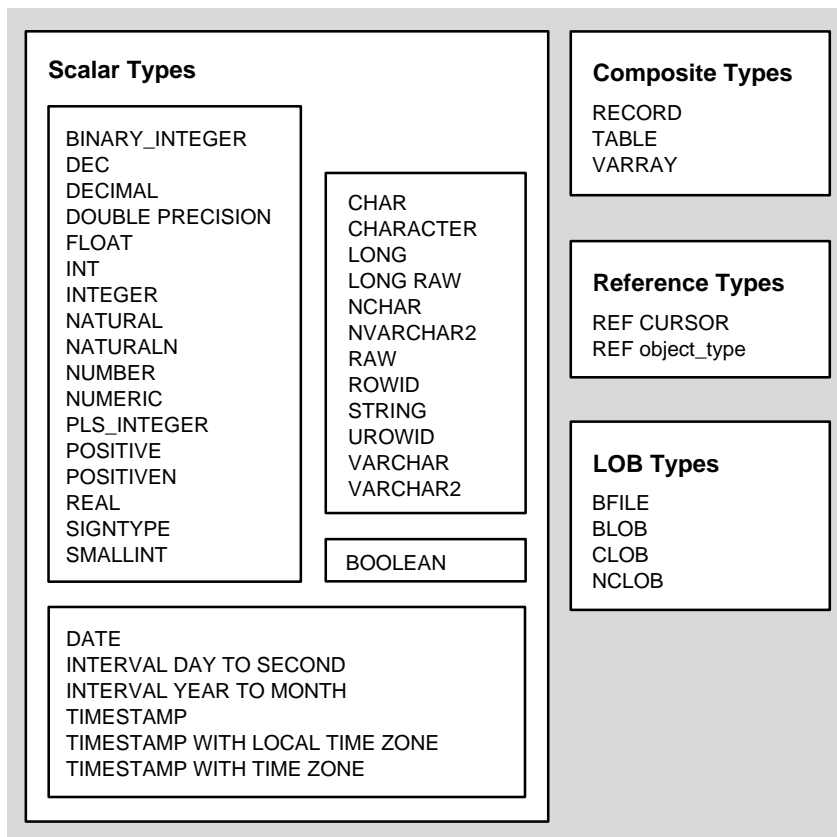
- [Predefined Datatypes](#)
- [User-Defined Subtypes](#)
- [Datatype Conversion](#)

Predefined Datatypes

A *scalar* type has no internal components. A *composite* type has internal components that can be manipulated individually. A *reference* type holds values, called *pointers*, that designate other program items. A *LOB* type holds values, called lob locators, that specify the location of large objects (graphic images for example) stored out-of-line.

Figure 3–1 shows the predefined datatypes available for your use. The scalar types fall into four families, which store number, character, Boolean, and date/time data, respectively.

Figure 3–1 Built-in Datatypes



Number Types

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

BINARY_INTEGER

You use the `BINARY_INTEGER` datatype to store signed integers. Its magnitude range is $-2^{31} .. 2^{31}$. Like `PLS_INTEGER` values, `BINARY_INTEGER` values require less storage than `NUMBER` values. However, most `BINARY_INTEGER` operations are slower than `PLS_INTEGER` operations.

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.

NUMBER

You use the `NUMBER` datatype to store fixed-point or floating-point numbers. Its magnitude range is $1E-130 .. 10E125$. If the value of an expression falls outside this range, you get a *numeric overflow or underflow* error. You can specify *precision*, which is the total number of digits, and *scale*, which is the number of digits to the right of the decimal point. The syntax follows:

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

To declare fixed-point numbers, for which you must specify *scale*, use the following form:

```
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:

```
NUMBER
```

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

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

You cannot use constants or variables to specify *precision* and *scale*; you must use integer literals. The maximum precision of a `NUMBER` value is 38 decimal digits. If you do not specify *precision*, it defaults to 38 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 (3.456 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 (3456 becomes 3000). A scale of 0 rounds to the nearest whole number. If you do not specify *scale*, it defaults to 0.

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  
INTEGER  
INT  
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

You use the `PLS_INTEGER` datatype to store signed integers. Its magnitude range is $-2^{31} .. 2^{31}$. `PLS_INTEGER` values require less storage than `NUMBER` values. Also, `PLS_INTEGER` operations use machine arithmetic, so they are faster than `NUMBER` and `BINARY_INTEGER` operations, which use library arithmetic. For efficiency, use `PLS_INTEGER` for all calculations that fall within its magnitude range.

Although `PLS_INTEGER` and `BINARY_INTEGER` have the same magnitude range, they are not fully compatible. When a `PLS_INTEGER` calculation overflows, an exception is raised. However, when a `BINARY_INTEGER` calculation overflows, no exception is raised if the result is assigned to a `NUMBER` variable.

Because of this small semantic difference, you might want to continue using `BINARY_INTEGER` in old applications for compatibility. In new applications, always use `PLS_INTEGER` for better performance.

Character Types

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

CHAR

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, the maximum width of a CHAR database column is 2000 bytes. So, 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 2**31 bytes or two gigabytes. However, you cannot retrieve a value longer than 32767 bytes from a LONG column into a CHAR(n) variable.

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.

Note: Semantic differences between the CHAR and VARCHAR2 base types are discussed in [Appendix B](#).

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

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.

Starting in Oracle9i, LOB variables can be used interchangeably with LONG and LONG RAW variables. Oracle recommends migrating any LONG data to the CLOB type, and any LONG RAW data to the BLOB type. See "[LOB Types](#)" on page 3-13 for more details.

You can insert any LONG value into a LONG database column because the maximum width of a LONG column is 2**31 bytes. 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 2**31 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 *Oracle9i SQL Reference*.

Note: 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

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.

The maximum width of a RAW database column is 2000 bytes. So, 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 2**31 bytes. However, you cannot retrieve a value longer than 32767 bytes from a LONG RAW column into a RAW variable.

ROWID and UROWID

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.

Suggestion: 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 6-51.

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

```
SQL> SELECT rowid, ename FROM emp WHERE empno = 7788;
```

might return the following row:

```
ROWID                ENAME
-----
AAAAqcAABAAADFNAAH  SCOTT
```

The format, OOOOOOFFFFBBBBBBRRRR, has four parts:

- OOOOOO: The data object number (AAAAqc in the example above) 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 (AAB in the example) identifies the data file that contains the row. File numbers are unique within a database.

- **BBBBBB**: The block number (AAADFN in the example) identifies the data block that contains the row. Block numbers are relative to their data file, not their tablespace. So, two rows in the same tablespace but in different data files can have the same block number.
- **RRR**: The row number (AAH 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.

Note: To manipulate rowids, you can use the supplied package `DBMS_ROWID`. For more information, see *Oracle9i Supplied PL/SQL Packages and Types Reference*.

VARCHAR2

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, the maximum width of a `VARCHAR2` database column is 4000 bytes. So, 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 2^{31} bytes. However, you cannot retrieve a value longer than 32767 bytes from a `LONG` column into a `VARCHAR2(n)` variable.

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 below have the same range of values as their base type. For example, `VARCHAR` is just another name for `VARCHAR2`.

```
STRING
VARCHAR
```

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

Note: 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. So, it is a good idea to use `VARCHAR2` rather than `VARCHAR`.

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 multibyte 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.

Note: When converting `CHAR` or `VARCHAR2` data between databases with different character sets, make sure the data consists of well-formed strings. For more information, see *Oracle9i Globalization and National Language 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 Corporation 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

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.

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

The maximum width of an `NCHAR` database column is 2000 bytes. So, 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

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.

```
my_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 (?).

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) up to four gigabytes in size. And, they allow efficient, random, piece-wise access to the data.

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 LOB is four gigabytes, but the maximum size of a LONG is two gigabytes. Also, LOBs support random access to data, but LONGs support only sequential access.

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.

Starting in Oracle9i, 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, see *Oracle9i Application Developer's Guide - Large Objects (LOBs)*.

BFILE

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. The size of a BFILE is system dependent but cannot exceed four gigabytes ($2^{32} - 1$ bytes). 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

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. The size of a BLOB cannot exceed four gigabytes.

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

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. The size of a CLOB cannot exceed four gigabytes.

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

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. The size of an NCLOB cannot exceed four gigabytes.

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.

Boolean Type

BOOLEAN

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. Also, you cannot select or fetch column values into a BOOLEAN variable.

Datetime 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/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

Field Name	Valid Datetime Values	Valid Interval Values
MINUTE	00 to 59	0 to 59
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 *Oracle9i SQL Reference*.

DATE

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.

Tip: 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.

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. For example, the following statement returns the number of days since an employee was hired:

```
SELECT SYSDATE - hiredate INTO days_worked FROM emp
       WHERE empno = 7499;
```

In arithmetic expressions, PL/SQL interprets integer literals as days. For instance, `SYSDATE + 1` is tomorrow.

TIMESTAMP

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 the following example, you declare a variable of type `TIMESTAMP`, then assign a literal value to it:

```
DECLARE
    checkout TIMESTAMP(3);
BEGIN
    checkout := '1999-06-22 07:48:53.275';
    ...
END;
```

In this example, the fractional part of the seconds field is 0.275.

TIMESTAMP WITH TIME ZONE

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 the following example, you declare a variable of type `TIMESTAMP WITH TIME ZONE`, then assign a literal value to it:

```
DECLARE
  logoff TIMESTAMP(3) WITH TIME ZONE;
BEGIN
  logoff := '1999-10-31 09:42:37.114 +02:00';
  ...
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 '1999-04-15 8:00:00 -8:00'
TIMESTAMP '1999-04-15 8:00:00 US/Pacific'
TIMESTAMP '1999-10-31 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:

```
'1999-08-29 08:00:00 -8:00'
'1999-08-29 11:00:00 -5:00'
```

TIMESTAMP WITH LOCAL TIME ZONE

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 the following example, you declare a variable of type `TIMESTAMP WITH LOCAL TIME ZONE`:

```
DECLARE
    logoff TIMESTAMP(3) WITH LOCAL TIME ZONE;
BEGIN
    ...
END;
```

You cannot assign literal values to a variable of this type.

INTERVAL YEAR TO MONTH

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 the following example, you declare a variable of type `INTERVAL YEAR TO MONTH`, then assign a value of 101 years and 3 months to it:

```
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

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 the following example, you declare a variable of type `INTERVAL DAY TO SECOND`:

```
DECLARE
    lag_time INTERVAL DAY(3) TO SECOND(3);
BEGIN
    IF lag_time > INTERVAL '6' DAY THEN ...
    ...
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

Operand 1	Operator	Operand 2	Result Type
numeric	*	interval	interval
interval	/	numeric	interval

You can also manipulate datetime value using various functions, such as `EXTRACT`. For a list of such functions, see [Figure 2-3, "Built-In Functions"](#) on page 2-36.

For further information and examples of datetime arithmetic, see *Oracle9i SQL Reference* and *Oracle9i 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
```

User-Defined 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. Thus, a subtype does *not* introduce a new type; it merely 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.

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 emp.empno%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. However, the subtype does *not* inherit other kinds of constraints such as `NOT NULL`.

Using Subtypes

Once you define a subtype, you can declare items of that type. In the example below, 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;
```

The following example shows that 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. In the example below, you restrict the subtype `Numeral` to storing integers in the range `-9 .. 9`. If your program tries to store a number outside that range in a `Numeral` variable, PL/SQL raises an exception.

```

DECLARE
    SUBTYPE Numeral IS NUMBER(1,0);
    x_axis Numeral; -- magnitude range is -9 .. 9
    y_axis Numeral;
BEGIN
    x_axis := 10; -- raises VALUE_ERROR
    ...
END;

```

Type Compatibility

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:

```

DECLARE
    SUBTYPE Accumulator IS NUMBER;
    amount NUMBER(7,2);
    total Accumulator;
BEGIN
    ...
    total := amount;
    ...
END;

```

Different subtypes are interchangeable if they have the same base type. For instance, given the following declarations, the value of `finished` can be assigned to `debugging`:

```

DECLARE
    SUBTYPE Sentinel IS BOOLEAN;
    SUBTYPE Switch IS BOOLEAN;
    finished Sentinel;
    debugging Switch;
BEGIN
    ...
    debugging := finished;
    ...

```

```
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;
    sentence  Text(150);
BEGIN
    ...
    sentence := verb;
    ...
END;
```

Datatype Conversion

Sometimes it is necessary to convert a value from one datatype to another. For example, if you want to examine a rowid, you must convert it to a character string. PL/SQL supports both explicit and implicit (automatic) datatype conversion.

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 *Oracle9i SQL Reference*.

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. In the example below, 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`. So, PL/SQL converts the `CHAR` values to `NUMBER` values automatically.

```
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;
    -- do something
    /* 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;
    INSERT INTO results VALUES (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 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.
- To convert between CLOB and NCLOB, you must 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 *Oracle9i 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_IN T	RAW	UROWID	VARCHAR2
BIN_INT			X			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				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.

Implicit versus Explicit Conversion

Generally, to rely on implicit datatype conversions is a poor programming practice because they can hamper performance and might change from one software release to the next. Also, implicit conversions are context sensitive and therefore not always predictable. Instead, use datatype conversion functions. That way, your applications will be more reliable and easier to maintain.

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. So, 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, you must call TO_CHAR with a format mask.

A conversion is also necessary when you insert a CHAR or VARCHAR2 value into a DATE column. So, PL/SQL calls the function TO_DATE, which expects the default

date format. To insert dates in other formats, you must 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 `VARCHAR2` value into a `RAW` or `LONG RAW` column. Each pair of characters in the variable must represent the hexadecimal equivalent of a binary byte. If either character does not represent the hexadecimal equivalent of a nibble, PL/SQL raises an exception.

PL/SQL Control Structures

*One ship drives east and another drives west
With the selfsame winds that blow.
'Tis the set of the sails and not the gales
Which tells us the way to go. —Ella Wheeler Wilcox*

This chapter shows you how to structure the flow of control through a PL/SQL program. You learn how statements are connected by simple but powerful control structures that have a single entry and exit point. Collectively, these structures can handle any situation. Their proper use leads naturally to a well-structured program.

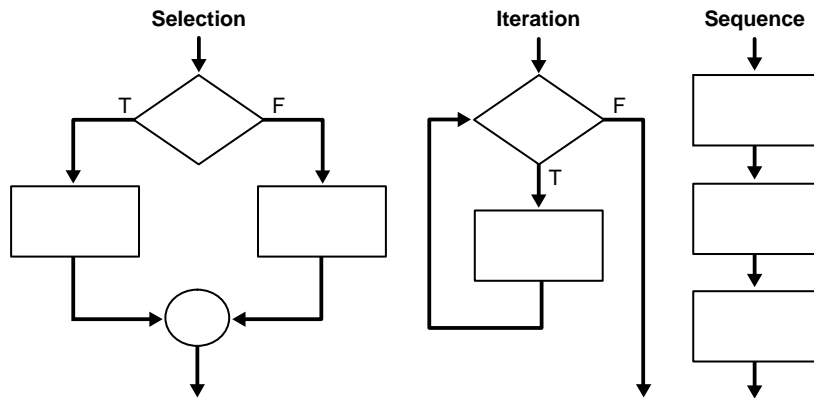
This chapter discusses the following topics:

- [Overview of PL/SQL Control Structures](#)
- [Conditional Control: IF and CASE Statements](#)
- [Iterative Control: LOOP and EXIT Statements](#)
- [Sequential Control: GOTO and NULL Statements](#)

Overview of PL/SQL Control Structures

According to the *structure theorem*, any computer program can be written using the basic control structures shown in [Figure 4-1](#). They can be combined in any way necessary to deal with a given problem.

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.

Conditional Control: IF and CASE Statements

Often, it is necessary to take alternative actions depending on circumstances. The IF statement lets you execute a sequence of statements conditionally. That is, whether the sequence is executed or not depends on the value of a condition. There are three forms of IF statements: IF-THEN, IF-THEN-ELSE, and IF-THEN-ELSIF. The CASE statement is a compact way to evaluate a single condition and choose between many alternative actions.

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 follows:

```
IF condition THEN
    sequence_of_statements
END IF;
```

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. An example follows:

```
IF sales > quota THEN
    compute_bonus(empid);
    UPDATE payroll SET pay = pay + bonus WHERE empno = emp_id;
END IF;
```

You might want to place brief IF statements on a single line, as in

```
IF x > y THEN high := x; END IF;
```

IF-THEN-ELSE Statement

The second form of IF statement adds the keyword ELSE followed by an alternative sequence of statements, as follows:

```
IF condition THEN
    sequence_of_statements1
ELSE
    sequence_of_statements2
END IF;
```

The sequence of statements in the ELSE clause is executed only if the condition is false or null. Thus, the ELSE clause ensures that a sequence of statements is executed. In the following example, the first UPDATE statement is executed when the condition is true, but the second UPDATE statement is executed when the condition is false or null:

```
IF trans_type = 'CR' THEN
    UPDATE accounts SET balance = balance + credit WHERE ...
ELSE
    UPDATE accounts SET balance = balance - debit WHERE ...
END IF;
```

The THEN and ELSE clauses can include IF statements. That is, IF statements can be nested, as the following example shows:

```
IF trans_type = 'CR' THEN
    UPDATE accounts SET balance = balance + credit WHERE ...
ELSE
    IF new_balance >= minimum_balance THEN
        UPDATE accounts SET balance = balance - debit WHERE ...
    ELSE
        RAISE insufficient_funds;
    END IF;
END IF;
```

IF-THEN-ELSIF Statement

Sometimes you want to select an action from several mutually exclusive alternatives. The third form of IF statement uses the keyword ELSIF (not ELSEIF) to introduce additional conditions, as follows:

```
IF condition1 THEN
    sequence_of_statements1
ELSIF condition2 THEN
    sequence_of_statements2
ELSE
    sequence_of_statements3
END IF;
```

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. Consider the following example:

```
BEGIN
    ...
    IF sales > 50000 THEN
        bonus := 1500;
    ELSIF sales > 35000 THEN
        bonus := 500;
    ELSE
        bonus := 100;
    END IF;
    INSERT INTO payroll VALUES (emp_id, bonus, ...);
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.

CASE Statement

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. (Recall from [Chapter 2](#) that a selector is an expression whose value is used to select one of several alternatives.) To compare the `IF` and `CASE` statements, consider the following code that outputs descriptions of school grades:

```
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;
```

Notice 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'. Let us rewrite the preceding code using the `CASE` statement, as follows:

```
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;
```

The `CASE` statement is more readable and more efficient. So, 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;
```

If the `CASE` statement selects the implicit `ELSE` clause, PL/SQL raises the predefined exception `CASE_NOT_FOUND`. So, there is always a default action, even when you omit the `ELSE` clause.

The keywords `END CASE` terminate the `CASE` statement. These two keywords must be separated by a space. The `CASE` statement has the following form:

```
[<<label_name>>]
CASE selector
    WHEN expression1 THEN sequence_of_statements1;
    WHEN expression2 THEN sequence_of_statements2;
    ...
    WHEN expressionN THEN sequence_of_statementsN;
    [ELSE sequence_of_statementsN+1;]
END CASE [label_name];
```

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 2-31.

Searched CASE Statement

PL/SQL also provides a *searched* CASE statement, which has the form:

```
[<<label_name>>]
CASE
    WHEN search_condition1 THEN sequence_of_statements1;
    WHEN search_condition2 THEN sequence_of_statements2;
    ...
    WHEN search_conditionN THEN sequence_of_statementsN;
    [ELSE sequence_of_statementsN+1;]
END CASE [label_name];
```

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. An example follows:

```
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;
```

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;
```

This code disregards two useful facts. First, the value of a Boolean expression can be assigned directly to a Boolean variable. So, you can replace the first IF statement with a simple assignment, as follows:

```
overdrawn := new_balance < minimum_balance;
```

Second, a Boolean variable is itself either true or false. So, you can simplify the condition in the second IF statement, as follows:

```
IF overdrawn THEN ...
```

When possible, use the ELSIF clause instead of nested IF statements. That way, your code will be easier to read and understand. Compare the following IF statements:

IF condition1 THEN		IF condition1 THEN
statement1;		statement1;
ELSE		ELSIF condition2 THEN
IF condition2 THEN		statement2;
statement2;		ELSIF condition3 THEN
ELSE		statement3;
IF condition3 THEN		END IF;
statement3;		
END IF;		
END IF;		
END IF;		

These statements are logically equivalent, but the first statement obscures the flow of logic, whereas the second statement reveals it.

If you are comparing 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.

Iterative Control: LOOP and EXIT Statements

`LOOP` statements let you execute a sequence of statements multiple times. There are three forms of `LOOP` statements: `LOOP`, `WHILE-LOOP`, and `FOR-LOOP`.

LOOP

The simplest form of `LOOP` statement is the basic (or infinite) 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. If further processing is undesirable or impossible, you can use an `EXIT` statement to complete the loop. You can place one or more `EXIT` statements anywhere inside a loop, but nowhere outside a loop. There are two forms of `EXIT` statements: `EXIT` and `EXIT-WHEN`.

EXIT

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. An example follows:

```
LOOP
    ...
    IF credit_rating < 3 THEN
        ...
        EXIT; -- exit loop immediately
    END IF;
END LOOP;
-- control resumes here
```

The next example shows that you cannot use the `EXIT` statement to complete a `PL/SQL` block:

```
BEGIN
  ...
  IF credit_rating < 3 THEN
    ...
    EXIT; -- illegal
  END IF;
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 8-8.

EXIT-WHEN

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. An example follows:

```
LOOP
  FETCH c1 INTO ...
  EXIT WHEN c1%NOTFOUND; -- exit loop if condition is true
  ...
END LOOP;
CLOSE c1;
```

Until the condition is true, the loop cannot complete. So, a statement inside the loop must change the value of the condition. In the last 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 WHEN count > 100;
  EXIT;                  |
END IF;                  |
```

These statements are logically equivalent, but the `EXIT-WHEN` statement is easier to read and understand.

Loop Labels

Like PL/SQL blocks, loops can be labeled. The label, an undeclared identifier enclosed by double angle brackets, must appear at the beginning of the LOOP statement, as follows:

```
<<label_name>>
LOOP
    sequence_of_statements
END LOOP;
```

Optionally, the label name can also appear at the end of the LOOP statement, as the following example shows:

```
<<my_loop>>
LOOP
    ...
END LOOP my_loop;
```

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 follows:

```
<<outer>>
LOOP
    ...
    LOOP
        ...
        EXIT outer WHEN ... -- exit both loops
    END LOOP;
    ...
END LOOP outer;
```

Every enclosing loop up to and including the labeled loop is exited.

WHILE-LOOP

The WHILE-LOOP statement associates a condition with a sequence of statements enclosed by the keywords LOOP and END LOOP, as follows:

```
WHILE condition LOOP
    sequence_of_statements
END LOOP;
```

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. An example follows:

```
WHILE total <= 25000 LOOP
    ...
    SELECT sal INTO salary FROM emp WHERE ...
    total := total + salary;
END LOOP;
```

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. In the last example, if the initial value of `total` is larger than 25000, the condition is false and the loop is bypassed.

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. Therefore, the sequence of statements is executed at least once. PL/SQL has no such structure, but you can easily build one, as follows:

```
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. Otherwise, you have an infinite loop. For example, the following `LOOP` statements are logically equivalent:

```
WHILE TRUE LOOP          |          LOOP
    ...                  |          ...
END LOOP;                |          END LOOP;
```


FOR-LOOP

Whereas the number of iterations through a `WHILE` loop is unknown until the loop completes, the number of iterations through a `FOR` loop is known before the loop is entered. `FOR` 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`. A double dot (`..`) serves as the range operator. The syntax follows:

```
FOR counter IN [REVERSE] lower_bound..higher_bound LOOP
    sequence_of_statements
END LOOP;
```

The range is evaluated when the `FOR` loop is first entered and is never re-evaluated.

As the next example shows, the sequence of statements is executed once for each integer in the range. After each iteration, the loop counter is incremented.

```
FOR i IN 1..3 LOOP -- assign the values 1,2,3 to i
    sequence_of_statements -- executes three times
END LOOP;
```

The following example shows that if the lower bound equals the higher bound, the sequence of statements is executed once:

```
FOR i IN 3..3 LOOP -- assign the value 3 to i
    sequence_of_statements -- executes one time
END LOOP;
```

By default, iteration proceeds upward from the lower bound to the higher bound. However, as the example below shows, 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. Nevertheless, you write the range bounds in ascending (not descending) order.

```
FOR i IN REVERSE 1..3 LOOP -- assign the values 3,2,1 to i
    sequence_of_statements -- executes three times
END LOOP;
```

Inside a `FOR` loop, the loop counter can be referenced like a constant but cannot be assigned values, as the following example shows:

```
FOR ctr IN 1..10 LOOP
    IF NOT finished THEN
        INSERT INTO ... VALUES (ctr, ...); -- legal
        factor := ctr * 2; -- legal
    ELSE
```

```
        ctr := 10; -- illegal
    END IF;
END LOOP;
```

Iteration Schemes

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, as the examples below show. However, 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 $-2^{31} .. 2^{31}$. So, if a bound evaluates to a number outside that range, you get a *numeric overflow* error when PL/SQL attempts the assignment, as the following example shows:

```
DECLARE
    hi NUMBER := 2**32;
BEGIN
    FOR j IN 1..hi LOOP -- causes a 'numeric overflow' error
        ...
    END LOOP;
END;
```

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 the following example, you assign today's date to elements 5, 10, and 15 of an index-by table:

```
DECLARE
    TYPE DateList IS TABLE OF DATE INDEX BY BINARY_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

PL/SQL lets you determine the loop range dynamically at run time, as the following example shows:

```
SELECT COUNT(empno) INTO emp_count FROM emp;
FOR i IN 1..emp_count LOOP
    ...
END LOOP;
```

The value of `emp_count` is **unknown at compile time**; the `SELECT` statement returns the value at run time.

What happens if the lower bound of a loop range evaluates to a larger integer than the upper bound? As the next example shows, the sequence of statements within the loop 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 Rules

The loop counter is defined only within the loop. You cannot reference it outside the loop. After the loop is exited, the loop counter is undefined, as the following example shows:

```
FOR ctr IN 1..10 LOOP
    ...
END LOOP;
sum := ctr - 1; -- illegal
```

You need not explicitly declare the loop counter because it is implicitly declared as a local variable of type `INTEGER`. The next example shows that the local declaration hides any global declaration:

```
DECLARE
    ctr INTEGER;
BEGIN
    ...
    FOR ctr IN 1..25 LOOP
        ...
        IF ctr > 10 THEN ... -- refers to loop counter
    END LOOP;
END;
```

To reference the global variable in this example, you must use a label and dot notation, as follows:

```
<<main>>
DECLARE
    ctr  INTEGER;
    ...
BEGIN
    ...
    FOR ctr IN 1..25 LOOP
        ...
        IF main.ctr > 10 THEN -- refers to global variable
            ...
        END IF;
    END LOOP;
END main;
```

The same scope rules apply to nested FOR loops. Consider the example below. Both loop counters have the same name. So, to reference the outer loop counter from the inner loop, you must use a label and dot notation, as follows:

```
<<outer>>
FOR step IN 1..25 LOOP
    FOR step IN 1..10 LOOP
        ...
        IF outer.step > 15 THEN ...
    END LOOP;
END LOOP outer;
```

Using the EXIT Statement

The EXIT statement lets a FOR loop complete prematurely. For example, the following 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:

```
FOR j IN 1..10 LOOP
    FETCH c1 INTO emp_rec;
    EXIT WHEN c1%NOTFOUND;
    ...
END LOOP;
```

Suppose you must exit from a nested FOR loop prematurely. 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 to specify which FOR loop to exit, as follows:

```
<<outer>>
FOR i IN 1..5 LOOP
    ...
    FOR j IN 1..10 LOOP
        FETCH c1 INTO emp_rec;
        EXIT outer WHEN c1%NOTFOUND; -- exit both FOR loops
    ...
    END LOOP;
END LOOP outer;
-- control passes here
```

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 structure of PL/SQL is such that 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 complex, unstructured code (sometimes called *spaghetti code*) that is hard to understand and maintain. So, 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.

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. In the following example, you go to an executable statement farther down in a sequence of statements:

```
BEGIN
    ...
    GOTO insert_row;
    ...
    <<insert_row>>
    INSERT INTO emp VALUES ...
END;
```

In the next example, you go to a PL/SQL block farther up in a sequence of statements:

```
BEGIN
    ...
    <<update_row>>
    BEGIN
        UPDATE emp SET ...
        ...
    END;
    ...
    GOTO update_row;
    ...
END;
```

The label `end_loop` in the following example is illegal because it does not precede an executable statement:

```
DECLARE
    done BOOLEAN;
BEGIN
    ...
    FOR i IN 1..50 LOOP
        IF done THEN
            GOTO end_loop;
        END IF;
        ...
        <<end_loop>> -- illegal
    END LOOP; -- not an executable statement
END;
```

To debug the last example, just add the `NULL` statement, as follows:

```
FOR i IN 1..50 LOOP
    IF done THEN
        GOTO end_loop;
    END IF;
    ...
    <<end_loop>>
    NULL; -- an executable statement
END LOOP;
```

As the following example shows, a `GOTO` statement can branch to an enclosing block from the current block:

```
DECLARE
```

```

    my_ename CHAR(10);
BEGIN
    <<get_name>>
    SELECT ename INTO my_ename FROM emp WHERE ...
    BEGIN
        ...
        GOTO get_name; -- branch to enclosing block
    END;
END;

```

The **GOTO** statement branches to the first enclosing block in which the referenced label appears.

Restrictions

Some possible destinations of a **GOTO** statement are illegal. Specifically, a **GOTO** statement cannot branch into an **IF** statement, **CASE** statement, **LOOP** statement, or sub-block. For example, the following **GOTO** statement is illegal:

```

BEGIN
    ...
    GOTO update_row; -- illegal branch into IF statement
    ...
    IF valid THEN
        ...
        <<update_row>>
        UPDATE emp SET ...
    END IF;
END;

```

As the example below shows, a **GOTO** statement cannot branch from one **IF** statement clause to another. Likewise, a **GOTO** statement cannot branch from one **CASE** statement **WHEN** clause to another.

```

BEGIN
    ...
    IF valid THEN
        ...
        GOTO update_row; -- illegal branch into ELSE clause
    ELSE
        ...
        <<update_row>>
        UPDATE emp SET ...
    END IF;
END;

```

The next example shows that a GOTO statement cannot branch from an enclosing block into a sub-block:

```
BEGIN
  ...
  IF status = 'OBSOLETE' THEN
    GOTO delete_part; -- illegal branch into sub-block
  END IF;
  ...
  BEGIN
    ...
    <<delete_part>>
    DELETE FROM parts WHERE ...
  END;
END;
```

Also, a GOTO statement cannot branch out of a subprogram, as the following example shows:

```
DECLARE
  ...
  PROCEDURE compute_bonus (emp_id NUMBER) IS
  BEGIN
    ...
    GOTO update_row; -- illegal branch out of subprogram
  END;
BEGIN
  ...
  <<update_row>>
  UPDATE emp SET ...
END;
```

Finally, a GOTO statement cannot branch from an exception handler into the current block. For example, the following GOTO statement is illegal:

```
DECLARE
  ...
  pe_ratio REAL;
BEGIN
  ...
  SELECT price / NVL(earnings, 0) INTO pe_ratio FROM ...
  <<insert_row>>
  INSERT INTO stats VALUES (pe_ratio, ...);
EXCEPTION
  WHEN ZERO_DIVIDE THEN
```



```

        pe_ratio := 0;
        GOTO insert_row; -- illegal branch into current block
    END;

```

However, a GOTO statement can branch from an exception handler into an enclosing block.

NULL Statement

The NULL statement explicitly specifies inaction; it does nothing other than pass control to the next statement. It can, however, improve readability. In a construct allowing alternative actions, the NULL statement serves as a placeholder. It tells readers that the associated alternative has not been overlooked, but that indeed no action is necessary. In the following example, the NULL statement shows that no action is taken for unnamed exceptions:

```

EXCEPTION
    WHEN ZERO_DIVIDE THEN
        ROLLBACK;
    WHEN VALUE_ERROR THEN
        INSERT INTO errors VALUES ...
        COMMIT;
    WHEN OTHERS THEN
        NULL;
END;

```

Each clause in an IF statement must contain at least one executable statement. The NULL statement is executable, so you can use it in clauses that correspond to circumstances in which no action is taken. In the following example, the NULL statement emphasizes that only top-rated employees get bonuses:

```

IF rating > 90 THEN
    compute_bonus(emp_id);
ELSE
    NULL;
END IF;

```

Also, the NULL statement is a handy way to create stubs when designing applications from the top down. A **stub** is dummy subprogram that lets you defer the definition of a procedure or function until you test and debug the main program. In the following example, the NULL statement meets the requirement that at least one statement must appear in the executable part of a subprogram:

```

PROCEDURE debit_account (acct_id INTEGER, amount REAL) IS

```

```
BEGIN  
    NULL;  
END debit_account;
```

PL/SQL Collections and Records

Knowledge is that area of ignorance that we arrange and classify. —Ambrose Bierce

Many programming techniques use collection types such as arrays, bags, lists, nested tables, sets, and trees. To support these techniques in database applications, PL/SQL provides the datatypes `TABLE` and `VARRAY`, which allow you to declare index-by tables, nested tables and variable-size arrays. In this chapter, you learn how those types let you reference and manipulate collections of data as whole objects. You also learn how the datatype `RECORD` lets you treat related but dissimilar data as a logical unit.

This chapter discusses the following topics:

- What Is a Collection?
- Defining and Declaring Collections
- Initializing and Referencing Collections
- Assigning and Comparing Collections
- Manipulating Collections
- Using Collection Methods
- Avoiding Collection Exceptions
- Reducing Loop Overhead for Collections with Bulk Binds
- What Is a Record?
- Defining and Declaring Records
- Initializing Records
- Assigning Records
- Manipulating Records

What Is a Collection?

A *collection* is an ordered group of elements, all of the same type (for example, the grades for a class of students). Each element has a unique subscript that determines its position in the collection. PL/SQL offers two collection types. Items of type `TABLE` are either *index-by tables* (Version 2 *PL/SQL tables*) or *nested tables* (which extend the functionality of index-by tables). Items of type `VARRAY` are *varrays* (short for variable-size arrays).

Collections work like the arrays found in most third-generation programming languages. Although collections can have only one dimension, you can model multi-dimensional arrays by creating collections whose elements are also collections.

You can define collection types in a package, then use them programmatically in your applications. Also, you can pass collections as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms. In addition, collections can store instances of an object type and (except for index-by tables) can be attributes of an object type.

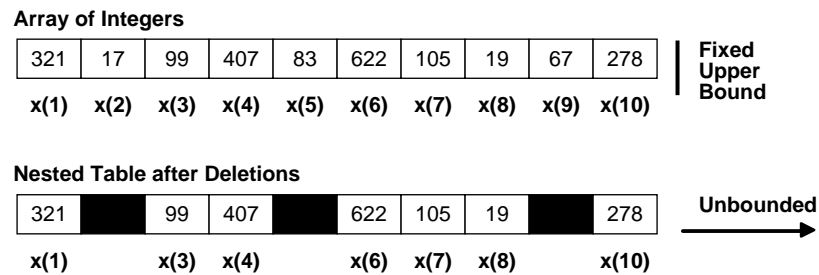
Understanding Nested Tables

Within the database, nested tables can be considered one-column database tables. Oracle stores the rows of a nested table in no particular order. But, when you retrieve the nested table into a PL/SQL variable, the rows are given consecutive subscripts starting at 1. That gives you array-like access to individual rows.

PL/SQL nested tables are like one-dimensional arrays. You can model multi-dimensional arrays by creating nested tables whose elements are also nested tables.

Nested tables differ from arrays in two important ways:

1. Arrays have a fixed upper bound, but nested tables are unbounded (see [Figure 5-1](#)). So, the size of a nested table can increase dynamically.

Figure 5–1 Array versus Nested Table

- Arrays must be *dense* (have consecutive subscripts). So, you cannot delete individual elements from an array. Initially, nested tables are dense, but they can become *sparse* (have nonconsecutive subscripts). So, you can delete elements from a nested table using the built-in procedure `DELETE`. That might leave gaps in the index, but the built-in function `NEXT` lets you iterate over any series of subscripts.

Nested Tables Versus Index-By Tables

Index-by tables and nested tables are similar. For example, they have the same structure, and their individual elements are accessed in the same way (using subscript notation). The main difference is that nested tables can be stored in a database column (hence the term "nested table") but index-by tables cannot.

Nested tables extend the functionality of index-by tables by letting you `SELECT`, `INSERT`, `UPDATE`, and `DELETE` nested tables stored in the database. (Remember, index-by tables cannot be stored in the database.) Also, some collection methods operate only on nested tables and varrays. For example, the built-in procedure `TRIM` cannot be applied to index-by tables.

Another advantage of nested tables is that an uninitialized nested table is atomically null (that is, the table itself is null, not its elements), but an uninitialized index-by table is merely empty. So, you can apply the `IS NULL` comparison operator to nested tables but not to index-by tables.

However, index-by tables also have some advantages. For example, PL/SQL supports implicit (automatic) datatype conversion between host arrays and index-by tables (but not nested tables). So, the most efficient way to pass collections to and from the database server is to use anonymous PL/SQL blocks to bulk-bind input and output host arrays to index-by tables.

Also, index-by tables are initially sparse. So, they are convenient for storing reference data using a numeric primary key (account numbers or employee numbers for example) as the index.

In some (relatively minor) ways, index-by tables are more flexible than nested tables. For example, index-by tables can have negative subscripts; nested tables cannot. Also, some element types are allowed for index-by tables but not for nested tables (see ["Referencing Collection Elements"](#) on page 5-10). Finally, to extend a nested table, you must use the built-in procedure `EXTEND`, but to extend an index-by table, you just specify larger subscripts.

Understanding Varrays

Items of type `VARRAY` are called *varrays*. They allow you to associate a single identifier with an entire collection. This association lets you manipulate the collection as a whole and reference individual elements easily. 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

Varray *Grades*

B	C	A	A	C	D	B			
(1)	(2)	(3)	(4)	(5)	(6)	(7)			

Maximum Size = 10

A varray has a maximum size, which you must 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 extend it to 8, 9, 10, and so on. Thus, a varray can contain a varying number of elements, from zero (when empty) to the maximum specified in its type definition.

Varrays Versus Nested Tables

Nested tables differ from varrays in the following ways:

- Varrays have a maximum size, but nested tables do not.
- Varrays are always dense, but nested tables can be sparse. So, you can delete individual elements from a nested table but not from a varray.
- By default, Oracle stores varray data in-line (in the same table) unless it exceeds 4K, in which case the data is stored out-of-line (but in the same tablespace).

Oracle stores nested table data out-of-line in a *store table*, which is a system-generated database table associated with the nested table.

- When stored in the database, varrays retain their ordering and subscripts, but nested tables do not.

Which collection type should you use? That depends on your wants and the size of the collection. A varray is stored as an opaque object, whereas a nested table is stored in a storage table with every element mapped to a row in the table. So, if you want efficient queries, use nested tables. If you want to retrieve entire collections as a whole, use varrays. However, when collections get very large, it becomes impractical to retrieve all elements at once. So, varrays are better suited for small collections.

Defining and Declaring Collections

To create collections, you define a collection type, then declare collections of that type. You can define `TABLE` and `VARRAY` types in the declarative part of any PL/SQL block, subprogram, or package. For nested tables, use the syntax:

```
TYPE type_name IS TABLE OF element_type [NOT NULL];
```

and for varrays, use the syntax:

```
TYPE type_name IS {VARRAY | VARYING ARRAY} (size_limit)
  OF element_type [NOT NULL];
```

where `type_name` is a type specifier used later to declare collections, `size_limit` is a positive integer literal, and `element_type` is any PL/SQL datatype except

```
BINARY_INTEGER, PLS_INTEGER
BOOLEAN
BLOB, CLOB (restriction applies only to varrays)
LONG, LONG RAW
NATURAL, NATURALN
NCHAR, NCLOB, NVARCHAR2
object types with BLOB or CLOB attributes (restriction applies only to varrays)
object types with TABLE or VARRAY attributes
POSITIVE, POSITIVEN
REF CURSOR
SIGNTYPE
STRING
```

For index-by tables, use the syntax

```
TYPE type_name IS TABLE OF element_type [NOT NULL]
    INDEX BY BINARY_INTEGER;
```

Unlike nested tables and varrays, index-by tables can have the following element types: BINARY_INTEGER, BOOLEAN, LONG, LONG RAW, NATURAL, NATURALN, PLS_INTEGER, POSITIVE, POSITIVEN, SIGNTYPE, and STRING.

Index-by tables are initially sparse. That enables you, for example, to store reference data in an index-by table using a numeric primary key as the index. In the example below, you declare an index-by table of records. Each element of the table stores a row from the emp database table.

```
DECLARE
    TYPE EmpTabTyp IS TABLE OF emp%ROWTYPE
        INDEX BY BINARY_INTEGER;
    emp_tab EmpTabTyp;
BEGIN
    /* Retrieve employee record. */
    SELECT * INTO emp_tab(7468) FROM emp WHERE empno = 7468;
    ...
END;
```

When defining a VARRAY type, you must specify its maximum size. In the following example, you define a type that stores up to 366 dates:

```
DECLARE
    TYPE Calendar IS VARRAY(366) OF DATE;
```

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. Two examples follow:

```
DECLARE
    TYPE EmpList IS TABLE OF emp.ename%TYPE; -- based on column
    CURSOR c1 IS SELECT * FROM dept;
    TYPE DeptFile IS VARRAY(20) OF c1%ROWTYPE; -- based on cursor
```

In the next example, you use a RECORD type to specify the element type:

```
DECLARE
    TYPE AnEntry IS RECORD (
        term    VARCHAR2(20),
        meaning VARCHAR2(200));
    TYPE Glossary IS VARRAY(250) OF AnEntry;
```

In the final example, you impose a NOT NULL constraint on the element type:


```
DECLARE
    TYPE EmpList IS TABLE OF emp.empno%TYPE NOT NULL;
```

An initialization clause is not required (or allowed).

Declaring Collections

Once you define a collection type, you can declare collections of that type, as the following SQL*Plus script shows:

```
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
/
```

The identifier `courses` represents an entire nested table. Each element of `courses` will store the code name of a college course such as 'Math 1020'.

The script below creates a database column that stores varrays. Each element of the varrays will store a `Project` object.

```
CREATE TYPE Project AS OBJECT( --create object
    project_no NUMBER(2),
    title      VARCHAR2(35),
    cost       NUMBER(7,2))
/
CREATE TYPE ProjectList AS VARRAY(50) OF Project -- define VARRAY
type
/
CREATE TABLE department ( -- create database table
    dept_id NUMBER(2),
    name    VARCHAR2(15),
    budget  NUMBER(11,2),
    projects ProjectList) -- declare varray as column
/
```

The following example shows that you can use `%TYPE` to provide the datatype of a previously declared collection:

```
DECLARE
    TYPE Platoon IS VARRAY(20) OF Soldier;
```

```
p1 Platoon;  
p2 p1%TYPE;
```

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. In the following example, you declare a nested table as the formal parameter of a packaged procedure:

```
CREATE PACKAGE personnel AS  
    TYPE Staff IS TABLE OF Employee;  
    ...  
    PROCEDURE award_bonuses (members IN Staff);  
END personnel;
```

Also, you can specify a collection type in the RETURN clause of a function specification, as the following example shows:

```
DECLARE  
    TYPE SalesForce IS VARRAY(25) OF Salesperson;  
    FUNCTION top_performers (n INTEGER) RETURN SalesForce IS ...
```

Collections follow the usual scoping and instantiation rules. In a block or subprogram, collections are instantiated when you enter the 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.

Initializing and Referencing Collections

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" collections from the elements passed to it. In the following example, you pass six elements to constructor `CourseList()`, which returns a nested table containing those elements:

```
DECLARE  
    my_courses CourseList;  
BEGIN  
    my_courses := CourseList('Econ 2010', 'Acct 3401', 'Mgmt 3100',  
        'PoSc 3141', 'Mktg 3312', 'Engl 2005');  
    ...  
END;
```

In the next example, you pass three objects to constructor `ProjectList()`, which returns a varray containing those objects:

```
DECLARE
    accounting_projects ProjectList;
BEGIN
    accounting_projects :=
        ProjectList(Project(1, 'Design New Expense Report', 3250),
                    Project(2, 'Outsource Payroll', 12350),
                    Project(3, 'Audit Accounts Payable', 1425));
    ...
END;
```

You need not initialize the whole varray. For example, if a varray has a maximum size of 50, you can pass fewer than 50 elements to its constructor.

Unless you impose the `NOT NULL` constraint or specify a record type for elements, you can pass null elements to a constructor. An example follows:

```
BEGIN
    my_courses := CourseList('Math 3010', NULL, 'Stat 3202', ...);
```

The next example shows that you can initialize a collection in its declaration, which is a good programming practice:

```
DECLARE
    my_courses CourseList :=
        CourseList('Art 1111', 'Hist 3100', 'Engl 2005', ...);
```

If you call a constructor without arguments, you get an empty but non-null collection, as the following example shows:

```
DECLARE
    TYPE Clientele IS VARRAY(100) OF Customer;
    vips Clientele := Clientele(); -- initialize empty varray
BEGIN
    IF vips IS NOT NULL THEN -- condition yields TRUE
        ...
    END IF;
END;
```

PL/SQL never calls a constructor implicitly, so you must call it explicitly. (That does not apply to index-by tables, which do not have constructors.) Constructor calls are allowed wherever function calls are allowed.

In the example below, you insert a Student object into object table sophomores. The table constructor CourseList() provides a value for attribute courses.

```
BEGIN
  INSERT INTO sophomores
    VALUES (Student(5035, 'Janet Alvarez', '122 Broad St', 'FT',
      CourseList('Econ 2010', 'Acct 3401', 'Mgmt 3100', ...)));
  ...
```

In the final example, you insert a row into database table department. The varray constructor ProjectList() provides a value for column projects.

```
BEGIN
  INSERT INTO department
    VALUES(60, 'Security', 750400,
      ProjectList(Project(1, 'Issue New Employee Badges', 9500),
        Project(2, 'Find Missing IC Chips', 2750),
        Project(3, 'Inspect Emergency Exits', 1900)));
  ...
```

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. For index-by tables, the legal subscript range is $-2^{31} .. 2^{31}$. For nested tables, the legal range is $1 .. 2^{31}$. And, for varrays, the legal range is $1 .. size_limit$.

You can reference a collection in all expression contexts. In the following example, you reference an element in nested table names:

```
DECLARE
  TYPE Roster IS TABLE OF VARCHAR2(15);
  names Roster := Roster('J Hamil', 'D Caruso', 'R Singh', ...);
  i BINARY_INTEGER;
BEGIN
  ...
  IF names(i) = 'J Hamil' THEN
    ...
  END IF;
END;
```

The next example shows that you can reference the elements of a collection in subprogram calls:

```
DECLARE
    TYPE Roster IS TABLE OF VARCHAR2(15);
    names Roster := Roster('J Hamil', 'D Piro', 'R Singh', ...);
    i BINARY_INTEGER;
BEGIN
    ...
    verify_name(names(i)); -- call procedure
END;
```

When calling a function that returns a collection, you can use the following syntax to reference an element in the returned collection, if you do not want to store the entire return value:

```
function_name(parameter_list)(subscript)
```

For example, the following call references the third element in the varray returned by function `new_hires`:

```
DECLARE
    TYPE Staff IS VARRAY(20) OF Employee;
    staffer Employee;
    FUNCTION new_hires (hiredate DATE) RETURN Staff IS ...
BEGIN
    staffer := new_hires('16-OCT-96')(3); -- 3rd element of varray
    ...
END;
```

Assigning and Comparing Collections

One collection can be assigned to another by an INSERT, UPDATE, FETCH, or SELECT statement, an assignment statement, or a subprogram call. As the example below shows, the collections must have the same datatype. Having the same element type is not enough.

```
DECLARE
    TYPE Clientele IS VARRAY(100) OF Customer;
    TYPE Vips IS VARRAY(100) OF Customer;
    group1 Clientele := Clientele(...);
    group2 Clientele := Clientele(...);
    group3 Vips := Vips(...);
BEGIN
    group2 := group1;
```

```
group3 := group2; -- not allowed; different datatypes
```

If you assign an atomically null collection to another collection, the other collection becomes atomically null (and must be reinitialized). Consider the following example:

```
DECLARE
    TYPE Clientele IS TABLE OF Customer;
    group1 Clientele := Clientele(...); -- initialized
    group2 Clientele; -- atomically null
BEGIN
    IF group1 IS NULL THEN ... -- condition yields FALSE
    group1 := group2;
    IF group1 IS NULL THEN ... -- condition yields TRUE
    ...
END;
```

Likewise, if you assign the non-value NULL to a collection, the collection becomes atomically null.

Assigning Collection Elements

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. If *subscript* is null or not convertible to an integer, PL/SQL raises the predefined exception `VALUE_ERROR`. 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`. Some examples follow:

```
DECLARE
    TYPE NumList IS TABLE OF INTEGER;
    nums NumList;
BEGIN
    /* Assume execution continues despite the raised exceptions. */
    nums(1) := 10; -- raises COLLECTION_IS_NULL
    nums := NumList(10,20,30);
    nums(1) := ASCII('A');
    nums(2) := 10 * nums(1);
    nums('B') := 15; -- raises VALUE_ERROR
    nums(4) := 40; -- raises SUBSCRIPT_BEYOND_COUNT
END;
```

Comparing Whole Collections

Nested tables and varrays can be atomically null, so they can be tested for nullity, as the following example shows:

```
DECLARE
    TYPE Staff IS TABLE OF Employee;
    members Staff;
BEGIN
    ...
    IF members IS NULL THEN ... -- condition yields TRUE;
END;
```

However, collections cannot be compared for equality or inequality. For instance, the following IF condition is not allowed:

```
DECLARE
    TYPE Clientele IS TABLE OF Customer;
    group1 Clientele := Clientele(...);
    group2 Clientele := Clientele(...);
BEGIN
    ...
    IF group1 = group2 THEN -- causes compilation error
        ...
    END IF;
END;
```

This restriction also applies to implicit comparisons. For example, collections cannot appear in a DISTINCT, GROUP BY, or ORDER BY list.

Manipulating Collections

Within PL/SQL, collections add flexibility and procedural power. A big advantage is that your program can compute subscripts to process specific elements. A bigger advantage is that the program can use SQL to manipulate in-memory collections.

Some Nested Table Examples

In SQL*Plus, suppose you define object type Course, as follows:

```
SQL> CREATE TYPE Course AS OBJECT (
2   course_no NUMBER(4),
3   title     VARCHAR2(35),
4   credits   NUMBER(1));
```

Next, you define **TABLE type** `CourseList`, which stores `Course` objects:

```
SQL> CREATE TYPE CourseList AS TABLE OF Course;
```

Finally, you create database table `department`, which has a column of type `CourseList`, as follows:

```
SQL> CREATE TABLE department (
  2  name          VARCHAR2(20),
  3  director     VARCHAR2(20),
  4  office       VARCHAR2(20),
  5  courses      CourseList)
  6  NESTED TABLE courses STORE AS courses_tab;
```

Each item in column `courses` is a nested table that will store the courses offered by a given department. The `NESTED TABLE` clause is required because `department` has a nested table column. The clause identifies the nested table and names a system-generated store table, in which Oracle stores data out-of-line.

Now, you can populate database table `department`. In the following example, notice how table constructor `CourseList()` provides values for column `courses`:

```
BEGIN
  INSERT INTO department
    VALUES('Psychology', 'Irene Friedman', 'Fulton Hall 133',
      CourseList(Course(1000, 'General Psychology', 5),
        Course(2100, 'Experimental Psychology', 4),
        Course(2200, 'Psychological Tests', 3),
        Course(2250, 'Behavior Modification', 4),
        Course(3540, 'Groups and Organizations', 3),
        Course(3552, 'Human Factors in Busines', 4),
        Course(4210, 'Theories of Learning', 4),
        Course(4320, 'Cognitive Processes', 4),
        Course(4410, 'Abnormal Psychology', 4)));
  INSERT INTO department
    VALUES('History', 'John Whalen', 'Applegate Hall 142',
      CourseList(Course(1011, 'History of Europe I', 4),
        Course(1012, 'History of Europe II', 4),
        Course(1202, 'American History', 5),
        Course(2130, 'The Renaissance', 3),
        Course(2132, 'The Reformation', 3),
        Course(3105, 'History of Ancient Greece', 4),
        Course(3321, 'Early Japan', 4),
        Course(3601, 'Latin America Since 1825', 4),
        Course(3702, 'Medieval Islamic History', 4)));
```



```

INSERT INTO department
VALUES('English', 'Lynn Saunders', 'Breakstone Hall 205',
      CourseList(Course(1002, 'Expository Writing', 3),
                 Course(2020, 'Film and Literature', 4),
                 Course(2418, 'Modern Science Fiction', 3),
                 Course(2810, 'Discursive Writing', 4),
                 Course(3010, 'Modern English Grammar', 3),
                 Course(3720, 'Introduction to Shakespeare', 4),
                 Course(3760, 'Modern Drama', 4),
                 Course(3822, 'The Short Story', 4),
                 Course(3870, 'The American Novel', 5)));
END;

```

In the following example, you revise the list of courses offered by the English Department:

```

DECLARE
  new_courses CourseList :=
    CourseList(Course(1002, 'Expository Writing', 3),
              Course(2020, 'Film and Literature', 4),
              Course(2810, 'Discursive Writing', 4),
              Course(3010, 'Modern English Grammar', 3),
              Course(3550, 'Realism and Naturalism', 4),
              Course(3720, 'Introduction to Shakespeare', 4),
              Course(3760, 'Modern Drama', 4),
              Course(3822, 'The Short Story', 4),
              Course(3870, 'The American Novel', 4),
              Course(4210, '20th-Century Poetry', 4),
              Course(4725, 'Advanced Workshop in Poetry', 5));
BEGIN
  UPDATE department
  SET courses = new_courses WHERE name = 'English';
END;

```

In the next example, you retrieve all the courses offered by the Psychology Department into a local nested table:

```

DECLARE
  psyc_courses CourseList;
BEGIN
  SELECT courses INTO psyc_courses FROM department
  WHERE name = 'Psychology';
  ...
END;

```

Some Varray Examples

In SQL*Plus, suppose you define object type `Project`, as follows:

```
SQL> CREATE TYPE Project AS OBJECT (  
2  project_no NUMBER(2),  
3  title      VARCHAR2(35),  
4  cost       NUMBER(7,2));
```

Next, you define `VARRAY` type `ProjectList`, which stores `Project` objects:

```
SQL> CREATE TYPE ProjectList AS VARRAY(50) OF Project;
```

Finally, you create relational table `department`, which has a column of type `ProjectList`, as follows:

```
SQL> CREATE TABLE department (  
2  dept_id NUMBER(2),  
3  name    VARCHAR2(15),  
4  budget  NUMBER(11,2),  
5  projects ProjectList);
```

Each item in column `projects` is a varray that will store the projects scheduled for a given department.

Now, you are ready to populate relational table `department`. In the following example, notice how varray constructor `ProjectList()` provides values for column `projects`:

```
BEGIN  
  INSERT INTO department  
    VALUES(30, 'Accounting', 1205700,  
      ProjectList(Project(1, 'Design New Expense Report', 3250),  
        Project(2, 'Outsource Payroll', 12350),  
        Project(3, 'Evaluate Merger Proposal', 2750),  
        Project(4, 'Audit Accounts Payable', 1425)));  
  INSERT INTO department  
    VALUES(50, 'Maintenance', 925300,  
      ProjectList(Project(1, 'Repair Leak in Roof', 2850),  
        Project(2, 'Install New Door Locks', 1700),  
        Project(3, 'Wash Front Windows', 975),  
        Project(4, 'Repair Faulty Wiring', 1350),  
        Project(5, 'Winterize Cooling System', 1125)));
```

```

INSERT INTO department
VALUES(60, 'Security', 750400,
      ProjectList(Project(1, 'Issue New Employee Badges', 13500),
                  Project(2, 'Find Missing IC Chips', 2750),
                  Project(3, 'Upgrade Alarm System', 3350),
                  Project(4, 'Inspect Emergency Exits', 1900)));
END;

```

In the following example, you update the list of projects assigned to the Security Department:

```

DECLARE
  new_projects ProjectList :=
    ProjectList(Project(1, 'Issue New Employee Badges', 13500),
                Project(2, 'Develop New Patrol Plan', 1250),
                Project(3, 'Inspect Emergency Exits', 1900),
                Project(4, 'Upgrade Alarm System', 3350),
                Project(5, 'Analyze Local Crime Stats', 825));
BEGIN
  UPDATE department
  SET projects = new_projects WHERE dept_id = 60;
END;

```

In the next example, you retrieve all the projects for the Accounting Department into a local varray:

```

DECLARE
  my_projects ProjectList;
BEGIN
  SELECT projects INTO my_projects FROM department
  WHERE dept_id = 30;
  ...
END;

```

In the final example, you delete the Accounting Department and its project list from table department:

```

BEGIN
  DELETE FROM department WHERE dept_id = 30;
END;

```

Manipulating Individual Collection Elements

So far, you have manipulated whole collections. Within SQL, to manipulate the individual elements of a collection, use the operator `TABLE`. The operand of `TABLE` is a subquery that returns a single column value for you to manipulate. That value is a nested table or varray.

In the following example, you add a row to the History Department nested table stored in column `courses`:

```
BEGIN
  INSERT INTO
    TABLE(SELECT courses FROM department WHERE name = 'History')
    VALUES(3340, 'Modern China', 4);
END;
```

In the next example, you revise the number of credits for two courses offered by the Psychology Department:

```
DECLARE
  adjustment INTEGER DEFAULT 1;
BEGIN
  UPDATE TABLE(SELECT courses FROM department
    WHERE name = 'Psychology')
    SET credits = credits + adjustment
    WHERE course_no IN (2200, 3540);
END;
```

In the following example, you retrieve the number and title of a specific course offered by the History Department:

```
DECLARE
  my_course_no NUMBER(4);
  my_title VARCHAR2(35);
BEGIN
  SELECT course_no, title INTO my_course_no, my_title
    FROM TABLE(SELECT courses FROM department
    WHERE name = 'History')
    WHERE course_no = 3105;
  ...
END;
```

In the next example, you delete all 5-credit courses offered by the English Department:

```
BEGIN
    DELETE TABLE(SELECT courses FROM department
        WHERE name = 'English')
        WHERE credits = 5;
END;
```

In the following example, you retrieve the title and cost of the Maintenance Department's fourth project from the varray column projects:

```
DECLARE
    my_cost NUMBER(7,2);
    my_title VARCHAR2(35);
BEGIN
    SELECT cost, title INTO my_cost, my_title
        FROM TABLE(SELECT projects FROM department
            WHERE dept_id = 50)
            WHERE project_no = 4;
    ...
END;
```

Currently, you cannot reference the individual elements of a varray in an INSERT, UPDATE, or DELETE statement. So, you must use PL/SQL procedural statements. In the following example, stored procedure `add_project` inserts a new project into a department's project list at a given position:

```
CREATE PROCEDURE add_project (
    dept_no      IN NUMBER,
    new_project  IN Project,
    position     IN NUMBER) AS
    my_projects  ProjectList;
BEGIN
    SELECT projects INTO my_projects FROM department
        WHERE dept_no = dept_id FOR UPDATE OF projects;
    my_projects.EXTEND; -- make room for new project
    /* Move varray elements forward. */
    FOR i IN REVERSE position..my_projects.LAST - 1 LOOP
        my_projects(i + 1) := my_projects(i);
    END LOOP;
    my_projects(position) := new_project; -- add new project
    UPDATE department SET projects = my_projects
        WHERE dept_no = dept_id;
END add_project;
```

-

The following stored procedure updates a given project:

```
CREATE PROCEDURE update_project (
    dept_no    IN NUMBER,
    proj_no    IN NUMBER,
    new_title  IN VARCHAR2 DEFAULT NULL,
    new_cost   IN NUMBER DEFAULT NULL) AS
    my_projects ProjectList;
BEGIN
    SELECT projects INTO my_projects FROM department
        WHERE dept_no = dept_id FOR UPDATE OF projects;
    /* Find project, update it, then exit loop immediately. */
    FOR i IN my_projects.FIRST..my_projects.LAST LOOP
        IF my_projects(i).project_no = proj_no THEN
            IF new_title IS NOT NULL THEN
                my_projects(i).title := new_title;
            END IF;
            IF new_cost IS NOT NULL THEN
                my_projects(i).cost := new_cost;
            END IF;
            EXIT;
        END IF;
    END LOOP;
    UPDATE department SET projects = my_projects
        WHERE dept_no = dept_id;
END update_project;
```

Manipulating Local Collections

Within PL/SQL, to manipulate a local collection, use the operators `TABLE` and `CAST`. The operands of `CAST` are a collection declared locally (in a PL/SQL anonymous block for example) and a SQL collection type. `CAST` converts the local collection to the specified type. That way, you can manipulate the collection as if it were a SQL database table. In the following example, you count the number of differences between a revised course list and the original (notice that the number of credits for course 3720 changed from 4 to 3):

```
DECLARE
    revised CourseList :=
        CourseList(Course(1002, 'Expository Writing', 3),
                  Course(2020, 'Film and Literature', 4),
                  Course(2810, 'Discursive Writing', 4),
                  Course(3010, 'Modern English Grammar ', 3),
                  Course(3550, 'Realism and Naturalism', 4),
```

```

        Course(3720, 'Introduction to Shakespeare', 3),
        Course(3760, 'Modern Drama', 4),
        Course(3822, 'The Short Story', 4),
        Course(3870, 'The American Novel', 5),
        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') AS 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 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.

Here are some examples showing the syntax and possibilities for multilevel collections.

Multilevel VARRAY Example

```

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;
    val t1;
begin
    -- multilevel access
    i := nva(2)(3); -- i will get value 73
    dbms_output.put_line(i);
    -- add a new varray element to nva
    nva.extend;

    nva(5) := t1(56, 32);
    -- replace an inner varray element
```

```
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;
/
```

Multilevel Table Example

```
declare
  type tbl is table of varchar2(20);
  type ntbl is table of tbl; -- table of table elements
  type tv1 is varray(10) of integer;
  type ntb2 is table of tv1; -- table of varray elements

  vtbl tbl := tbl('one', 'three');
  vntbl ntbl := ntbl(vtbl);
  vntb2 ntb2 := ntb2(tv1(3,5), tv1(5,7,3)); -- table of varray
elements
begin
  vntbl.extend;
  vntbl(2) := vntbl(1);
  -- delete the first element in vntbl
  vntbl.delete(1);
  -- delete the first string from the second table in the nested
table
  vntbl(2).delete(1);
end;
/
```

Multilevel Index-By Table Example

```
declare
  type tbl is table of integer index by binary_integer;
  -- the following is index-by table of index-by tables
  type ntbl is table of tbl index by binary_integer;
  type val is varray(10) of varchar2(20);
  -- the following is index-by table of varray elements
  type ntb2 is table of val index by binary_integer;

  v1 val := val('hello', 'world');
```



```

v2 ntb1;
v3 ntb2;
v4 tbl;
v5 tbl; -- null table
begin
v4(1) := 34;
v4(2) := 46456;
v4(456) := 343;
v2(23) := v4;
v3(34) := val(33, 456, 656, 343);
-- note that the following assignment raises
-- ORA-06531: Reference to uninitialized collection
-- because the element 35 in v2 does not yet exist.
-- v2(35)(2) := 78;
-- assign v2(35) to a null table and try again
v2(35) := v5;
v2(35)(2) := 78; -- it works now
end;
/

```

Example of Multilevel Collections and Bulk SQL

```

create type t1 is varray(10) of integer;
/
create table tabl (c1 t1);

insert into tabl values (t1(2,3,5));
insert into tabl values (t1(9345, 5634, 432453));

declare
type t2 is table of t1;
v2 t2;
begin
select c1 BULK COLLECT INTO v2 from tabl;
dbms_output.put_line(v2.count); -- prints 2
end;
/

```

Using Collection Methods

The following collection methods help generalize code, make collections easier to use, and make your applications easier to maintain:

EXISTS
COUNT
LIMIT
FIRST and LAST
PRIOR and NEXT
EXTEND
TRIM
DELETE

A **collection method** is a built-in function or procedure that operates on collections and is called using dot notation. The syntax follows:

```
collection_name.method_name[(parameters)]
```

Collection methods cannot be called from SQL statements. Also, `EXTEND` and `TRIM` cannot be used with index-by tables. `EXISTS`, `COUNT`, `LIMIT`, `FIRST`, `LAST`, `PRIOR`, and `NEXT` are functions; `EXTEND`, `TRIM`, and `DELETE` are procedures. `EXISTS`, `PRIOR`, `NEXT`, `TRIM`, `EXTEND`, and `DELETE` take integer parameters.

Only `EXISTS` can be applied to atomically null collections. If you apply another method to such collections, PL/SQL raises `COLLECTION_IS_NULL`.

Using the EXISTS Collection Method

`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. In the following example, PL/SQL executes the assignment statement only if element *i* exists:

```
IF courses.EXISTS(i) THEN courses(i) := new_course; END IF;
```

When passed an out-of-range subscript, `EXISTS` returns `FALSE` instead of raising `SUBSCRIPT_OUTSIDE_LIMIT`.

Using the COUNT Collection Method

`COUNT` returns the number of elements that a collection currently contains. For instance, if varray `projects` contains 25 elements, the following `IF` condition is true:

```
IF projects.COUNT = 25 THEN ...
```

`COUNT` is useful because the current size of a collection is not always known. For example, if you fetch a column of Oracle data into a nested table, how many elements does the table contain? `COUNT` gives you the answer.

You can use `COUNT` wherever an integer expression is allowed. In the next example, you use `COUNT` to specify the upper bound of a loop range:

```
FOR i IN 1..courses.COUNT LOOP ...
```

For varrays, `COUNT` always equals `LAST`. 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 the `LIMIT` Collection Method

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). For instance, if the maximum size of varray `projects` is 25 elements, the following `IF` condition is true:

```
IF projects.LIMIT = 25 THEN ...
```

You can use `LIMIT` wherever an integer expression is allowed. In the following example, you use `LIMIT` to determine if you can add 15 more elements to varray `projects`:

```
IF (projects.COUNT + 15) < projects.LIMIT THEN ...
```

Using the `FIRST` and `LAST` Collection Methods

`FIRST` and `LAST` return the first and last (smallest and largest) index numbers in a collection. If the collection is empty, `FIRST` and `LAST` return `NULL`. If the collection contains only one element, `FIRST` and `LAST` return the same index number, as the following example shows:

```
IF courses.FIRST = courses.LAST THEN ... -- only one element
```

The next example shows that you can use `FIRST` and `LAST` to specify the lower and upper bounds of a loop range provided each element in that range exists:

```
FOR i IN courses.FIRST..courses.LAST LOOP ...
```

In fact, you can use `FIRST` or `LAST` wherever an integer expression is allowed. In the following example, you use `FIRST` to initialize a loop counter:

```
i := courses.FIRST;
WHILE i IS NOT NULL LOOP ...
```

For varrays, `FIRST` always returns 1 and `LAST` always equals `COUNT`. For nested tables, `FIRST` normally returns 1. But, if you delete elements from the beginning of a nested table, `FIRST` returns a number larger than 1. Also for nested tables, `LAST` normally equals `COUNT`. But, 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.

Using the `PRIOR` and `NEXT` Collection 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`. Likewise, if `n` has no successor, `NEXT(n)` returns `NULL`.

`PRIOR` and `NEXT` do not wrap from one end of a collection to the other. For example, the following statement assigns `NULL` to `n` because the first element in a collection has no predecessor:

```
n := courses.PRIOR(courses.FIRST); -- assigns NULL to n
```

`PRIOR` is the inverse of `NEXT`. For instance, if element `i` exists, the following statement assigns element `i` to itself:

```
projects(i) := projects.PRIOR(projects.NEXT(i));
```

You can use `PRIOR` or `NEXT` to traverse collections indexed by any series of subscripts. In the following example, you use `NEXT` to traverse a nested table from which some elements have been deleted:

```
i := courses.FIRST; -- get subscript of first element
WHILE i IS NOT NULL LOOP
  -- do something with courses(i)
  i := courses.NEXT(i); -- get subscript of next element
END LOOP;
```

When traversing elements, `PRIOR` and `NEXT` ignore deleted elements.

Using the EXTEND Collection Method

To increase the size of a collection, use `EXTEND`. (You cannot use `EXTEND` with index-by tables.) 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. For example, the following statement appends 5 copies of element 1 to nested table `courses`:

```
courses.EXTEND(5,1);
```

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.

`EXTEND` operates on the internal size of a collection, which includes any deleted elements. So, if `EXTEND` encounters deleted elements, it includes them in its tally. `PL/SQL` keeps placeholders for deleted elements so that you can replace them if you wish. Consider the following example:

```
DECLARE
    TYPE CourseList IS TABLE OF VARCHAR2(10);
    courses CourseList;
BEGIN
    courses := CourseList('Biol 4412', 'Psyc 3112', 'Anth 3001');
    courses.DELETE(3); -- delete element 3
    /* PL/SQL keeps a placeholder for element 3. So, the
       next statement appends element 4, not element 3. */
    courses.EXTEND; -- append one null element
    /* Now element 4 exists, so the next statement does
       not raise SUBSCRIPT_BEYOND_COUNT. */
    courses(4) := 'Engl 2005';
```

When it includes deleted elements, the internal size of a nested table differs from the values returned by `COUNT` and `LAST`. 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 (whether leading, in the middle, or trailing) are treated alike.

Using the TRIM Collection 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. For example, this statement removes the last three elements from nested table `courses`:

```
courses.TRIM(3);
```

If n is greater than `COUNT`, `TRIM(n)` raises `SUBSCRIPT_BEYOND_COUNT`.

`TRIM` operates on the internal size of a collection. So, if `TRIM` encounters deleted elements, it includes them in its tally. Consider the following example:

```
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'
```

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`.

PL/SQL does not keep placeholders for trimmed elements. So, you cannot replace a trimmed element simply by assigning it a new value.

Using the DELETE Collection Method

This procedure has three forms. `DELETE` removes all elements from a collection. `DELETE(n)` removes the n th element from an index-by table or nested table. If n is null, `DELETE(n)` does nothing. `DELETE(m, n)` removes all elements in the range $m..n$ from an index-by table or nested table. If m is larger than n or if m or n is null, `DELETE(m, n)` does nothing. Some examples follow:

```
BEGIN
    ...
    courses.DELETE(2);      -- deletes element 2
    courses.DELETE(7,7);   -- deletes element 7
    courses.DELETE(6,3);   -- does nothing
    courses.DELETE(3,6);   -- deletes elements 3 through 6
    projects.DELETE;      -- deletes all elements
END;
```

Varrays are dense, so you cannot delete their individual elements.

If an element to be deleted does not exist, `DELETE` simply skips it; no exception is raised. PL/SQL keeps placeholders for deleted elements. So, you can replace a deleted element simply by assigning it a new value.

`DELETE` lets you maintain sparse nested tables. In the following example, you retrieve nested table `prospects` into a temporary table, prune it, then store it back in the database:

```
DECLARE
    my_prospects ProspectList;
    revenue      NUMBER;
BEGIN
    SELECT prospects INTO my_prospects FROM customers WHERE ...
    FOR i IN my_prospects.FIRST..my_prospects.LAST LOOP
        estimate_revenue(my_prospects(i), revenue); -- call procedure
        IF revenue < 25000 THEN
            my_prospects.DELETE(i);
        END IF;
    END LOOP;
    UPDATE customers SET prospects = my_prospects WHERE ...
```

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. So, you can apply the built-in collection methods (`FIRST`, `LAST`, `COUNT`, and so on) to such parameters. In the following example, a nested table is declared as the formal parameter of a packaged procedure:

```
CREATE PACKAGE personnel AS
    TYPE Staff IS TABLE OF Employee;
    ...
    PROCEDURE award_bonuses (members IN Staff);
END personnel;
CREATE PACKAGE BODY personnel AS
    ...
    PROCEDURE award_bonuses (members IN Staff) IS
    BEGIN
        ...
        IF members.COUNT > 10 THEN -- apply method
```

```

        ...
        END IF;
    END;
END personnel;

```

Note: For varray parameters, the value of `LIMIT` is always derived from the parameter type definition, regardless of the parameter mode.

Avoiding Collection Exceptions

In most cases, if you reference a nonexistent collection element, PL/SQL raises a predefined exception. Consider the following example:

```

DECLARE
    TYPE NumList IS TABLE OF NUMBER;
    nums NumList; -- atomically null
BEGIN
    /* Assume execution continues despite the raised exceptions. */
    nums(1) := 1; -- raises COLLECTION_IS_NULL (1)
    nums := NumList(1,2); -- initialize table
    nums(NULL) := 3 -- raises VALUE_ERROR (2)
    nums(0) := 3; -- raises SUBSCRIPT_OUTSIDE_LIMIT (3)
    nums(3) := 3; -- raises SUBSCRIPT_BEYOND_COUNT (4)
    nums.DELETE(1); -- delete element 1
    IF nums(1) = 1 THEN ... -- raises NO_DATA_FOUND (5)

```

In the first case, the nested table is atomically null. In the second case, the subscript is null. In the third case, the subscript is outside the legal range. In the fourth case, the subscript exceeds the number of elements in the table. In the fifth case, the subscript designates a deleted element.

The following list shows when a given exception is raised:

Exception	Raised when ...
<code>COLLECTION_IS_NULL</code>	you try to operate on an atomically null collection
<code>NO_DATA_FOUND</code>	a subscript designates an element that was deleted
<code>SUBSCRIPT_BEYOND_COUNT</code>	a subscript exceeds the number of elements in a collection
<code>SUBSCRIPT_OUTSIDE_LIMIT</code>	a subscript is outside the legal range
<code>VALUE_ERROR</code>	a subscript is null or not convertible to an integer

In some cases, you can pass "invalid" subscripts to a method without raising an exception. For instance, when you pass a null subscript to procedure `DELETE`, it does nothing. Also, you can replace deleted elements without raising `NO_DATA_FOUND`, as the following example shows:

```
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; -- legal; 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:

```
CREATE PACKAGE pkg1 AS
    TYPE NumList IS VARRAY(25) OF NUMBER(4);
    PROCEDURE delete_emps (emp_list NumList);
    ...
END pkg1;

CREATE PACKAGE BODY pkg1 AS
    PROCEDURE delete_emps (emp_list NumList) IS ...
    ...
END pkg1;
```

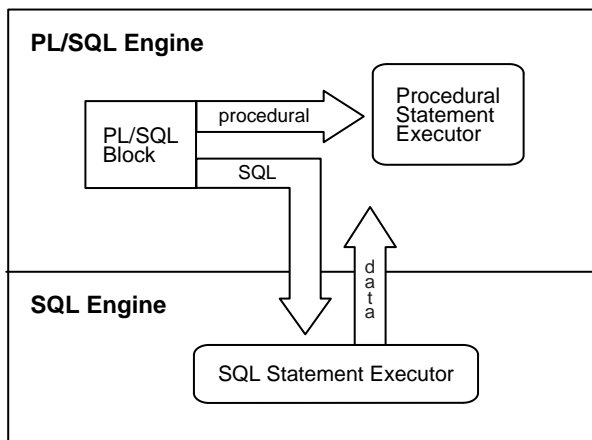
When you run the PL/SQL block below, the second procedure call fails with a *wrong number or types of arguments* error. That is because the packaged and local `VARRAY` types are incompatible even though their definitions are identical.

```
DECLARE
    TYPE NumList IS VARRAY(25) OF NUMBER(4);
    emps pkg1.NumList := pkg1.NumList(7369, 7499);
    emps2 NumList := NumList(7521, 7566);
BEGIN
    pkg1.delete_emps(emps);
    pkg1.delete_emps(emps2); -- causes a compilation error
END;
```

Reducing Loop Overhead for Collections with Bulk Binds

Embedded in the Oracle RDBMS, the PL/SQL engine accepts any valid PL/SQL block or subprogram. As [Figure 5-3](#) shows, the PL/SQL engine executes procedural statements but sends SQL statements to the SQL engine, which executes the SQL statements and, in some cases, returns data to the PL/SQL engine.

Figure 5-3 Context Switching



Each context switch between the PL/SQL and SQL engines adds to overhead. So, if many switches are required, performance suffers. That can happen when SQL statements execute inside a loop using collection (index-by table, nested table, varray, or host array) elements as bind variables. For example, the following DELETE statement is sent to the SQL engine with each iteration of the FOR loop:

```

DECLARE
    TYPE NumList IS VARRAY(20) OF NUMBER;
    depts NumList := NumList(10, 30, 70); -- department numbers
BEGIN
    ...
    FOR i IN depts.FIRST..depts.LAST LOOP
        DELETE FROM emp WHERE deptno = depts(i);
    END LOOP;
END;
  
```

In such cases, if the SQL statement affects four or more database rows, the use of bulk binds can improve performance considerably.

How Do Bulk Binds Improve Performance?

The assigning of values to PL/SQL variables in SQL statements is called *binding*. The binding of an entire collection at once is called *bulk binding*. Bulk binds improve performance by minimizing the number of context switches between the PL/SQL and SQL engines. With bulk binds, entire collections, not just individual elements, are passed back and forth. For example, the following DELETE statement is sent to the SQL engine just once, with an entire nested table:

```
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 emp WHERE deptno = depts(i);
END;
```

In the example below, 5000 part numbers and names are loaded into index-by tables. Then, all table elements are inserted into a database table twice. First, they are inserted using a FOR loop, which completes in 32 seconds. Then, they are bulk-inserted using a FORALL statement, which completes in only 3 seconds.

```
SQL> SET SERVEROUTPUT ON
SQL> CREATE TABLE parts (pnum NUMBER(4), pname CHAR(15));
```

Table created.

```
SQL> GET test.sql
1  DECLARE
2      TYPE NumTab IS TABLE OF NUMBER(4) INDEX BY BINARY_INTEGER;
3      TYPE NameTab IS TABLE OF CHAR(15) INDEX BY BINARY_INTEGER;
4      pnums NumTab;
5      pnames NameTab;
6      t1 NUMBER(5);
7      t2 NUMBER(5);
8      t3 NUMBER(5);
9      PROCEDURE get_time (t OUT NUMBER) IS
10     BEGIN SELECT TO_CHAR(SYSDATE,'SSSSS') INTO t FROM dual; END;
11 BEGIN
12     FOR j IN 1..5000 LOOP -- load index-by tables
13         pnums(j) := j;
14         pnames(j) := 'Part No. ' || TO_CHAR(j);
15     END LOOP;
16     get_time(t1);
```

```

17     FOR i IN 1..5000 LOOP -- use FOR loop
18         INSERT INTO parts VALUES (pnums(i), pnames(i));
19     END LOOP;
20     get_time(t2);
21     FORALL i IN 1..5000 -- use FORALL statement
22         INSERT INTO parts VALUES (pnums(i), pnames(i));
23     get_time(t3);
24     dbms_output.put_line('Execution Time (secs)');
25     dbms_output.put_line('-----');
26     dbms_output.put_line('FOR loop: ' || TO_CHAR(t2 - t1));
27     dbms_output.put_line('FORALL:   ' || TO_CHAR(t3 - t2));
28* END;
SQL> /
Execution Time (secs)
-----
FOR loop: 32
FORALL:   3

PL/SQL procedure successfully completed.

```

To bulk-bind input collections, you use the FORALL statement. To bulk-bind output collections, you use the BULK COLLECT clause.

Using the FORALL Statement

The keyword FORALL instructs the PL/SQL engine to bulk-bind input collections before sending them to the SQL engine. Although the FORALL statement contains an iteration scheme, it is *not* a FOR loop. Its syntax follows:

```

FORALL index IN lower_bound..upper_bound
    sql_statement;

```

The index can be referenced only within the FORALL statement and only as a collection subscript. The SQL statement must be an INSERT, UPDATE, or DELETE statement that references collection elements. And, the bounds must specify a valid range of consecutive index numbers. The SQL engine executes the SQL statement once for each index number in the range. As the following example shows, you can use the bounds to bulk-bind arbitrary slices of a collection:

```

DECLARE
    TYPE NumList IS VARRAY(15) OF NUMBER;
    depts NumList := NumList();
BEGIN
    -- fill varray here

```

```

...
FORALL j IN 6..10 -- bulk-bind middle third of varray
    UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(j);
END;

```

The SQL statement can reference more than one collection. However, the PL/SQL engine bulk-binds only subscripted collections. So, in the following example, it does not bulk-bind the collection `sals`, which is passed to the function `median`:

```

FORALL i IN 1..20
    INSERT INTO emp2 VALUES (enums(i), names(i), median(sals), ...);

```

In addition to relational tables, the FORALL statement can manipulate object tables, as the following example shows:

```

CREATE TYPE PNum AS OBJECT (n NUMBER);
CREATE TABLE partno OF PNum;

DECLARE
    TYPE NumTab IS TABLE OF NUMBER;
    nums NumTab := NumTab(1, 2, 3, 4);
    TYPE PNumTab IS TABLE OF PNum;
    pnums PNumTab := PNumTab(PNum(1), PNum(2), PNum(3), PNum(4));
BEGIN
    FORALL i IN pnums.FIRST..pnums.LAST
        INSERT INTO partno VALUES(pnums(i));
    FORALL i IN nums.FIRST..nums.LAST
        DELETE FROM partno WHERE n = 2 * nums(i);
    FORALL i IN nums.FIRST..nums.LAST
        INSERT INTO partno VALUES(100 + nums(i));
END;

```

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 follows:

```

CREATE TABLE emp2 (deptno NUMBER(2), job VARCHAR2(15));

```

Next, you insert some rows into the table, as follows:

```
INSERT INTO emp2 VALUES(10, 'Clerk');
INSERT INTO emp2 VALUES(10, 'Clerk');
INSERT INTO emp2 VALUES(20, 'Bookkeeper'); -- 10-char job title
INSERT INTO emp2 VALUES(30, 'Analyst');
INSERT INTO emp2 VALUES(30, 'Analyst');
```

Then, you try to append the 7-character string ' (temp)' to certain job titles using the following UPDATE statement:

```
DECLARE
    TYPE NumList IS TABLE OF NUMBER;
    depts NumList := NumList(10, 20, 30);
BEGIN
    FORALL j IN depts.FIRST..depts.LAST
        UPDATE emp2 SET job = job || ' (temp)'
            WHERE deptno = depts(j);
        -- raises a "value too large" exception
EXCEPTION
    WHEN OTHERS THEN
        COMMIT;
END;
```

The SQL engine executes the UPDATE statement three times, once for each index number in the specified range, that is, once for `depts(10)`, once for `depts(20)`, and once for `depts(30)`. The first execution succeeds, but the second execution fails because the string value 'Bookkeeper (temp)' is too large for the job column. In this case, only the second execution is rolled back.

When any execution of the SQL statement raises an exception, the FORALL statement halts. In our example, the second execution of the UPDATE statement raises an exception, so the third execution is never done.

Counting Rows Affected by FORALL Iterations with the %BULK_ROWCOUNT Attribute

To process SQL data manipulation statements, the SQL engine opens an implicit cursor named SQL. This cursor's scalar attributes, %FOUND, %ISOPEN, %NOTFOUND, and %ROWCOUNT, return useful information about the most recently executed SQL data manipulation statement.

The SQL cursor has one composite attribute, %BULK_ROWCOUNT, designed for use with the FORALL statement. This attribute has the semantics of an index-by table. Its *i*th element stores the number of rows processed by the *i*th execution of an INSERT,

UPDATE or DELETE statement. If the *i*th execution affects no rows, %BULK_ROWCOUNT(*i*) returns zero. An example follows:

```

DECLARE
    TYPE NumList IS TABLE OF NUMBER;
    depts NumList := NumList(10, 20, 50);
BEGIN
    FORALL j IN depts.FIRST..depts.LAST
        UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(j);
    -- Did the 3rd UPDATE statement affect any rows?
    IF SQL%BULK_ROWCOUNT(3) = 0 THEN ...
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.

%BULK_ROWCOUNT is usually equal to 1 for inserts, because a typical insert operation affects only a single row. But for the INSERT ... SELECT construct, %BULK_ROWCOUNT might be greater than 1. For example, the FORALL statement below inserts an arbitrary number of rows for each iteration. After each iteration, %BULK_ROWCOUNT returns the number of items inserted:

```

SET SERVEROUTPUT ON;
DECLARE
    TYPE num_tab IS TABLE OF NUMBER;
    deptnums num_tab;
BEGIN
    SELECT deptno BULK COLLECT INTO deptnums FROM DEPT;

    FORALL i IN 1..deptnums.COUNT
        INSERT INTO emp_by_dept
            SELECT empno, deptno FROM emp WHERE deptno =
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` with bulk binds. 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. However, 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. The syntax follows:

```
FORALL index IN lower_bound..upper_bound SAVE EXCEPTIONS
  {insert_stmt | update_stmt | delete_stmt}
```

All exceptions raised during the execution are saved in the new cursor attribute `%BULK_EXCEPTIONS`, which stores a collection of records. Each record has two fields. The first field, `%BULK_EXCEPTIONS(i).ERROR_INDEX`, holds the "iteration" of the FORALL statement during which the exception was raised. The second field, `%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 the count attribute of `%BULK_EXCEPTIONS`, that is, `%BULK_EXCEPTIONS.COUNT`. Its subscripts range from 1 to `COUNT`.

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.

The following example shows how useful the cursor attribute `%BULK_EXCEPTIONS` can be:

```
DECLARE
  TYPE NumList IS TABLE OF NUMBER;
  num_tab NumList := NumList(10,0,11,12,30,0,20,199,2,0,9,1);
  errors NUMBER;
```



```

BEGIN
    ...
    FORALL i IN num_tab.FIRST..num_tab.LAST SAVE EXCEPTIONS
        DELETE * FROM emp WHERE sal > 500000/num_tab(i);
    errors := SQL%BULK_EXCEPTIONS.COUNT;
    dbms_output.put_line('Number of errors is ' || 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('Oracle error is ' ||
            SQLERRM(SQL%BULK_EXCEPTIONS(i).ERROR_CODE));
    END LOOP;
END;

```

In this example, PL/SQL raised the predefined exception `ZERO_DIVIDE` when `i` equaled 2, 6, 10. After the bulk-bind completed, `SQL%BULK_EXCEPTIONS.COUNT` returned 3, and the contents of `SQL%BULK_EXCEPTIONS` were (2,1476), (6,1476), and (10,1476). To get the Oracle error message (which includes the code), we passed `SQL%BULK_EXCEPTIONS(i).ERROR_CODE` to the error-reporting function `SQLERRM`. Here is the output:

```

Number of errors is 3
Error 1 occurred during iteration 2
Oracle error is ORA-01476: divisor is equal to zero
Error 2 occurred during iteration 6
Oracle error is ORA-01476: divisor is equal to zero
Error 3 occurred during iteration 10
Oracle error is ORA-01476: divisor is equal to zero

```

Restrictions on FORALL

The following restrictions apply to the `FORALL` statement:

- You can use the `FORALL` statement only in server-side programs (not in client-side programs). Otherwise, you get the error *this feature is not supported in client-side programs*.
- The `INSERT`, `UPDATE`, or `DELETE` statement must reference at least one collection. Consider the following example:

```

CREATE TABLE pairs (n NUMBER, m NUMBER);

DECLARE
    TYPE NumTab IS TABLE OF NUMBER;
    nums NumTab := NumTab(1, 2, 3);

```

```
BEGIN
  FORALL j IN nums.FIRST..nums.LAST
    INSERT INTO pairs VALUES(nums(i), 10); -- works
  FORALL j IN 1..3
    INSERT INTO pairs VALUES(5, 10); -- raises an exception
END;
```

- All collection elements in the specified range must exist. If an element is missing or was deleted, you get an error. An example follows:

```
DECLARE
  TYPE NumList IS TABLE OF NUMBER;
  depts NumList := NumList(10, 20, 30, 40);
BEGIN
  depts.DELETE(3); -- delete third element
  FORALL i IN depts.FIRST..depts.LAST
    DELETE FROM emp WHERE deptno = depts(i); -- causes an error
END;
```

- As the following example shows, input collections of composite values cannot be decomposed and bound to database columns:

```
CREATE TABLE coords (x NUMBER, y NUMBER);
CREATE TYPE Pair AS OBJECT (m NUMBER, n NUMBER);

DECLARE
  TYPE PairTab IS TABLE OF Pair;
  pairs PairTab := PairTab(Pair(1,2), Pair(3,4), Pair(5,6));
  TYPE NumTab IS TABLE OF NUMBER;
  nums NumTab := NumTab(1, 2, 3);
BEGIN
  /* The following statement fails. */
  FORALL i IN 1..3
    UPDATE coords SET (x, y) = pairs(i)
      WHERE x = nums(i);
END;
```

The workaround is to decompose the composite values manually:

```
DECLARE
  TYPE PairTab IS TABLE OF Pair;
  pairs PairTab := PairTab(Pair(1,2), Pair(3,4), Pair(5,6));
  TYPE NumTab IS TABLE OF NUMBER;
  nums NumTab := NumTab(1, 2, 3);
BEGIN
  /* The following statement succeeds. */
```

```

FORALL i in 1..3
    UPDATE coords SET (x, y) = (pairs(i).m, pairs(i).n)
        WHERE x = nums(i);
END;
```

- Collection subscripts cannot be expressions, as the following example shows:

```

FORALL j IN mgrs.FIRST..mgrs.LAST
    DELETE FROM emp WHERE mgr = mgrs(j+1); -- illegal subscript
```

- The cursor attribute %BULK_ROWCOUNT cannot be assigned to other collections. Also, it cannot be passed as a parameter to subprograms.

Retrieving Query Results into Collections with the BULK COLLECT Clause

The keywords `BULK COLLECT` tell the SQL engine to bulk-bind output collections before returning them to the PL/SQL engine. You can use these keywords in the `SELECT INTO`, `FETCH INTO`, and `RETURNING INTO` clauses. Here is the syntax:

```
... BULK COLLECT INTO collection_name[, collection_name] ...
```

The SQL engine bulk-binds all collections referenced in the `INTO` list. The corresponding columns can store scalar or composite values including objects. In the following example, the SQL engine loads the entire `empno` and `ename` database columns into nested tables before returning the tables to the PL/SQL engine:

```

DECLARE
    TYPE NumTab IS TABLE OF emp.empno%TYPE;
    TYPE NameTab IS TABLE OF emp.ename%TYPE;
    enums NumTab; -- no need to initialize
    names NameTab;
BEGIN
    SELECT empno, ename BULK COLLECT INTO enums, names FROM emp;
    ...
END;
```

In the next example, the SQL engine loads all the values in an object column into a nested table before returning the table to the PL/SQL engine:

```

CREATE TYPE Coords AS OBJECT (x NUMBER, y NUMBER);
CREATE TABLE grid (num NUMBER, loc Coords);
INSERT INTO grid VALUES(10, Coords(1,2));
INSERT INTO grid VALUES(20, Coords(3,4));
```

```
DECLARE
    TYPE CoordsTab IS TABLE OF Coords;
    pairs CoordsTab;
BEGIN
    SELECT loc BULK COLLECT INTO pairs FROM grid;
    -- now pairs contains (1,2) and (3,4)
END;
```

The SQL engine initializes and extends collections for you. (However, it cannot extend varrays beyond their maximum size.) Then, starting at index 1, it inserts elements consecutively and overwrites any pre-existent elements.

The SQL engine bulk-binds entire database columns. So, if a table has 50,000 rows, the engine loads 50,000 column values into the target collection. However, you can use the pseudocolumn `ROWNUM` to limit the number of rows processed. In the following example, you limit the number of rows to 100:

```
DECLARE
    TYPE Sallist IS TABLE OF emp.sal%TYPE;
    sals Sallist;
BEGIN
    SELECT sal BULK COLLECT INTO sals FROM emp
        WHERE ROWNUM <= 100;
    ...
END;
```

Example of a Bulk Fetch from a Cursor

The following example shows that you can bulk-fetch from a cursor into one or more collections:

```
DECLARE
    TYPE NameList IS TABLE OF emp.ename%TYPE;
    TYPE Sallist IS TABLE OF emp.sal%TYPE;
    CURSOR c1 IS SELECT ename, sal FROM emp WHERE sal > 1000;
    names NameList;
    sals Sallist;
BEGIN
    OPEN c1;
    FETCH c1 BULK COLLECT INTO names, sals;
    ...
END;
```

Limiting the Rows for a Bulk FETCH Operation with the LIMIT Clause

The optional `LIMIT` clause, allowed only in bulk (not scalar) `FETCH` statements, lets you limit the number of rows fetched from the database. The syntax is

```
FETCH ... BULK COLLECT INTO ... [LIMIT rows];
```

where `rows` can be a literal, variable, or expression but must evaluate to a number. Otherwise, PL/SQL raises the predefined exception `VALUE_ERROR`. If the number is not positive, PL/SQL raises `INVALID_NUMBER`. If necessary, PL/SQL rounds the number to the nearest integer.

In the example below, with each iteration of the loop, the `FETCH` statement fetches ten rows (or less) into index-by table `empnos`. The previous values are overwritten.

```
DECLARE
    TYPE NumTab IS TABLE OF NUMBER INDEX BY BINARY_INTEGER;
    CURSOR c1 IS SELECT empno FROM emp;
    empnos NumTab;
    rows    NATURAL := 10;
BEGIN
    OPEN c1;
    LOOP
        /* The following statement fetches 10 rows (or less). */
        FETCH c1 BULK COLLECT INTO empnos LIMIT rows;
        EXIT WHEN c1%NOTFOUND;
        ...
    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, as the following example shows:

```
DECLARE
    TYPE NumList IS TABLE OF emp.empno%TYPE;
    enums NumList;
BEGIN
    DELETE FROM emp WHERE deptno = 20
        RETURNING empno BULK COLLECT INTO enums;
    -- if there were five employees in department 20,
    -- then enums contains five employee numbers
END;
```

Restrictions on BULK COLLECT

The following restrictions apply to the BULK COLLECT clause:

- 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 targets in a BULK COLLECT INTO clause must be collections, as the following example shows:

```
DECLARE
    TYPE NameList IS TABLE OF emp.ename%TYPE;
    names NameList;
    salary emp.sal%TYPE;
BEGIN
    SELECT ename, sal BULK COLLECT INTO names, salary -- illegal target
    FROM emp WHERE ROWNUM < 50;
    ...
END;
```

- You cannot bulk-fetch from a cursor into a collection of records, as the following example shows:

```
DECLARE
    TYPE DeptRecTab IS TABLE OF dept%ROWTYPE;
    dept_recs DeptRecTab;
    CURSOR c1 IS
        SELECT deptno, dname, loc FROM dept WHERE deptno > 10;
BEGIN
    OPEN c1;
    FETCH c1 BULK COLLECT INTO dept_recs; -- illegal
    ...
END;
```

- 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.

Using FORALL and BULK COLLECT Together

You can combine the `BULK COLLECT` clause with a `FORALL` statement, in which case, the SQL engine bulk-binds column values incrementally. In the following example, if collection `depts` has 3 elements, each of which causes 5 rows to be deleted, then collection `enums` has 15 elements when the statement completes:

```
FORALL j IN depts.FIRST..depts.LAST
  DELETE FROM emp WHERE empno = depts(j)
  RETURNING empno BULK COLLECT INTO enums;
```

The column values returned by each execution are added to the values returned previously. (With a `FOR` loop, the previous values are overwritten.)

You cannot use the `SELECT ... BULK COLLECT` statement in a `FORALL` statement. Otherwise, you get the error *implementation restriction: cannot use FORALL and BULK COLLECT INTO together in SELECT statements*.

Using Host Arrays with Bulk Binds

Client-side programs can use anonymous PL/SQL blocks to bulk-bind input and output host arrays. In fact, that 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 Pro*C program and must be prefixed with a colon to distinguish them from PL/SQL collections. In the example below, 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 emp WHERE deptno = :depts(i);
  ...
END;
```

What Is a Record?

A *record* is a group of related data items stored in *fields*, each with its own name and datatype. Suppose you have various data about an employee such as name, salary, and hire date. These items are logically related but dissimilar in type. A record containing a field for each item lets you treat the data as a logical unit. Thus, records make it easier to organize and represent information.

The attribute `%ROWTYPE` lets you declare a record that represents a row in a database table. However, you cannot specify the datatypes of fields in the record or declare fields of your own. The datatype `RECORD` lifts those restrictions and lets you define your own records.

Defining and Declaring Records

To create records, you define a `RECORD` type, then declare records of that type. You can define `RECORD` types in the declarative part of any PL/SQL block, subprogram, or package using the syntax

```
TYPE type_name IS RECORD (field_declaration[,field_declaration]...);
```

where `field_declaration` stands for

```
field_name field_type [[NOT NULL] {:= | DEFAULT} expression]
```

and where `type_name` is a type specifier used later to declare records, `field_type` is any PL/SQL datatype except `REF CURSOR`, and `expression` yields a value of the same type as `field_type`.

Note: Unlike `VARRAY` and (nested) `TABLE` types, `RECORD` types cannot be `CREATED` and stored in the database.

You can use `%TYPE` and `%ROWTYPE` to specify field types. In the following example, you define a `RECORD` type named `DeptRec`:

```
DECLARE
    TYPE DeptRec IS RECORD (
        dept_id    dept.deptno%TYPE,
        dept_name  VARCHAR2(14),
        dept_loc   VARCHAR2(13));
BEGIN
    ...
END;
```


Notice that field declarations are like variable declarations. Each field has a unique name and specific datatype. So, the value of a record is actually a collection of values, each of some simpler type.

As the example below shows, PL/SQL lets you define records that contain objects, collections, and other records (called *nested* records). However, object types cannot have attributes of type RECORD.

```

DECLARE
    TYPE TimeRec IS RECORD (
        seconds SMALLINT,
        minutes SMALLINT,
        hours    SMALLINT);
    TYPE FlightRec IS RECORD (
        flight_no    INTEGER,
        plane_id     VARCHAR2(10),
        captain      Employee, -- declare object
        passengers   PassengerList, -- declare varray
        depart_time  TimeRec, -- declare nested record
        airport_code VARCHAR2(10));
BEGIN
    ...
END;
```

The next example shows that you can specify a RECORD type in the RETURN clause of a function specification. That allows the function to return a user-defined record of the same type.

```

DECLARE
    TYPE EmpRec IS RECORD (
        emp_id     NUMBER(4)
        last_name  VARCHAR2(10),
        dept_num   NUMBER(2),
        job_title  VARCHAR2(9),
        salary     NUMBER(7,2));
    ...
    FUNCTION nth_highest_salary (n INTEGER) RETURN EmpRec IS ...
BEGIN
    ...
END;
```

Declaring Records

Once you define a `RECORD` type, you can declare records of that type, as the example below shows. The identifier `item_info` represents an entire record.

```
DECLARE
    TYPE StockItem IS RECORD (
        item_no      INTEGER(3),
        description  VARCHAR2(50),
        quantity     INTEGER,
        price        REAL(7,2));
    item_info StockItem; -- declare record
BEGIN
    ...
END;
```

Like scalar variables, user-defined records can be declared as the formal parameters of procedures and functions. An example follows:

```
DECLARE
    TYPE EmpRec IS RECORD (
        emp_id      emp.empno%TYPE,
        last_name   VARCHAR2(10),
        job_title   VARCHAR2(9),
        salary      NUMBER(7,2));
    ...
    PROCEDURE raise_salary (emp_info EmpRec);
BEGIN
    ...
END;
```

Initializing Records

The example below shows that you can initialize a record in its type definition. When you declare a record of type `TimeRec`, its three fields assume an initial value of zero.

```
DECLARE
    TYPE TimeRec IS RECORD (
        secs SMALLINT := 0,
        mins SMALLINT := 0,
        hrs  SMALLINT := 0);
BEGIN
    ...
END;
```

The next example shows that you can impose the NOT NULL constraint on any field, and so prevent the assigning of nulls to that field. Fields declared as NOT NULL must be initialized.

```
DECLARE
    TYPE StockItem IS RECORD (
        item_no      INTEGER(3) NOT NULL := 999,
        description  VARCHAR2(50),
        quantity     INTEGER,
        price        REAL(7,2));
BEGIN
    ...
END;
```

Referencing Records

Unlike elements in a collection, which are accessed using subscripts, fields in a record are accessed by name. To reference an individual field, use dot notation and the following syntax:

```
record_name.field_name
```

For example, you reference field `hire_date` in record `emp_info` as follows:

```
emp_info.hire_date ...
```

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
```

For example, the following call to function `nth_highest_sal` references the field `salary` in record `emp_info`:

```
DECLARE
    TYPE EmpRec IS RECORD (
        emp_id      NUMBER(4),
        job_title   VARCHAR2(9),
        salary      NUMBER(7,2));
    middle_sal     NUMBER(7,2);
    FUNCTION nth_highest_sal (n INTEGER) RETURN EmpRec IS
        emp_info EmpRec;
BEGIN
    ...
    RETURN emp_info; -- return record
END;
```

```
BEGIN
    middle_sal := nth_highest_sal(10).salary; -- call function
    ...
END;
```

When calling a parameterless function, use the following syntax:

```
function_name().field_name -- note empty parameter list
```

To reference nested fields in a record returned by a function, use extended dot notation. The syntax follows:

```
function_name(parameter_list).field_name.nested_field_name
```

For instance, the following call to function `item` references the nested field `minutes` in record `item_info`:

```
DECLARE
    TYPE TimeRec IS RECORD (minutes SMALLINT, hours SMALLINT);
    TYPE AgendaItem IS RECORD (
        priority INTEGER,
        subject VARCHAR2(100),
        duration TimeRec);
    FUNCTION item (n INTEGER) RETURN AgendaItem IS
        item_info AgendaItem;
    BEGIN
        ...
        RETURN item_info; -- return record
    END;
BEGIN
    ...
    IF item(3).duration.minutes > 30 THEN ... -- call function
END;
```

Also, use extended dot notation to reference the attributes of an object stored in a field, as the following example shows:

```
DECLARE
    TYPE FlightRec IS RECORD (
        flight_no    INTEGER,
        plane_id     VARCHAR2(10),
        captain      Employee, -- declare object
        passengers   PassengerList, -- declare varray
        depart_time  TimeRec, -- declare nested record
        airport_code VARCHAR2(10));
    flight FlightRec;
```

```

BEGIN
    ...
    IF flight.captain.name = 'H Rawlins' THEN ...
END;

```

Nulling Records

To null all the fields in a record, simply assign to it an uninitialized record of the same type, as shown in the following example:

```

DECLARE
    TYPE EmpRec IS RECORD (
        emp_id      emp.empno%TYPE,
        job_title   VARCHAR2(9),
        salary      NUMBER(7,2));
    emp_info EmpRec;
    emp_null EmpRec;
BEGIN
    emp_info.emp_id := 7788;
    emp_info.job_title := 'ANALYST';
    emp_info.salary := 3500;
    emp_info := emp_null; -- nulls all fields in emp_info
    ...
END;

```

Assigning Records

You can assign the value of an expression to a specific field in a record using the following syntax:

```
record_name.field_name := expression;
```

In the following example, you convert an employee name to upper case:

```
emp_info.ename := UPPER(emp_info.ename);
```

Instead of assigning values separately to each field in a record, you can assign values to all fields at once. This can be done in two ways. First, you can assign one user-defined record to another if they have the same datatype. Having fields that match exactly is not enough. Consider the following example:

```

DECLARE
    TYPE DeptRec IS RECORD (
        dept_num  NUMBER(2),
        dept_name VARCHAR2(14));

```

```
TYPE DeptItem IS RECORD (  
    dept_num NUMBER(2),  
    dept_name VARCHAR2(14));  
dept1_info DeptRec;  
dept2_info DeptItem;  
BEGIN  
    ...  
    dept1_info := dept2_info; -- illegal; different datatypes  
END;
```

As the next example shows, 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:

```
DECLARE  
    TYPE DeptRec IS RECORD (  
        dept_num NUMBER(2),  
        dept_name VARCHAR2(14),  
        location VARCHAR2(13));  
    dept1_info DeptRec;  
    dept2_info dept%ROWTYPE;  
BEGIN  
    SELECT * INTO dept2_info FROM dept WHERE deptno = 10;  
    dept1_info := dept2_info;  
    ...  
END;
```

Second, you can use the `SELECT` or `FETCH` statement to fetch column values into a record, as the example below shows. The columns in the select-list must appear in the same order as the fields in your record.

```
DECLARE  
    TYPE DeptRec IS RECORD (  
        dept_num NUMBER(2),  
        dept_name VARCHAR2(14),  
        location VARCHAR2(13));  
    dept_info DeptRec;  
BEGIN  
    SELECT * INTO dept_info FROM dept WHERE deptno = 20;  
    ...  
END;
```

However, you cannot assign a list of values to a record using an assignment statement. Therefore, the following syntax is illegal:

```
record_name := (value1, value2, value3, ...); -- illegal
```

The example below shows that you can assign one nested record to another if they have the same datatype. Such assignments are allowed even if the enclosing records have different datatypes.

```

DECLARE
    TYPE TimeRec IS RECORD (mins SMALLINT, hrs SMALLINT);
    TYPE MeetingRec IS RECORD (
        day      DATE,
        time_of TimeRec, -- nested record
        room_no INTEGER(4));
    TYPE PartyRec IS RECORD (
        day      DATE,
        time_of TimeRec, -- nested record
        place   VARCHAR2(25));
    seminar MeetingRec;
    party    PartyRec;
BEGIN
    ...
    party.time_of := seminar.time_of;
END;

```

Comparing Records

Records cannot be tested for nullity, equality, or inequality. For instance, the following IF conditions are not allowed:

```

BEGIN
    ...
    IF emp_info IS NULL THEN ... -- illegal
    IF dept2_info > dept1_info THEN ... -- illegal
END;

```

Manipulating Records

The datatype RECORD lets you collect information about the attributes of something. The information is easy to manipulate because you can refer to the collection as a whole. In the following example, you collect accounting figures from database tables `assets` and `liabilities`, then use ratio analysis to compare the performance of two subsidiary companies:

```

DECLARE
    TYPE FiguresRec IS RECORD (cash REAL, notes REAL, ...);
    sub1_figs FiguresRec;

```

```

sub2_figs FiguresRec;
FUNCTION acid_test (figs FiguresRec) RETURN REAL IS ...
BEGIN
  SELECT cash, notes, ... INTO sub1_figs FROM assets, liabilities
    WHERE assets.sub = 1 AND liabilities.sub = 1;
  SELECT cash, notes, ... INTO sub2_figs FROM assets, liabilities
    WHERE assets.sub = 2 AND liabilities.sub = 2;
  IF acid_test(sub1_figs) > acid_test(sub2_figs) THEN ...
  ...
END;
```

Notice how easy it is to pass the collected figures to the function `acid_test`, which computes a financial ratio.

In SQL*Plus, suppose you define object type `Passenger`, as follows:

```

SQL> CREATE TYPE Passenger AS OBJECT(
  2  flight_no NUMBER(3),
  3  name      VARCHAR2(20),
  4  seat      CHAR(5));
```

Next, you define `VARRAY` type `PassengerList`, which stores `Passenger` objects:

```

SQL> CREATE TYPE PassengerList AS VARRAY(300) OF Passenger;
```

Finally, you create relational table `flights`, which has a column of type `PassengerList`, as follows:

```

SQL> CREATE TABLE flights (
  2  flight_no NUMBER(3),
  3  gate      CHAR(5),
  4  departure CHAR(15),
  5  arrival   CHAR(15),
  6  passengers PassengerList);
```

Each item in column `passengers` is a `varray` that will store the passenger list for a given flight. Now, you can populate database table `flights`, as follows:

```

BEGIN
  INSERT INTO flights
    VALUES(109, '80', 'DFW 6:35PM', 'HOU 7:40PM',
      PassengerList(Passenger(109, 'Paula Trusdale', '13C'),
        Passenger(109, 'Louis Jemenez', '22F'),
        Passenger(109, 'Joseph Braun', '11B'), ...));
  INSERT INTO flights
    VALUES(114, '12B', 'SFO 9:45AM', 'LAX 12:10PM',
      PassengerList(Passenger(114, 'Earl Benton', '23A'),
```



```

                Passenger(114, 'Alma Breckenridge', '10E'),
                Passenger(114, 'Mary Rizutto', '11C'), ...));
INSERT INTO flights
VALUES(27, '34', 'JFK 7:05AM', 'MIA 9:55AM',
      PassengerList(Passenger(27, 'Raymond Kiley', '34D'),
                    Passenger(27, 'Beth Steinberg', '3A'),
                    Passenger(27, 'Jean Lafevre', '19C'), ...));
END;
```

In the example below, you fetch rows from database table `flights` into record `flight_info`. That way, you can treat all the information about a flight, including its passenger list, as a logical unit.

```

DECLARE
  TYPE FlightRec IS RECORD (
    flight_no  NUMBER(3),
    gate       CHAR(5),
    departure  CHAR(15),
    arrival    CHAR(15),
    passengers PassengerList);
  flight_info FlightRec;
  CURSOR c1 IS SELECT * FROM flights;
  seat_not_available EXCEPTION;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO flight_info;
    EXIT WHEN c1%NOTFOUND;
    FOR i IN 1..flight_info.passengers.LAST LOOP
      IF flight_info.passengers(i).seat = 'NA' THEN
        dbms_output.put_line(flight_info.passengers(i).name);
        RAISE seat_not_available;
      END IF;
      ...
    END LOOP;
  END LOOP;
  CLOSE c1;
EXCEPTION
  WHEN seat_not_available THEN
    ...
END;
```

Interaction Between PL/SQL and Oracle

Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it. —Samuel Johnson

This chapter helps you harness the power of Oracle. You learn how PL/SQL supports the SQL commands, functions, and operators that let you manipulate Oracle data. You also learn how to manage cursors, use cursor variables, and process transactions.

This chapter discusses the following topics:

- Overview of SQL Support in PL/SQL
- Managing Cursors
- Separating Cursor Specs and Bodies with Packages
- Using Cursor FOR Loops
- Using Cursor Variables
- Using Cursor Attributes
- Using Cursor Expressions
- Overview of Transaction Processing in PL/SQL
- Doing Independent Units of Work with Autonomous Transactions
- Ensuring Backward Compatibility of PL/SQL Programs

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 supports dynamic SQL, which enables you to execute SQL data definition, data control, and session control statements dynamically. In addition, PL/SQL conforms to the current ANSI/ISO SQL standard.

Data Manipulation

To manipulate Oracle data, you use the `INSERT`, `UPDATE`, `DELETE`, `SELECT`, and `LOCK TABLE` commands. `INSERT` adds new rows of data to database tables; `UPDATE` modifies rows; `DELETE` removes unwanted rows; `SELECT` retrieves rows that meet your search criteria; and `LOCK TABLE` temporarily limits access to a table.

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.

Simultaneously, Oracle makes permanent or undoes all database changes made by a transaction. If your program fails in the middle of a transaction, Oracle detects the error and rolls back the transaction. Thus, the database is restored to its former state automatically.

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.

SQL Functions

PL/SQL lets you use all the SQL functions including the following aggregate functions, which summarize entire columns of Oracle data: `AVG`, `COUNT`, `GROUPING`, `MAX`, `MIN`, `STDDEV`, `SUM`, and `VARIANCE`. Except for `COUNT (*)`, all aggregate functions ignore nulls.

You can use the aggregate functions in SQL statements, but *not* in procedural statements. Aggregate functions operate on entire columns unless you use the `SELECT GROUP BY` statement to sort returned rows into subgroups. If you omit the `GROUP BY` clause, the aggregate function treats all returned rows as a single group.

You call an aggregate function using the syntax

```
function_name([ALL | DISTINCT] expression)
```

where `expression` refers to one or more database columns. If you specify `ALL` (the default), the aggregate function considers all column values including duplicates. If you specify `DISTINCT`, the aggregate function considers only distinct values. For example, the following statement returns the number of different job titles in the database table `emp`:

```
SELECT COUNT(DISTINCT job) INTO job_count FROM emp;
```

The function `COUNT` lets you use the asterisk (*) row operator, which returns the number of rows in a table. For example, the following statement returns the number of rows in table `emp`:

```
SELECT COUNT(*) INTO emp_count FROM emp;
```

SQL Pseudocolumns

PL/SQL recognizes the following SQL pseudocolumns, which return specific data items: `CURRVAL`, `LEVEL`, `NEXTVAL`, `ROWID`, and `ROWNUM`. Pseudocolumns are not actual columns in a table but they behave like columns. For example, you can select values from a pseudocolumn. However, you cannot insert into, update, or delete from a pseudocolumn. Also, pseudocolumns are allowed in SQL statements, but *not* in procedural statements.

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 obtain the current or next value in a sequence, you must use dot notation, as follows:

```
sequence_name.CURRVAL
sequence_name.NEXTVAL
```

After creating a sequence, you can use it to generate unique sequence numbers for transaction processing. However, you can use `CURRVAL` and `NEXTVAL` only in a `SELECT` list, the `VALUES` clause, and the `SET` clause. In the following example, you use a sequence to insert the same employee number into two tables:

```
INSERT INTO emp VALUES (empno_seq.NEXTVAL, my_ename, ...);
INSERT INTO sals VALUES (empno_seq.CURRVAL, my_sal, ...);
```

If a transaction generates a sequence number, the sequence is incremented immediately whether you commit or roll back the transaction.

LEVEL

You use `LEVEL` with the `SELECT CONNECT BY` statement to organize rows from a database table into a tree structure. `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 walks 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. In the following example, you declare a variable named `row_id` for that purpose:

```
DECLARE
    row_id UROWID;
```

When you select or fetch a physical rowid into a `UROWID` variable, you can use the function `ROWIDTOCHAR`, which converts the binary value to an 18-byte character string. Then, 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 6-51.

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.

You can use `ROWNUM` in an `UPDATE` statement to assign unique values to each row in a table. Also, you can use `ROWNUM` in the `WHERE` clause of a `SELECT` statement to limit the number of rows retrieved, as follows:

```
DECLARE
  CURSOR c1 IS SELECT empno, sal FROM emp
    WHERE sal > 2000 AND ROWNUM < 10; -- returns 10 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;
```

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 *Oracle9i 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 always yield `TRUE`, `FALSE`, or `NULL`. You can use all the comparison operators listed below to form predicates. Moreover, you can combine predicates using the logical operators `AND`, `OR`, and `NOT`.

Operator	Description
<code>ALL</code>	Compares a value to each value in a list or returned by a subquery and yields <code>TRUE</code> if all of the individual comparisons yield <code>TRUE</code> .
<code>ANY, SOME</code>	Compares a value to each value in a list or returned by a subquery and yields <code>TRUE</code> if any of the individual comparisons yields <code>TRUE</code> .
<code>BETWEEN</code>	Tests whether a value lies in a specified range.
<code>EXISTS</code>	Returns <code>TRUE</code> if a subquery returns at least one row.
<code>IN</code>	Tests for set membership.
<code>IS NULL</code>	Tests for nulls.
<code>LIKE</code>	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

PL/SQL uses two types of cursors: *implicit* and *explicit*. PL/SQL declares a cursor implicitly for all SQL data manipulation statements, including queries that return only one row. However, for queries that return more than one row, you must declare an explicit cursor, use a cursor `FOR` loop, or use the `BULK COLLECT` clause.

Overview of Explicit Cursors

The set of rows returned by a query can consist of zero, one, or multiple rows, depending on how many rows meet your search criteria. When a query returns multiple rows, you can explicitly declare a cursor to process the rows. Moreover, you can 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. You can process several queries in parallel by declaring and opening multiple cursors.

Declaring a Cursor

Forward references are not allowed in PL/SQL. So, you must declare a cursor before referencing it in other statements. When you declare a cursor, you name it and associate it with a specific query using the syntax

```
CURSOR cursor_name [(parameter[, parameter]...)]
```



```
[RETURN return_type] IS select_statement;
```

where `return_type` must represent a record or a row in a database table, and parameter stands for the following syntax:

```
cursor_parameter_name [IN] datatype [{:= | DEFAULT} expression]
```

For example, you might declare cursors named `c1` and `c2`, as follows:

```
DECLARE
  CURSOR c1 IS SELECT empno, ename, job, sal FROM emp
    WHERE sal > 2000;
  CURSOR c2 RETURN dept%ROWTYPE IS
    SELECT * FROM dept WHERE deptno = 10;
```

The cursor name is an undeclared identifier, not the name of a PL/SQL variable. You cannot assign values to a cursor name or use it in an expression. However, cursors and variables follow the same scoping rules. Naming cursors after database tables is allowed 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. Therefore, they cannot return values to actual parameters. Also, you cannot impose the constraint `NOT NULL` on a cursor parameter.

As the example below shows, you can initialize cursor parameters to default values. That way, 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 every reference to the cursor.

```
DECLARE
  CURSOR c1 (low INTEGER DEFAULT 0,
    high INTEGER DEFAULT 99) IS SELECT ...
```

The scope of cursor parameters is local to the cursor, meaning that they can be referenced only within the query specified in the cursor declaration. The values of cursor parameters 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 ename, job FROM emp WHERE sal < 3000;
...
BEGIN
    OPEN c1;
    ...
END;
```

Rows in the result set are not retrieved when the `OPEN` statement is executed. Rather, the `FETCH` statement retrieves the rows.

Passing Cursor Parameters

You use the `OPEN` statement to pass parameters to a cursor. Unless you want to accept default values, each formal parameter in the cursor declaration must have a corresponding actual parameter in the `OPEN` statement. For example, given the cursor declaration

```
DECLARE
    emp_name emp.ename%TYPE;
    salary emp.sal%TYPE;
    CURSOR c1 (name VARCHAR2, salary NUMBER) IS SELECT ...
```

any of the following statements opens the cursor:

```
OPEN c1(emp_name, 3000);
OPEN c1('ATTLEY', 1500);
OPEN c1(emp_name, salary);
```

In the last example, when the identifier `salary` is used in the cursor declaration, it refers to the formal parameter. But, when it is used in the `OPEN` statement, it refers to the PL/SQL variable. To avoid confusion, use unique identifiers.

Formal parameters declared with a default value need not have a corresponding actual parameter. They can simply 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. The datatypes of each actual parameter and its corresponding formal parameter must be compatible.

Fetching with a Cursor

Unless you use the `BULK COLLECT` clause (discussed in the next section), the `FETCH` statement retrieves the rows in the result set one at a time. After each fetch, the cursor advances to the next row in the result set. An example follows:

```
FETCH c1 INTO my_empno, my_ename, my_deptno;
```

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 in the following way:

```
LOOP
    FETCH c1 INTO my_record;
    EXIT WHEN c1%NOTFOUND;
    -- process data record
END LOOP;
```

The query can reference PL/SQL variables within its scope. However, any variables in the query are evaluated only when the cursor is opened. In the following example, each retrieved salary is multiplied by 2, even though `factor` is incremented after every fetch:

```
DECLARE
    my_sal emp.sal%TYPE;
    my_job emp.job%TYPE;
    factor INTEGER := 2;
    CURSOR c1 IS SELECT factor*sal FROM emp WHERE job = my_job;
BEGIN
    ...
    OPEN c1; -- here factor equals 2
    LOOP
        FETCH c1 INTO my_sal;
        EXIT WHEN c1%NOTFOUND;
        factor := factor + 1; -- does not affect FETCH
    END LOOP;
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 the following example shows:

```
DECLARE
```

```
CURSOR c1 IS SELECT ename FROM emp;
name1 emp.ename%TYPE;
name2 emp.ename%TYPE;
name3 emp.ename%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 indeterminate.

Note: Eventually, the `FETCH` statement must fail to return a row, so when that happens, no exception is raised. To detect the failure, you must use the cursor attribute `%FOUND` or `%NOTFOUND`. For more information, see ["Using Cursor Attributes"](#) on page 6-34

Fetching Bulk Data with a Cursor

The `BULK COLLECT` clause lets you bulk-bind entire columns of Oracle data (see ["Retrieving Query Results into Collections with the BULK COLLECT Clause"](#) on page 5-41). That way, you can fetch all rows from the result set at once. In the following example, you bulk-fetch from a cursor into two collections:

```
DECLARE
  TYPE NumTab IS TABLE OF emp.empno%TYPE;
  TYPE NameTab IS TABLE OF emp.ename%TYPE;
  nums NumTab;
  names NameTab;
  CURSOR c1 IS SELECT empno, ename FROM emp WHERE job = 'CLERK';
BEGIN
  OPEN c1;
  FETCH c1 BULK COLLECT INTO nums, names;
  ...
  CLOSE c1;
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. Any other operation on a closed cursor raises the predefined exception `INVALID_CURSOR`.

Using Subqueries in Cursors

A *subquery* is a query (usually enclosed by parentheses) that appears within another SQL data manipulation statement. When evaluated, the subquery provides a value or set of values to the statement. Often, subqueries are used in the `WHERE` clause. For example, the following query returns employees not located in Chicago:

```
DECLARE
  CURSOR c1 IS SELECT empno, ename FROM emp
                WHERE deptno IN (SELECT deptno FROM dept
                                WHERE loc <> 'CHICAGO');
```

Using a subquery in the `FROM` clause, the following query returns the number and name of each department with five or more employees:

```
DECLARE
  CURSOR c1 IS SELECT t1.deptno, dname, "STAFF"
                FROM dept t1, (SELECT deptno, COUNT(*) "STAFF"
                              FROM emp GROUP BY deptno) t2
                WHERE t1.deptno = t2.deptno AND "STAFF" >= 5;
```

Whereas a subquery is evaluated only once for each table, a *correlated subquery* is evaluated once for each row. Consider the query below, which returns the name and salary of each employee whose salary exceeds the departmental average. For each row in the `emp` table, the correlated subquery computes the average salary for that row's department. The row is returned if that row's salary exceeds the average.

```
DECLARE
  CURSOR c1 IS SELECT deptno, ename, sal FROM emp t
                WHERE sal > (SELECT AVG(sal) FROM emp WHERE t.deptno = deptno)
                ORDER BY deptno;
```

Overview of Implicit Cursors

Oracle implicitly opens a cursor to process each SQL statement not associated with an explicitly declared cursor. You can refer to the most recent implicit cursor as the SQL cursor. Although you cannot use the `OPEN`, `FETCH`, and `CLOSE` statements to control the SQL cursor, you can use cursor attributes to get information about the most recently executed SQL statement. See ["Using Cursor Attributes"](#) on page 6-34.

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. You code the cursor spec in the package spec using this syntax:

```
CURSOR cursor_name [(parameter[, parameter]...)] RETURN return_type;
```

In the following example, you use the `%ROWTYPE` attribute to provide a record type that represents a row in the database table `emp`:

```
CREATE PACKAGE emp_stuff AS
    CURSOR c1 RETURN emp%ROWTYPE;  -- declare cursor spec
    ...
END emp_stuff;

CREATE PACKAGE BODY emp_stuff AS
    CURSOR c1 RETURN emp%ROWTYPE IS
        SELECT * FROM emp WHERE sal > 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 instance, you can change the cursor body in the last example, as follows, without having to change the cursor spec:

```
CREATE PACKAGE BODY emp_stuff AS
    CURSOR c1 RETURN emp%ROWTYPE IS
        SELECT * FROM emp WHERE deptno = 20;  -- new WHERE clause
    ...
END emp_stuff;
```

From a PL/SQL block or subprogram, you use dot notation to reference a packaged cursor, as the following example shows:

```
DECLARE
    emp_rec emp%ROWTYPE;
    ...
BEGIN
    ...
    OPEN emp_stuff.c1;
```

```

LOOP
    FETCH emp_stuff.c1 INTO emp_rec;
    EXIT WHEN emp_suff.c1%NOTFOUND;
    ...
END LOOP;
CLOSE emp_stuff.c1;
END;

```

The scope of a packaged cursor is not limited to a particular PL/SQL block. So, when you open a packaged cursor, it remains open until you close it or you disconnect your Oracle session.

Using Cursor FOR Loops

In most situations that require an explicit cursor, you can simplify coding by using a cursor FOR loop instead of the OPEN, FETCH, and CLOSE statements. 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.

Consider the PL/SQL block below, which computes results from an experiment, then stores the results in a temporary table. The FOR loop index `c1_rec` is implicitly declared as a record. Its fields store all the column values fetched from the cursor `c1`. Dot notation is used to reference individual fields.

```

-- available online in file 'examp7'
DECLARE
    result temp.col1%TYPE;
    CURSOR c1 IS
        SELECT n1, n2, n3 FROM data_table WHERE exper_num = 1;
BEGIN
    FOR c1_rec IN c1 LOOP
        /* calculate and store the results */
        result := c1_rec.n2 / (c1_rec.n1 + c1_rec.n3);
        INSERT INTO temp VALUES (result, NULL, NULL);
    END LOOP;
    COMMIT;
END;

```

When the cursor FOR loop is entered, the cursor name cannot belong to a cursor already opened by an OPEN statement or enclosing cursor FOR loop. Before each iteration of the FOR loop, PL/SQL fetches into the implicitly declared record. The record is defined only inside the loop. You cannot refer to its fields outside the loop.

The sequence of statements inside the loop is executed once for each row that satisfies the query associated with the cursor. When you leave the loop, the cursor is closed automatically—even if you use an `EXIT` or `GOTO` statement to leave the loop prematurely or an exception is raised inside the loop.

Using Subqueries Instead of Explicit Cursors

You need not declare a cursor because PL/SQL lets you substitute a subquery. The following cursor `FOR` loop calculates a bonus, then inserts the result into a database table:

```
DECLARE
    bonus REAL;
BEGIN
    FOR emp_rec IN (SELECT empno, sal, comm FROM emp) LOOP
        bonus := (emp_rec.sal * 0.05) + (emp_rec.comm * 0.25);
        INSERT INTO bonuses VALUES (emp_rec.empno, bonus);
    END LOOP;
    COMMIT;
END;
```

Using Cursor Subqueries

You can use cursor subqueries, also known 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 ["Accepting and Returning Multiple Rows with Table Functions"](#) on page 8-30.

Defining Aliases for Expression Values in a Cursor FOR Loop

Fields in the implicitly declared record hold column values from the most recently fetched row. The fields have the same names as corresponding columns in the `SELECT` list. But, what happens if a select item is an expression? Consider the following example:

```
CURSOR c1 IS
    SELECT empno, sal+NVL(comm,0), job FROM ...
```


In such cases, you must include an alias for the select item. In the following example, `wages` is an alias for the select item `sal+NVL(comm,0)`:

```
CURSOR c1 IS
    SELECT empno, sal+NVL(comm,0) wages, job FROM ...
```

To reference the corresponding field, use the alias instead of a column name, as follows:

```
IF emp_rec.wages < 1000 THEN ...
```

Passing Parameters to a Cursor FOR Loop

You can pass parameters to the cursor in a cursor FOR loop. In the following example, you pass a department number. Then, you compute the total wages paid to employees in that department. Also, you determine how many employees have salaries higher than \$2000 and/or commissions larger than their salaries.

```
-- available online in file 'examp8'
DECLARE
    CURSOR emp_cursor(dnum NUMBER) IS
        SELECT sal, comm FROM emp WHERE deptno = dnum;
    total_wages NUMBER(11,2) := 0;
    high_paid    NUMBER(4) := 0;
    higher_comm  NUMBER(4) := 0;
BEGIN
    /* The number of iterations will equal the number of rows
       returned by emp_cursor. */
    FOR emp_record IN emp_cursor(20) LOOP
        emp_record.comm := NVL(emp_record.comm, 0);
        total_wages := total_wages + emp_record.sal +
            emp_record.comm;
        IF emp_record.sal > 2000.00 THEN
            high_paid := high_paid + 1;
        END IF;
        IF emp_record.comm > emp_record.sal THEN
            higher_comm := higher_comm + 1;
        END IF;
    END LOOP;
    INSERT INTO temp VALUES (high_paid, higher_comm,
        'Total Wages: ' || TO_CHAR(total_wages));
    COMMIT;
END;
```

Using Cursor Variables

Like a cursor, a cursor variable points to the current row in the result set of a multi-row query. But, cursors differ from cursor variables the way constants differ from variables. Whereas a cursor is static, a cursor variable is dynamic because it is not tied to a specific query. You can open a cursor variable for any type-compatible query. This gives you more flexibility.

Also, you can assign new values to a cursor variable and pass it as a parameter to local and stored subprograms. This gives you an easy way to centralize data retrieval.

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. Moreover, application development tools such as Oracle Forms and Oracle Reports, which have a PL/SQL engine, can use cursor variables entirely on the client side.

The Oracle server also has a PL/SQL engine. So, you can pass cursor variables back and forth between an application and server through remote procedure calls (RPCs).

What Are Cursor Variables?

Cursor variables are like C or Pascal pointers, which hold the memory location (address) of some item instead of the item itself. So, declaring a cursor variable creates a pointer, *not* an item. In PL/SQL, a pointer has datatype `REF X`, where `REF` is short for `REFERENCE` and `X` stands for a class of objects. Therefore, a cursor variable has datatype `REF CURSOR`.

To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. To access the information, you can use an explicit cursor, which names the work area. Or, you can use a cursor variable, which points to the work area. Whereas a cursor always refers to the same query work area, a cursor variable can refer to different work areas. So, cursors and cursor variables are *not* interoperable; that is, you cannot use one where the other is expected.

Why Use Cursor Variables?

Mainly, you use cursor variables to pass query result sets between PL/SQL stored subprograms and various clients. Neither PL/SQL nor any of its clients owns a result set; they simply 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 server can all refer to the same work area.

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.

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. Also, you can reduce network traffic by having a PL/SQL block open (or close) several host cursor variables in a single round trip.

Defining REF CURSOR Types

To create cursor variables, you take two steps. First, 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 using the syntax

```
TYPE ref_type_name IS REF CURSOR [RETURN return_type];
```

where `ref_type_name` is a type specifier used in subsequent declarations of cursor variables and `return_type` must represent a record or a row in a database table. In the following example, you specify a return type that represents a row in the database table `dept`:

```
DECLARE
    TYPE DeptCurTyp IS REF CURSOR RETURN dept%ROWTYPE;
```

REF CURSOR types can be *strong* (restrictive) or *weak* (nonrestrictive). As the next example shows, a strong REF CURSOR type definition specifies a return type, but a weak definition does not:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE; -- strong
    TYPE GenericCurTyp IS REF CURSOR; -- weak
```

Strong REF CURSOR types are less error prone because the PL/SQL compiler lets you associate a strongly typed cursor variable only with type-compatible queries. However, weak REF CURSOR types are more flexible because the compiler lets you associate a weakly typed cursor variable with any query.

Declaring Cursor Variables

Once you define a `REF CURSOR` type, you can declare cursor variables of that type in any PL/SQL block or subprogram. In the following example, you declare the cursor variable `dept_cv`:

```
DECLARE
    TYPE DeptCurTyp IS REF CURSOR RETURN dept%ROWTYPE;
    dept_cv DeptCurTyp; -- declare cursor variable
```

Note: You cannot declare cursor variables in a package. Unlike packaged variables, cursor variables do not have persistent state. Remember, declaring a cursor variable creates a pointer, not an item. So, cursor variables cannot be saved in the database.

Cursor variables follow the usual scoping and instantiation rules. Local PL/SQL cursor variables are instantiated when you enter a block or subprogram and cease to exist when you exit.

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, as follows:

```
DECLARE
    TYPE TmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    tmp_cv TmpCurTyp; -- declare cursor variable
    TYPE EmpCurTyp IS REF CURSOR RETURN tmp_cv%ROWTYPE;
    emp_cv EmpCurTyp; -- declare cursor variable
```

Likewise, you can use `%TYPE` to provide the datatype of a record variable, as the following example shows:

```
DECLARE
    dept_rec dept%ROWTYPE; -- declare record variable
    TYPE DeptCurTyp IS REF CURSOR RETURN dept_rec%TYPE;
    dept_cv DeptCurTyp; -- declare cursor variable
```

In the final example, you specify a user-defined `RECORD` type in the `RETURN` clause:

```
DECLARE
    TYPE EmpRecTyp IS RECORD (
        empno NUMBER(4),
        ename VARCHAR2(10),
        sal    NUMBER(7,2));
    TYPE EmpCurTyp IS REF CURSOR RETURN EmpRecTyp;
    emp_cv EmpCurTyp; -- declare cursor variable
```

Cursor Variables As Parameters

You can declare cursor variables as the formal parameters of functions and procedures. In the following example, you define the `REF CURSOR` type `EmpCurTyp`, then declare a cursor variable of that type as the formal parameter of a procedure:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp) IS ...
```

Caution: Like all pointers, cursor variables increase the possibility of parameter aliasing. See "[Understanding Subprogram Parameter Aliasing](#)" on page 8-21.

Controlling Cursor Variables

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. Here is the syntax:

```
OPEN {cursor_variable | :host_cursor_variable} FOR
{ select_statement
| dynamic_string [USING bind_argument[, bind_argument]...] };
```

where `host_cursor_variable` is a cursor variable declared in a PL/SQL host environment such as an OCI program, and `dynamic_string` is a string expression that represents a multi-row query.

Note: 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 "[Opening the Cursor Variable](#)" on page 11-8.

Unlike cursors, cursor variables take no parameters. However, no flexibility is lost because 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.

In the example below, you open the cursor variable `emp_cv`. Notice that you can apply cursor attributes (`%FOUND`, `%NOTFOUND`, `%ISOPEN`, and `%ROWCOUNT`) to a cursor variable.

```
IF NOT emp_cv%ISOPEN THEN
    /* Open cursor variable. */
    OPEN emp_cv FOR SELECT * FROM emp;
END IF;
```

Other `OPEN-FOR` statements can open the same cursor variable for different queries. You need not close a cursor variable before reopening it. (Recall that consecutive `OPENS` 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 a cursor variable as one of its formal parameters. For example, the following packaged procedure opens the cursor variable `emp_cv`:

```
CREATE PACKAGE emp_data AS
    ...
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%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 emp;
    END open_emp_cv;
END emp_data;
```

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.

Alternatively, you can use a standalone procedure to open the cursor variable. Simply define the `REF CURSOR` type in a separate package, then reference that type in the standalone procedure. For instance, if you create the following bodiless package, you can create standalone procedures that reference the types it defines:

```
CREATE PACKAGE cv_types AS
    TYPE GenericCurTyp IS REF CURSOR;
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    TYPE DeptCurTyp IS REF CURSOR RETURN dept%ROWTYPE;
    ...
```

```
END cv_types;
```

In the next example, you create a standalone procedure that references the REF CURSOR type EmpCurTyp, which is defined in the package cv_types:

```
CREATE PROCEDURE open_emp_cv (emp_cv IN OUT cv_types.EmpCurTyp) AS
BEGIN
    OPEN emp_cv FOR SELECT * FROM emp;
END open_emp_cv;
```

To centralize data retrieval, you can group type-compatible queries in a stored procedure. In the example below, 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.

```
CREATE PACKAGE emp_data AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%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 emp WHERE comm IS NOT NULL;
        ELSIF choice = 2 THEN
            OPEN emp_cv FOR SELECT * FROM emp WHERE sal > 2500;
        ELSIF choice = 3 THEN
            OPEN emp_cv FOR SELECT * FROM emp WHERE deptno = 20;
        END IF;
    END;
END emp_data;
```

For more flexibility, you can pass a cursor variable and a selector to a stored procedure that executes queries with different return types. Here is an example:

```
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 emp;
    ELSIF choice = 2 THEN
        OPEN generic_cv FOR SELECT * FROM dept;
    ELSIF choice = 3 THEN
        OPEN generic_cv FOR SELECT * FROM salgrade;
    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 emp;
    ELSIF :choice = 2 THEN
        OPEN :generic_cv FOR SELECT * FROM dept;
    ELSIF :choice = 3 THEN
        OPEN :generic_cv FOR SELECT * FROM salgrade;
    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. Here is the syntax:

```
FETCH {cursor_variable_name | :host_cursor_variable_name}
[BULK COLLECT]
INTO {variable_name[, variable_name]... | record_name};
```

In the following example, you fetch rows one at a time from the cursor variable `emp_cv` into the user-defined record `emp_rec`:

```
LOOP
  /* Fetch from cursor variable. */
  FETCH emp_cv INTO emp_rec;
  EXIT WHEN emp_cv%NOTFOUND; -- exit when last row is fetched
  -- process data record
END LOOP;
```

Using the `BULK COLLECT` clause, you can bulk fetch rows from a cursor variable into one or more collections. An example follows:

```
DECLARE
  TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
  TYPE NameList IS TABLE OF emp.ename%TYPE;
  TYPE SalList IS TABLE OF emp.sal%TYPE;
  emp_cv EmpCurTyp;
  names NameList;
  sals SalList;
BEGIN
  OPEN emp_cv FOR SELECT ename, sal FROM emp;
  FETCH emp_cv BULK COLLECT INTO names, sals;
  ...
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, you must reopen the cursor variable with the variables set to their new values. However, 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. 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. The 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. So, if you trap the error and execute the FETCH statement using a different 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. However, 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. After that, the associated result set is undefined. Here is the syntax:

```
CLOSE {cursor_variable_name | :host_cursor_variable_name};
```

In the following example, when the last row is processed, you close the cursor variable `emp_cv`:

```
LOOP
    FETCH emp_cv INTO emp_rec;
    EXIT WHEN emp_cv%NOTFOUND;
    -- process data record
END LOOP;
/* Close cursor variable. */
CLOSE emp_cv;
```

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`.

Cursor Variable Example: Master Table and Details Tables

Consider the stored procedure below, which searches the database of a main library for books, periodicals, and tapes. A master table stores the title and category code (where 1 = book, 2 = periodical, 3 = tape) of each item. Three detail tables store category-specific information. When called, the procedure searches the master table by title, uses the associated category code to pick an `OPEN-FOR` statement, then opens a cursor variable for a query of the proper detail table.

```
CREATE PACKAGE cv_types AS
    TYPE LibCurTyp IS REF CURSOR;
    ...
END cv_types;

CREATE PROCEDURE find_item (
    title VARCHAR2(100),
    lib_cv IN OUT
    cv_types.LibCurTyp)
AS
    code BINARY_INTEGER;
BEGIN
    SELECT item_code FROM titles INTO code
        WHERE item_title = title;
    IF code = 1 THEN
        OPEN lib_cv FOR SELECT * FROM books
            WHERE book_title = title;
    ELSIF code = 2 THEN
        OPEN lib_cv FOR SELECT * FROM periodicals
            WHERE periodical_title = title;
    ELSIF code = 3 THEN
        OPEN lib_cv FOR SELECT * FROM tapes
            WHERE tape_title = title;
    END IF;
END find_item;
```

Cursor Variable Example: Client-Side PL/SQL Block

A client-side application in a branch library might use the following PL/SQL block to display the retrieved information:

```
DECLARE
    lib_cv          cv_types.LibCurTyp;
    book_rec        books%ROWTYPE;
    periodical_rec  periodicals%ROWTYPE;
    tape_rec        tapes%ROWTYPE;
BEGIN
    get_title(:title); -- title is a host variable
    find_item(:title, lib_cv);
    FETCH lib_cv INTO book_rec;
    display_book(book_rec);
EXCEPTION
    WHEN ROWTYPE_MISMATCH THEN
        BEGIN
            FETCH lib_cv INTO periodical_rec;
            display_periodical(periodical_rec);
        EXCEPTION
            WHEN ROWTYPE_MISMATCH THEN
                FETCH lib_cv INTO tape_rec;
                display_tape(tape_rec);
        END;
END;
```

Cursor Variable Example: Pro*C Program

The following Pro*C program prompts the user to select a database table, opens a cursor variable for a query of that table, then fetches rows returned by the query:

```
#include <stdio.h>
#include <sqlca.h>
void sql_error();
main()
{
    char temp[32];

    EXEC SQL BEGIN DECLARE SECTION;

    char * uid = "scott/tiger";
    SQL_CURSOR generic_cv; /* cursor variable */
    int table_num; /* selector */
    struct /* EMP record */
```

```
{
    int    emp_num;
    char  emp_name[11];
    char  job_title[10];
    int   manager;
    char  hire_date[10];
    float salary;
    float commission;
    int   dept_num;
} emp_rec;
struct          /* DEPT record    */
{
    int   dept_num;
    char  dept_name[15];
    char  location[14];
} dept_rec;
struct          /* BONUS record   */
{
    char  emp_name[11];
    char  job_title[10];
    float salary;
} bonus_rec;

EXEC SQL END DECLARE SECTION;

/* Handle Oracle errors. */
EXEC SQL WHENEVER SQLERROR DO sql_error();

/* Connect to Oracle. */
EXEC SQL CONNECT :uid;

/* Initialize cursor variable. */
EXEC SQL ALLOCATE :generic_cv;

/* Exit loop when done fetching. */
EXEC SQL WHENEVER NOT FOUND DO break;

for (;;)
{
    printf("\n1 = EMP, 2 = DEPT, 3 = BONUS");
    printf("\nEnter table number (0 to quit): ");
    gets(temp);
    table_num = atoi(temp);
    if (table_num <= 0) break;
}
```

```
/* Open cursor variable. */
EXEC SQL EXECUTE
BEGIN
    IF :table_num = 1 THEN
        OPEN :generic_cv FOR SELECT * FROM emp;
    ELSIF :table_num = 2 THEN
        OPEN :generic_cv FOR SELECT * FROM dept;
    ELSIF :table_num = 3 THEN
        OPEN :generic_cv FOR SELECT * FROM bonus;
    END IF;
END;
END-EXEC;
for (;;)
{
    switch (table_num)
    {
        case 1: /* Fetch row into EMP record. */
            EXEC SQL FETCH :generic_cv INTO :emp_rec;
            break;
        case 2: /* Fetch row into DEPT record. */
            EXEC SQL FETCH :generic_cv INTO :dept_rec;
            break;
        case 3: /* Fetch row into BONUS record. */
            EXEC SQL FETCH :generic_cv INTO :bonus_rec;
            break;
    }
    /* Process data record here. */
}
/* Close cursor variable. */
EXEC SQL CLOSE :generic_cv;
}
exit(0);
}
void sql_error()
{
    /* Handle SQL error here. */
}
```

Cursor Variable Example: Manipulating Host Variables in SQL*Plus

A host variable is a variable you declare in a host environment, then pass to one or more PL/SQL programs, which can use it like any other variable. In the SQL*Plus environment, to declare a host variable, use the command `VARIABLE`. For example, you declare a variable of type `NUMBER` as follows:

```
VARIABLE return_code NUMBER
```

Both SQL*Plus and PL/SQL can reference the host variable, and SQL*Plus can display its value. However, to reference a host variable in PL/SQL, you must prefix its name with a colon (:), as the following example shows:

```
DECLARE
    ...
BEGIN
    :return_code := 0;
    IF credit_check_ok(acct_no) THEN
        :return_code := 1;
    END IF;
    ...
END;
```

To display the value of a host variable in SQL*Plus, use the `PRINT` command, as follows:

```
SQL> PRINT return_code
```

```
RETURN_CODE
-----
          1
```

The SQL*Plus datatype `REFCURSOR` lets you declare cursor variables, which you can use to return query results from stored subprograms. In the script below, you declare a host variable of type `REFCURSOR`. You use the SQL*Plus command `SET AUTOPRINT ON` to display the query results automatically.

```
CREATE PACKAGE emp_data AS
    TYPE EmpRecTyp IS RECORD (
        emp_id    NUMBER(4),
        emp_name  VARCHAR2(10),
        job_title VARCHAR2(9),
        dept_name VARCHAR2(14),
        dept_loc  VARCHAR2(13));
    TYPE EmpCurTyp IS REF CURSOR RETURN EmpRecTyp;
    PROCEDURE get_staff (
```

```
        dept_no IN NUMBER,
        emp_cv IN OUT EmpCurTyp);
END;
/
CREATE PACKAGE BODY emp_data AS
    PROCEDURE get_staff (
        dept_no IN NUMBER,
        emp_cv IN OUT EmpCurTyp) IS
    BEGIN
        OPEN emp_cv FOR
            SELECT empno, ename, job, dname, loc FROM emp, dept
                WHERE emp.deptno = dept_no AND emp.deptno = dept.deptno
                ORDER BY empno;
    END;
END;
/
COLUMN EMPNO HEADING Number
COLUMN ENAME HEADING Name
COLUMN JOB HEADING JobTitle
COLUMN DNAME HEADING Department
COLUMN LOC HEADING Location
SET AUTOPRINT ON

VARIABLE cv REFCURSOR
EXECUTE emp_data.get_staff(20, :cv)
```

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 five cursor variables in a single round trip:

```
/* anonymous PL/SQL block in host environment */
BEGIN
    OPEN :emp_cv FOR SELECT * FROM emp;
    OPEN :dept_cv FOR SELECT * FROM dept;
    OPEN :grade_cv FOR SELECT * FROM salgrade;
    OPEN :pay_cv FOR SELECT * FROM payroll;
    OPEN :ins_cv FOR SELECT * FROM insurance;
END;
```

This 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. That allows your OCI or Pro*C program to use these work areas for ordinary cursor operations. In the following 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;
    OPEN :c4 FOR SELECT 1 FROM dual;
    OPEN :c5 FOR SELECT 1 FROM dual;
    ...
END;
```

The cursors assigned to `c1`, `c2`, `c3`, `c4`, and `c5` behave normally, and you can use them for any purpose. When finished, simply release the cursors, as follows:

```
BEGIN
    CLOSE :c1;
    CLOSE :c2;
    CLOSE :c3;
    CLOSE :c4;
    CLOSE :c5;
    ...
END;
```

Avoiding Errors with Cursor Variables

If both cursor variables involved in an assignment are strongly typed, they must have the same datatype. In the following example, even though the cursor variables have the same return type, the assignment raises an exception because they have different datatypes:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    TYPE TmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    PROCEDURE open_emp_cv (
        emp_cv IN OUT EmpCurTyp,
        tmp_cv IN OUT TmpCurTyp) IS
    BEGIN
        ...
        emp_cv := tmp_cv; -- causes 'wrong type' error
    END;
```

However, if one or both cursor variables are weakly typed, they need not have the same datatype.

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 `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.

The following example shows how these ways interact:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    emp_cv1 EmpCurTyp;
    emp_cv2 EmpCurTyp;
    emp_rec emp%ROWTYPE;
BEGIN
    /* The following assignment is useless because emp_cv1
       does not point to a query work area yet. */
    emp_cv2 := emp_cv1; -- useless
    /* Make emp_cv1 point to a query work area. */
    OPEN emp_cv1 FOR SELECT * FROM emp;
    /* Use emp_cv1 to fetch first row from emp table. */
    FETCH emp_cv1 INTO emp_rec;
    /* The following fetch raises an exception because emp_cv2
       does not point to a query work area yet. */
    FETCH emp_cv2 INTO emp_rec; -- raises INVALID_CURSOR
EXCEPTION
    WHEN INVALID_CURSOR THEN
        /* Make emp_cv1 and emp_cv2 point to same work area. */
        emp_cv2 := emp_cv1;
        /* Use emp_cv2 to fetch second row from emp table. */
        FETCH emp_cv2 INTO emp_rec;
        /* Reuse work area for another query. */
        OPEN emp_cv2 FOR SELECT * FROM old_emp;
        /* Use emp_cv1 to fetch first row from old_emp table.
           The following fetch succeeds because emp_cv1 and
           emp_cv2 point to the same query work area. */
        FETCH emp_cv1 INTO emp_rec; -- succeeds
END;
```

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.

In the Pro*C example below, you define a packaged `REF CURSOR` type, specifying the return type `emp%ROWTYPE`. Next, you create a standalone procedure that references the new type. Then, inside a PL/SQL block, you open a host cursor variable for a query of the `dept` table. Later, when you pass the open host cursor variable to the stored procedure, PL/SQL raises `ROWTYPE_MISMATCH` because the return types of the actual and formal parameters are incompatible.

```
CREATE PACKAGE cv_types AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    ...
END cv_types;
/
CREATE PROCEDURE open_emp_cv (emp_cv IN OUT cv_types.EmpCurTyp) AS
BEGIN
    OPEN emp_cv FOR SELECT * FROM emp;
END open_emp_cv;
/
-- anonymous PL/SQL block in Pro*C program
EXEC SQL EXECUTE
    BEGIN
        OPEN :cv FOR SELECT * FROM dept;
        ...
        open_emp_cv(:cv); -- raises ROWTYPE_MISMATCH
    END;
END-EXEC;
```

Restrictions on Cursor Variables

Currently, cursor variables are subject to the following restrictions:

- You cannot declare cursor variables in a package. For example, the following declaration is not allowed:

```
CREATE PACKAGE emp_stuff AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    emp_cv EmpCurTyp; -- not allowed
END emp_stuff;
```

- Remote subprograms on another server cannot accept the values of cursor variables. Therefore, you cannot use RPCs to pass cursor variables from one server to another.

- If you pass a host cursor variable to PL/SQL, 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.
- You cannot assign nulls to a cursor variable.
- You cannot use REF CURSOR types to specify column types in a CREATE TABLE or CREATE VIEW statement. So, database columns cannot store the values of cursor variables.
- You cannot use a REF CURSOR type to specify the element type of a collection, which means that elements in an index-by table, nested table, or varray cannot store the values of cursor variables.
- Cursors and cursor variables are not interoperable; that is, you cannot use one where the other is expected. For example, the following cursor FOR loop is not allowed because it attempts to fetch from a cursor variable:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    emp_cv EmpCurTyp;
    ...
BEGIN
    ...
    FOR emp_rec IN emp_cv LOOP ... -- not allowed
END;
```

Using 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. You can use cursor attributes in procedural statements but not in SQL statements.

Overview of Explicit Cursor Attributes

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 yields NULL. Thereafter, it yields TRUE if the last fetch returned a row, or FALSE if the last fetch failed to return a row. In the following example, you use %FOUND to select an action:

```
LOOP
    FETCH c1 INTO my_ename, my_sal, my_hiredate;
    IF c1%FOUND THEN -- fetch succeeded
        ...
    ELSE -- fetch failed, so exit loop
        EXIT;
    END IF;
END LOOP;
```

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 yields TRUE if its cursor or cursor variable is open; otherwise, %ISOPEN yields FALSE. In the following example, you use %ISOPEN to select an action:

```
IF c1%ISOPEN THEN -- cursor is open
    ...
ELSE -- cursor is closed, so open it
    OPEN c1;
END IF;
```

%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 the following example, you use %NOTFOUND to exit a loop when FETCH fails to return a row:

```
LOOP
    FETCH c1 INTO my_ename, my_sal, my_hiredate;
    EXIT WHEN c1%NOTFOUND;
    ...
END LOOP;
```

Before the first fetch, %NOTFOUND evaluates to NULL. So, if FETCH never executes successfully, the loop is never exited. That is 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 `INVALID_CURSOR`.

%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. In the next example, you use `%ROWCOUNT` to take action if more than ten rows have been fetched:

```
LOOP
    FETCH c1 INTO my_ename, my_deptno;
    IF c1%ROWCOUNT > 10 THEN
        ...
    END IF;
    ...
END LOOP;
```

If a cursor or cursor variable is not open, referencing it with `%ROWCOUNT` raises `INVALID_CURSOR`.

[Table 6–1](#) shows what each cursor attribute yields 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

Table 6–1 *Cursor Attribute Values*

	%FOUND	%ISOPEN	%NOTFOUND	%ROWCOUNT
Notes:				
1.	Referencing %FOUND, %NOTFOUND, or %ROWCOUNT before a cursor is opened or after it is closed raises INVALID_CURSOR.			
2.	After the first FETCH, if the result set was empty, %FOUND yields FALSE, %NOTFOUND yields TRUE, and %ROWCOUNT yields 0.			

Some Examples of Cursor Attributes

Suppose you have a table named `data_table` that holds data collected from laboratory experiments, and you want to analyze the data from experiment 1. In the following example, you compute the results and store them in a database table named `temp`:

```
-- available online in file 'examp5'
DECLARE
    num1    data_table.n1%TYPE;  -- Declare variables
    num2    data_table.n2%TYPE;  -- having same types as
    num3    data_table.n3%TYPE;  -- database columns
    result  temp.coll%TYPE;
    CURSOR c1 IS
        SELECT n1, n2, n3 FROM data_table WHERE exper_num = 1;
BEGIN
    OPEN c1;
    LOOP
        FETCH c1 INTO num1, num2, num3;
        EXIT WHEN c1%NOTFOUND;  -- TRUE when FETCH finds no more rows
        result := num2/(num1 + num3);
        INSERT INTO temp VALUES (result, NULL, NULL);
    END LOOP;
    CLOSE c1;
    COMMIT;
END;
```

In the next example, you check all storage bins that contain part number 5469, withdrawing their contents until you accumulate 1000 units:

```
-- available online in file 'examp6'
DECLARE
    CURSOR bin_cur(part_number NUMBER) IS
        SELECT amt_in_bin FROM bins
            WHERE part_num = part_number AND amt_in_bin > 0
```

```
        ORDER BY bin_num
        FOR UPDATE OF amt_in_bin;
bin_amt      bins.amt_in_bin%TYPE;
total_so_far NUMBER(5) := 0;
amount_needed CONSTANT NUMBER(5) := 1000;
bins_looked_at NUMBER(3) := 0;
BEGIN
OPEN bin_cur(5469);
WHILE total_so_far < amount_needed LOOP
    FETCH bin_cur INTO bin_amt;
    EXIT WHEN bin_cur%NOTFOUND;
    -- if we exit, there's not enough to fill the order
    bins_looked_at := bins_looked_at + 1;
    IF total_so_far + bin_amt < amount_needed THEN
        UPDATE bins SET amt_in_bin = 0
            WHERE CURRENT OF bin_cur;
        -- take everything in the bin
        total_so_far := total_so_far + bin_amt;
    ELSE -- we finally have enough
        UPDATE bins SET amt_in_bin = amt_in_bin
            - (amount_needed - total_so_far)
            WHERE CURRENT OF bin_cur;
        total_so_far := amount_needed;
    END IF;
END LOOP;

CLOSE bin_cur;
INSERT INTO temp
    VALUES (NULL, bins_looked_at, '<- bins looked at');
COMMIT;
END;
```

Overview of Implicit Cursor Attributes

Implicit cursor attributes return information about the execution of an INSERT, UPDATE, DELETE, or SELECT INTO statement. 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.

Note: The SQL cursor has another attribute, %BULK_ROWCOUNT, designed for use with the FORALL statement. For more information, see ["Counting Rows Affected by FORALL Iterations with the %BULK_ROWCOUNT Attribute"](#) on page 5-36.

%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 the following example, you use %FOUND to insert a row if a delete succeeds:

```
DELETE FROM emp WHERE empno = my_empno;
IF SQL%FOUND THEN -- delete succeeded
    INSERT INTO new_emp VALUES (my_empno, my_ename, ...);
```

%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 the following example, you use %ROWCOUNT to take action if more than ten rows have been deleted:

```
DELETE FROM emp WHERE ...
IF SQL%ROWCOUNT > 10 THEN -- more than 10 rows were deleted
    ...
END IF;
```

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.

Guidelines for Using Implicit Cursor Attributes

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). So, if you want to save an attribute value for later use, assign it to a

Boolean variable immediately. In the following example, relying on the `IF` condition is dangerous because the procedure `check_status` might have changed the value of `%NOTFOUND`:

```
BEGIN
  ...
  UPDATE parts SET quantity = quantity - 1 WHERE partno = part_id;
  check_status(part_id); -- procedure call
  IF SQL%NOTFOUND THEN -- dangerous!
    ...
  END;
END;
```

You can improve the code as follows:

```
BEGIN
  ...
  UPDATE parts SET quantity = quantity - 1 WHERE partno = part_id;
  sql_notfound := SQL%NOTFOUND; -- assign value to Boolean variable
  check_status(part_id);
  IF sql_notfound THEN ...
END;
```

If a `SELECT INTO` statement fails to return a row, PL/SQL raises the predefined exception `NO_DATA_FOUND` whether you check `%NOTFOUND` on the next line or not. Consider the following example:

```
BEGIN
  ...
  SELECT sal INTO my_sal FROM emp WHERE empno = my_empno;
  -- might raise NO_DATA_FOUND
  IF SQL%NOTFOUND THEN -- condition tested only when false
    ... -- this action is never taken
  END IF;
```

The check is useless because the `IF` condition is tested only when `%NOTFOUND` is false. When PL/SQL raises `NO_DATA_FOUND`, normal execution stops and control transfers to the exception-handling part of the block.

However, a `SELECT INTO` statement that calls a SQL aggregate function never raises `NO_DATA_FOUND` because aggregate functions always return a value or a null. In such cases, `%NOTFOUND` yields `FALSE`, as the following example shows:

```
BEGIN
  ...
  SELECT MAX(sal) INTO my_sal FROM emp WHERE deptno = my_deptno;
  -- never raises NO_DATA_FOUND
```

```
IF SQL%NOTFOUND THEN -- always tested but never true
    ... -- this action is never taken
END IF;
EXCEPTION
    WHEN NO_DATA_FOUND THEN ... -- never invoked
```

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. Thus, 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 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

- 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 this example, 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.

```
CREATE OR REPLACE procedure emp_report(p_locid number) is
TYPE refcursor is ref cursor;
-- The query returns only 2 columns, but the second column is
-- a cursor that lets us traverse a set of related information.

CURSOR c1 is
SELECT l.city,
CURSOR(SELECT d.department_name,
CURSOR(SELECT e.last_name
FROM employees e
WHERE e.department_id = d.department_id) as ename
FROM departments d where l.location_id = d.location_id) dname
FROM locations l
WHERE l.location_id = p_locid;

loccur refcursor;
deptcur refcursor;
empcur refcursor;

V_city locations.city%type;
V_dname departments.department_name%type;
V_ename employees.last_name%type;

BEGIN
OPEN c1;
LOOP
FETCH C1 INTO v_city, loccur;
EXIT WHEN c1%notfound;
-- We can access the column C1.city, then process the results of
-- the nested cursor.
```

```

LOOP
FETCH loccur INTO v_dname, deptcur; -- No need to open
EXIT WHEN loccur%notfound;

LOOP
FETCH deptcur into v_ename; -- No need to open
EXIT WHEN deptcur%notfound;
DBMS_OUTPUT.PUT_LINE(v_city || ' ' || v_dname || ' ' || v_ename);
END LOOP;
END LOOP;
END LOOP;
close c1;
END;
/

```

Overview of Transaction Processing in PL/SQL

This section explains how to do transaction processing. You learn the basic techniques that safeguard the consistency of your database, including how to control whether changes to Oracle data are made permanent or undone.

The jobs or tasks that Oracle manages are called *sessions*. A *user session* is started when you run an application program or an Oracle tool and connect to Oracle. To allow user sessions to work "simultaneously" and share computer resources, Oracle must control *concurrency*, the accessing of the same data by many users. Without adequate concurrency controls, there might be a loss of *data integrity*. That is, changes to data might be made in the wrong order.

Oracle uses *locks* to control concurrent access to data. A lock gives you temporary ownership of a database resource such as a table or row of data. Thus, data cannot be changed by other users until you finish with it. You need never explicitly lock a resource because default locking mechanisms protect Oracle data and structures. However, you can request *data locks* on tables or rows when it is to your advantage to override default locking. You can choose from several *modes* of locking such as *row share* and *exclusive*.

A *deadlock* can occur when two or more users try to access the same schema object. For example, two users updating the same table might wait if each tries to update a row currently locked by the other. Because each user is waiting for resources held by another user, neither can continue until Oracle breaks the deadlock by signaling an error to the last participating transaction.

When a table is being queried by one user and updated by another at the same time, Oracle generates a *read-consistent* view of the data for the query. That is, once a query begins and as it proceeds, the data read by the query does not change. As update activity continues, Oracle takes *snapshots* of the table's data and records changes in a *rollback segment*. Oracle uses rollback segments to build read-consistent query results and to undo changes if necessary.

How Transactions Guard Your Database

A transaction is a series of SQL data manipulation statements that does a logical unit of work. Oracle treats the series of SQL statements as a unit so that all the changes brought about by the statements are either *committed* (made permanent) or *rolled back* (undone) at the same time. If your program fails in the middle of a transaction, the database is automatically restored to its former state.

The first SQL statement in your program begins a transaction. When one transaction ends, the next SQL statement automatically begins another transaction. Thus, every SQL statement is part of a transaction. A *distributed transaction* includes at least one SQL statement that updates data at multiple nodes in a distributed database.

The `COMMIT` and `ROLLBACK` statements ensure that all database changes brought about by SQL operations are either made permanent or undone at the same time. All the SQL statements executed since the last commit or rollback make up the current transaction. The `SAVEPOINT` statement names and marks the current point in the processing of a transaction.

Making Changes Permanent with COMMIT

The `COMMIT` statement ends the current transaction and makes permanent any changes made during that transaction. Until you commit the changes, other users cannot access the changed data; they see the data as it was before you made the changes.

Consider a simple transaction that transfers money from one bank account to another. The transaction requires two updates because it debits the first account, then credits the second. In the example below, after crediting the second account, you issue a commit, which makes the changes permanent. Only then do other users see the changes.

```
BEGIN
    ...
    UPDATE accts SET bal = my_bal - debit
        WHERE acctno = 7715;
```

```
...
UPDATE accts SET bal = my_bal + credit
WHERE acctno = 7720;
COMMIT WORK;
END;
```

The `COMMIT` statement releases all row and table locks. It also erases any savepoints (discussed later) marked since the last commit or rollback. The optional keyword `WORK` has no effect other than to improve readability. The keyword `END` signals the end of a PL/SQL block, *not* the end of a transaction. Just as a block can span multiple transactions, a transaction can span multiple blocks.

The optional `COMMENT` clause lets you specify a comment to be associated with a distributed transaction. When you issue a commit, changes to each database affected by a distributed transaction are made permanent. However, 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. The text must be a quoted literal up to 50 characters long. An example follows:

```
COMMIT COMMENT 'In-doubt order transaction; notify Order Entry';
```

PL/SQL does not support the `FORCE` clause, which, in SQL, manually commits an in-doubt distributed transaction. For example, the following `COMMIT` statement is illegal:

```
COMMIT FORCE '23.51.54'; -- illegal
```

Undoing Changes with ROLLBACK

The `ROLLBACK` statement ends the current transaction and undoes any changes made during that transaction. Rolling back is useful for two reasons. First, if you make a mistake like deleting the wrong row from a table, a rollback restores the original data. Second, if you start a transaction that you cannot finish because an exception is raised or a SQL statement fails, a rollback lets you return to the starting point to take corrective action and perhaps try again.

Consider the example below, in which you insert information about an employee into three different database tables. All three tables have a column that holds employee numbers and is constrained by a unique index. If an `INSERT` statement tries to store a duplicate employee number, the predefined exception `DUP_VAL_ON_INDEX` is raised. In that case, you want to undo all changes, so you issue a rollback in the exception handler.

```

DECLARE
    emp_id  INTEGER;
    ...
BEGIN
    SELECT empno, ... INTO emp_id, ... FROM new_emp WHERE ...
    ...
    INSERT INTO emp VALUES (emp_id, ...);
    INSERT INTO tax VALUES (emp_id, ...);
    INSERT INTO pay VALUES (emp_id, ...);
    ...
EXCEPTION
    WHEN DUP_VAL_ON_INDEX THEN
        ROLLBACK;
    ...
END;
```

Statement-Level Rollbacks

Before executing a SQL statement, Oracle marks an implicit savepoint. Then, if the statement fails, Oracle rolls it back automatically. For example, if an `INSERT` statement raises an exception by trying to insert a duplicate value in a unique index, the statement is rolled back. Only work started by the failed SQL statement is lost. Work done before that statement in the current transaction is kept.

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.

Undoing Partial Changes with SAVEPOINT

`SAVEPOINT` names and marks the current point in the processing of a transaction. Used with the `ROLLBACK TO` statement, savepoints let you undo parts of a transaction instead of the whole transaction. In the example below, you mark a savepoint before doing an insert. If the `INSERT` statement tries to store a duplicate value in the `empno` column, the predefined exception `DUP_VAL_ON_INDEX` is raised. In that case, you roll back to the savepoint, undoing just the insert.

```

DECLARE
    emp_id  emp.empno%TYPE;
BEGIN
```



```

UPDATE emp SET ... WHERE empno = emp_id;
DELETE FROM emp WHERE ...
...
SAVEPOINT do_insert;
INSERT INTO emp VALUES (emp_id, ...);
EXCEPTION
  WHEN DUP_VAL_ON_INDEX THEN
    ROLLBACK TO do_insert;
END;

```

When you roll back to a savepoint, any savepoints marked after that savepoint are erased. However, the savepoint to which you roll back is not erased. For example, if you mark five savepoints, then roll back to the third, only the fourth and fifth are 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. However, you can only roll back to the most recently marked savepoint.

Savepoint names are undeclared identifiers and can be reused within a transaction. This moves the savepoint from its old position to the current point in the transaction. Thus, a rollback to the savepoint affects only the current part of your transaction. An example follows:

```

BEGIN
  SAVEPOINT my_point;
  UPDATE emp SET ... WHERE empno = emp_id;
  ...
  SAVEPOINT my_point; -- move my_point to current point
  INSERT INTO emp VALUES (emp_id, ...);
EXCEPTION
  WHEN OTHERS THEN
    ROLLBACK TO my_point;
END;

```

The number of active savepoints for each session is unlimited. An *active savepoint* is one marked since the last commit or rollback.

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. Normally, just the failed SQL statement is rolled back, not the whole

transaction. However, if the statement raises an unhandled exception, the host environment determines what is rolled back.

If you exit a stored subprogram with an unhandled exception, PL/SQL does not assign values to `OUT` parameters. Also, PL/SQL does not roll back database work done by the subprogram.

Ending Transactions

A good programming practice is to commit or roll back every transaction explicitly. Whether you issue the commit or rollback in your PL/SQL program or in the host environment depends on the flow of application logic. If you neglect to commit or roll back a transaction explicitly, the host 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.

In the Oracle Precompiler environment, if your program does not terminate normally, Oracle rolls back your transaction. A program terminates normally when it explicitly commits or rolls back work and disconnects from Oracle using the `RELEASE` parameter, as follows:

```
EXEC SQL COMMIT WORK RELEASE;
```

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 against one or more tables 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 the example below, as a store manager, you use a read-only transaction to gather sales figures for the day, the past week, and the past month. The figures are unaffected by other users updating the database during the transaction.

```
DECLARE
    daily_sales    REAL;
```

```

weekly_sales REAL;
monthly_sales REAL;
BEGIN
    ...
    COMMIT; -- ends previous transaction
    SET TRANSACTION READ ONLY NAME 'Calculate sales figures';
    SELECT SUM(amt) INTO daily_sales FROM sales
        WHERE dte = SYSDATE;
    SELECT SUM(amt) INTO weekly_sales FROM sales
        WHERE dte > SYSDATE - 7;
    SELECT SUM(amt) INTO monthly_sales FROM sales
        WHERE dte > 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. Also, queries cannot be `FOR UPDATE`.

Overriding Default Locking

By default, Oracle locks data structures for you automatically. However, you can request specific data locks on rows or tables when it is to your advantage to override default locking. Explicit locking lets you share or deny access to a table 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 before an update or delete is executed. However, Oracle automatically obtains row-level locks at update or delete time. So, use the `FOR UPDATE` clause only if you want to lock the rows *before* the update or delete.

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 empno, sal FROM emp
                WHERE job = 'SALESMAN' AND comm > sal
                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. So, you cannot fetch from a `FOR UPDATE` cursor after a commit. (For a workaround, see ["Fetching Across Commits"](#) on page 6-51.)

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 `emp` table but not in the `dept` table:

```
DECLARE
  CURSOR c1 IS SELECT ename, dname FROM emp, dept
                WHERE emp.deptno = dept.deptno AND job = 'MANAGER'
                FOR UPDATE OF sal;
```

As the next example shows, you use the `CURRENT OF` clause in an `UPDATE` or `DELETE` statement to refer to the latest row fetched from a cursor:

```
DECLARE
  CURSOR c1 IS SELECT empno, job, sal FROM emp FOR UPDATE;
  ...
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO ...
```

```

...
    UPDATE emp SET sal = new_sal WHERE CURRENT OF c1;
END LOOP;

```

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. For example, the statement below locks the `emp` table in *row share* mode. 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 emp 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 *Oracle9i 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

The `FOR UPDATE` clause acquires exclusive row locks. All rows are locked when you open the cursor, and they are unlocked when you commit your transaction. So, you cannot fetch from a `FOR UPDATE` cursor after a commit. If you do, PL/SQL raises an exception. In the following example, the cursor `FOR` loop fails after the tenth insert:

```

DECLARE
    CURSOR c1 IS SELECT ename FROM emp FOR UPDATE OF sal;
    ctr NUMBER := 0;
BEGIN
    FOR emp_rec IN c1 LOOP -- FETCHes implicitly
        ...
        ctr := ctr + 1;
        INSERT INTO temp VALUES (ctr, 'still going');
        IF ctr >= 10 THEN
            COMMIT; -- releases locks
        END IF;
    END LOOP;
END;

```

If you want to fetch across commits, do not use the `FOR UPDATE` and `CURRENT OF` clauses. Instead, use the `ROWID` pseudocolumn to mimic the `CURRENT OF` clause. Simply select the rowid of each row into a `UROWID` variable. Then, use the rowid to identify the current row during subsequent updates and deletes. An example follows:

```
DECLARE
    CURSOR c1 IS SELECT ename, job, rowid FROM emp;
    my_ename emp.ename%TYPE;
    my_job emp.job%TYPE;
    my_rowid UROWID;
BEGIN
    OPEN c1;
    LOOP
        FETCH c1 INTO my_ename, my_job, my_rowid;
        EXIT WHEN c1%NOTFOUND;
        UPDATE emp SET sal = sal * 1.05 WHERE rowid = my_rowid;
        -- this mimics WHERE CURRENT OF c1
        COMMIT;
    END LOOP;
    CLOSE c1;
END;
```

Be careful. In the last example, the fetched rows are *not* locked because no `FOR UPDATE` clause is used. So, other users might unintentionally overwrite your changes. Also, the cursor must have a read-consistent view of the data, so rollback segments used in the update are not released until the cursor is closed. This can slow down processing when many rows are updated.

The next example shows that you can use the `%ROWTYPE` attribute with cursors that reference the `ROWID` pseudocolumn:

```
DECLARE
    CURSOR c1 IS SELECT ename, sal, rowid FROM emp;
    emp_rec c1%ROWTYPE;
BEGIN
    OPEN c1;
    LOOP
        FETCH c1 INTO emp_rec;
        EXIT WHEN c1%NOTFOUND;
        ...
        IF ... THEN
            DELETE FROM emp WHERE rowid = emp_rec.rowid;
        END IF;
    END LOOP;
END;
```

```

END LOOP;
CLOSE c1;
END;

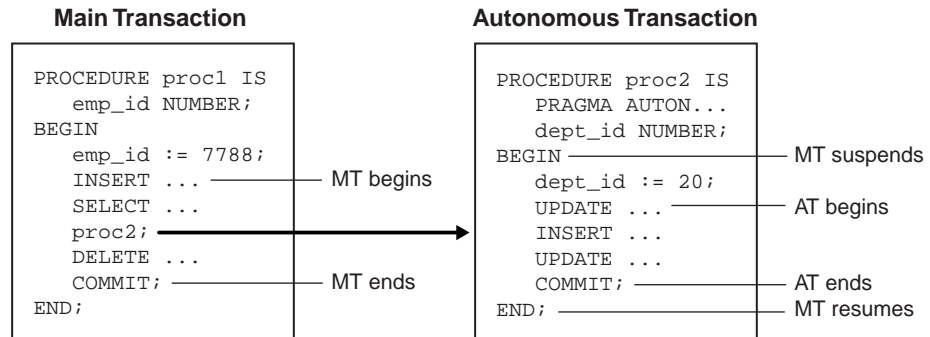
```

Doing Independent Units of Work with Autonomous Transactions

A transaction is a series of SQL statements that does a logical unit of work. Often, one transaction starts another. In some applications, a transaction must operate outside the scope of the transaction that started it. This can happen, for example, when a transaction calls out to a data cartridge.

An *autonomous transaction* is an independent transaction started by another transaction, 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. [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



Advantages of Autonomous Transactions

Once started, an autonomous transaction is fully independent. It shares no locks, resources, or commit-dependencies with the main transaction. So, 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. For example, stored procedures can start and finish autonomous transactions on their own. A calling application need not know about a procedure's autonomous operations, and the procedure need not know about the

application's transaction context. That makes autonomous transactions less error-prone than regular transactions and easier to use.

Furthermore, autonomous transactions have all the functionality of regular transactions. They allow parallel queries, distributed processing, and all the transaction control statements including `SET TRANSACTION`.

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 follows:

```
PRAGMA AUTONOMOUS_TRANSACTION;
```

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

```
CREATE PACKAGE banking AS
    ...
    FUNCTION balance (acct_id INTEGER) RETURN REAL;
END banking;

CREATE PACKAGE BODY banking AS
    ...
    FUNCTION balance (acct_id INTEGER) RETURN REAL IS
        PRAGMA AUTONOMOUS_TRANSACTION;
        my_bal REAL;
    BEGIN
        ...
    END;
END banking;
```

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


```

CREATE PACKAGE banking AS
    PRAGMA AUTONOMOUS_TRANSACTION; -- illegal
    ...
    FUNCTION balance (acct_id INTEGER) RETURN REAL;
END banking;

```

In the next example, you mark a standalone procedure as autonomous:

```

CREATE PROCEDURE close_account (acct_id INTEGER, OUT balance) AS
    PRAGMA AUTONOMOUS_TRANSACTION;
    my_bal REAL;
BEGIN ... END;

```

In the following example, you mark a PL/SQL block as autonomous:

```

DECLARE
    PRAGMA AUTONOMOUS_TRANSACTION;
    my_empno NUMBER(4);
BEGIN ... END;

```

Restriction: You cannot mark a nested PL/SQL block as autonomous.

In the example below, you mark a database trigger as autonomous. Unlike regular triggers, autonomous triggers can contain transaction control statements such as COMMIT and ROLLBACK.

```

CREATE TRIGGER parts_trigger
BEFORE INSERT ON parts FOR EACH ROW
DECLARE
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
    INSERT INTO parts_log VALUES (:new.pnum, :new.pname);
    COMMIT; -- allowed only in autonomous triggers
END;

```

Autonomous Versus Nested Transactions

Although an autonomous transaction is started by another transaction, it is *not* a nested transaction for the following reasons:

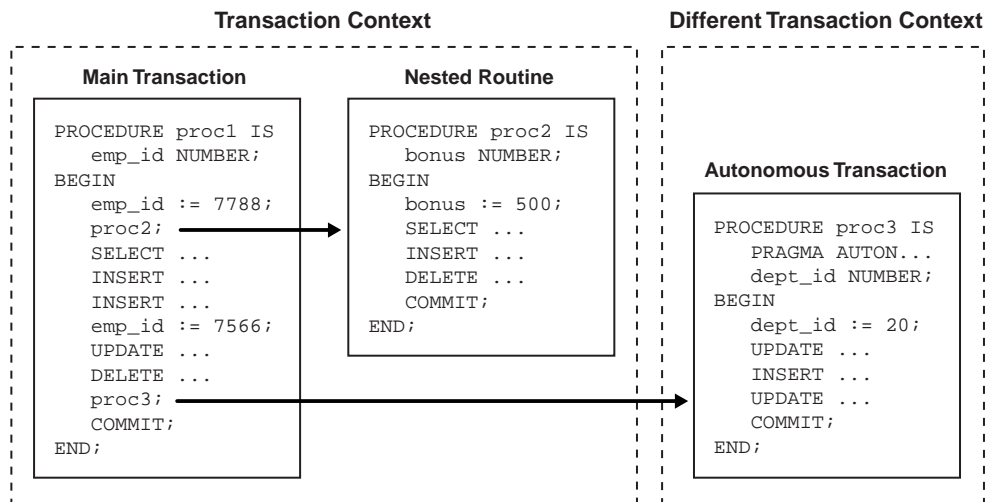
- It does not share transactional resources (such as locks) with the main transaction.
- It does not depend on the main transaction. For example, if the main transaction rolls back, nested transactions roll back, but autonomous transactions do not.

- 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

As [Figure 6–2](#) shows, the main transaction shares its context with nested routines, but not with autonomous transactions. Likewise, when one autonomous routine calls another (or itself recursively), the routines share no transaction context. However, when an autonomous routine calls a non-autonomous routine, the routines share the same transaction context.

Figure 6–2 Transaction Context



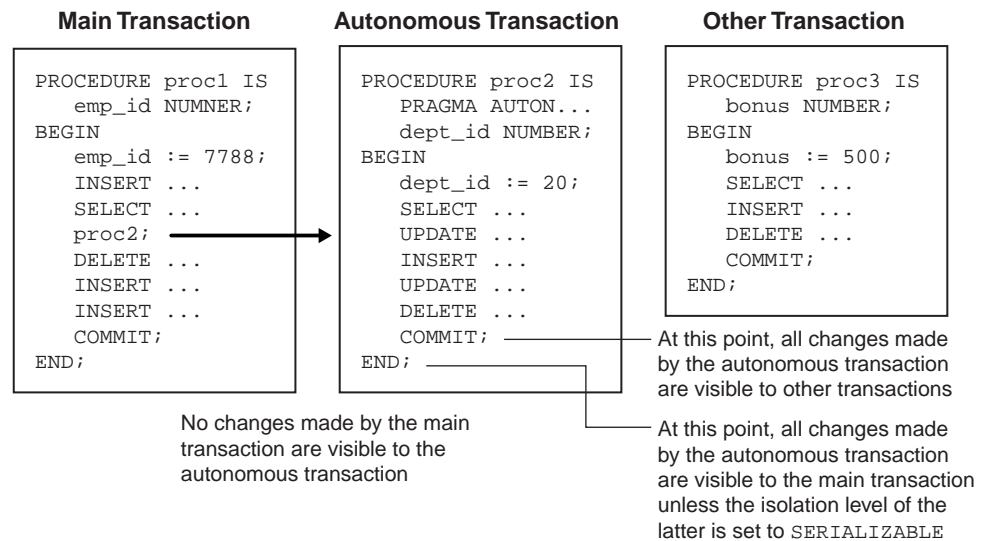
Transaction Visibility

As [Figure 6–3](#) on page 6-57 shows, 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`, as follows, changes made by its autonomous transactions are *not* visible to the main transaction when it resumes:

```
SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
```

Figure 6–3 Transaction Visibility



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`

COMMIT ends the current transaction and makes permanent changes made during that transaction. ROLLBACK ends the current transaction and undoes changes made during that transaction. ROLLBACK TO undoes part of a transaction. SAVEPOINT names and marks the current point in a transaction. SET TRANSACTION sets transaction properties such as read/write access and isolation level.

Note: Transaction properties set in the main transaction apply only to that transaction, not to its autonomous transactions, and vice versa.

Entering and Exiting

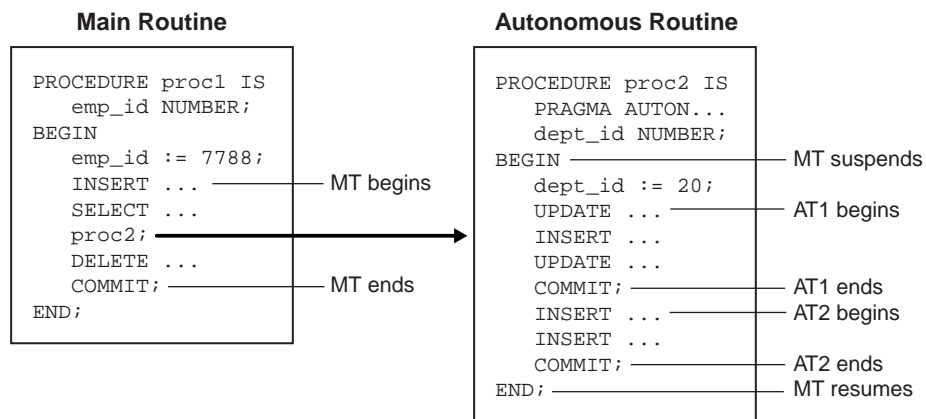
When you enter the executable section of an autonomous routine, the main transaction suspends. When you exit the routine, the main transaction resumes.

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. As Figure 6–4 shows, when one transaction ends, the next SQL statement begins another transaction.

Figure 6–4 Multiple Autonomous Transactions



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. So, when 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

To avoid some common errors, keep the following points in mind when designing autonomous transactions:

- 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. In that case, 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 if autonomous transactions (which run concurrently with the main transaction) are not taken into account.
- 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 the example below, you use a trigger to insert duplicate rows into a shadow table. Because it is autonomous, the trigger can commit inserts into the shadow table whether or not you commit inserts into the main table.

```
-- create a main table and its shadow table
CREATE TABLE parts (pnum NUMBER(4), pname VARCHAR2(15));
CREATE TABLE parts_log (pnum NUMBER(4), pname VARCHAR2(15));

-- create an autonomous trigger that inserts into the
-- shadow table before each insert into the main table
```

```

CREATE TRIGGER parts_trig
BEFORE INSERT ON parts FOR EACH ROW
DECLARE
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
    INSERT INTO parts_log VALUES (:new.pnum, :new.pname);
    COMMIT;
END;

-- insert a row into the main table, and then commit the insert
INSERT INTO parts VALUES (1040, 'Head Gasket');
COMMIT;

-- insert another row, but then roll back the insert
INSERT INTO parts VALUES (2075, 'Oil Pan');
ROLLBACK;

-- show that only committed inserts add rows to the main table
SELECT * FROM parts ORDER BY pnum;
    PNUM PNAME
-----
    1040 Head Gasket

-- show that both committed and rolled-back inserts add rows
-- to the shadow table
SELECT * FROM parts_log ORDER BY pnum;
    PNUM PNAME
-----
    1040 Head Gasket
    2075 Oil Pan

```

Unlike regular triggers, autonomous triggers can execute DDL statements using native dynamic SQL (discussed in [Chapter 11](#)). In the following example, trigger `bonus_trig` drops a temporary database table after table `bonus` is updated:

```

CREATE TRIGGER bonus_trig
AFTER UPDATE ON bonus
DECLARE
    PRAGMA AUTONOMOUS_TRANSACTION; -- enables trigger to perform DDL
BEGIN
    EXECUTE IMMEDIATE 'DROP TABLE temp_bonus';
END;

```

For more information about database triggers, see *Oracle9i 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 8-9.) To check for violations of the rules, you can use the pragma `RESTRICT_REFERENCES`. The pragma asserts that a function does not read and/or write database tables and/or package variables. (For more information, See *Oracle9i 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 the example below 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."

```
-- 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_empno NUMBER(4);
    my_ename VARCHAR2(15);
BEGIN
    ...
    SELECT debugging.log_msg(ename) INTO my_ename FROM emp
        WHERE empno = my_empno;
```

```
-- even if you roll back in this scope, the insert
-- into 'debug_output' remains committed because
-- it is part of an autonomous transaction
IF ... THEN
    ROLLBACK;
END IF;
END;
```

Ensuring Backward Compatibility of PL/SQL Programs

PL/SQL Version 2 allows some abnormal behavior that are no longer allowed. Specifically, Version 2 lets you:

- Make forward references to `RECORD` and `TABLE` types when declaring variables
- Specify the name of a variable (not a datatype) in the `RETURN` clause of a function spec
- Assign values to the elements of an index-by table `IN` parameter
- Pass the fields of a record `IN` parameter to another subprogram as `OUT` parameters
- Use the fields of a record `OUT` parameter on the right-hand side of an assignment statement
- Use `OUT` parameters in the `FROM` list of a `SELECT` statement

For backward compatibility, you might want to keep this particular Version 2 behavior. You can do that by setting the `PLSQL_V2_COMPATIBILITY` flag. On the server side, you can set the flag in two ways:

- Add the following line to the Oracle initialization file:

```
PLSQL_V2_COMPATIBILITY=TRUE
```

- Execute one of the following SQL statements:

```
ALTER SESSION SET PLSQL_V2_COMPATIBILITY = TRUE;
ALTER SYSTEM SET PLSQL_V2_COMPATIBILITY = TRUE;
```

If you specify `FALSE` (the default), only the current default behavior is allowed.

On the client side, a command-line option sets the flag. For example, with the Oracle Precompilers, you specify the run-time option `DBMS` on the command line.

Handling PL/SQL Errors

There is nothing more exhilarating than to be shot at without result. —Winston Churchill

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 discusses the following topics:

- Overview of PL/SQL Error Handling
- Advantages of PL/SQL Exceptions
- Predefined PL/SQL Exceptions
- Defining Your Own PL/SQL Exceptions
- How PL/SQL Exceptions Are Raised
- How PL/SQL Exceptions Propagate
- Reraising a PL/SQL Exception
- Handling Raised PL/SQL Exceptions
- Tips for Handling PL/SQL Errors

Overview of PL/SQL Error Handling

In PL/SQL, a warning or error condition is called an *exception*. Exceptions can be internally defined (by the run-time 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.

In the example below, you calculate and store a price-to-earnings ratio for a company with ticker symbol XYZ. If the company has zero earnings, the predefined exception `ZERO_DIVIDE` is raised. This stops normal execution of the block and transfers control to the exception handlers. The optional `OTHERS` handler catches all exceptions that the block does not name specifically.

```
DECLARE
    pe_ratio NUMBER(3,1);
BEGIN
    SELECT price / earnings INTO pe_ratio FROM stocks
        WHERE symbol = 'XYZ'; -- might cause division-by-zero error
    INSERT INTO stats (symbol, ratio) VALUES ('XYZ', pe_ratio);
    COMMIT;
EXCEPTION -- exception handlers begin
    WHEN ZERO_DIVIDE THEN -- handles 'division by zero' error
        INSERT INTO stats (symbol, ratio) VALUES ('XYZ', NULL);
        COMMIT;
    ...
    WHEN OTHERS THEN -- handles all other errors
        ROLLBACK;
END; -- exception handlers and block end here
```

The last example illustrates exception handling, not the effective use of `INSERT` statements. For example, a better way to do the insert follows:

```
INSERT INTO stats (symbol, ratio)
  SELECT symbol, DECODE(earnings, 0, NULL, price / earnings)
  FROM stocks WHERE symbol = 'XYZ';
```

In this example, a subquery supplies values to the `INSERT` statement. If earnings are zero, the function `DECODE` returns a null. Otherwise, `DECODE` returns the price-to-earnings ratio.

Advantages of PL/SQL Exceptions

Using exceptions for error handling has several advantages. Without exception handling, every time you issue a command, you must check for execution errors:

```
BEGIN
  SELECT ...
    -- check for 'no data found' error
  SELECT ...
    -- check for 'no data found' error
  SELECT ...
    -- check for 'no data found' error
```

Error processing is not clearly separated from normal processing; nor is it robust. If you neglect to code a check, the error goes undetected and is likely to cause other, seemingly unrelated errors.

With exceptions, you can handle errors conveniently without the need to code multiple checks, as follows:

```
BEGIN
  SELECT ...
  SELECT ...
  SELECT ...
  ...
EXCEPTION
  WHEN NO_DATA_FOUND THEN -- catches all 'no data found' errors
```

Exceptions improve readability by letting you isolate error-handling routines. The primary algorithm is not obscured by error recovery algorithms. Exceptions also improve reliability. You need not worry about 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.

Predefined PL/SQL Exceptions

An internal exception is raised implicitly whenever your PL/SQL program violates an Oracle rule or exceeds a system-dependent limit. Every Oracle error has a number, but exceptions must be handled by name. So, 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.

To handle other Oracle errors, you can use the `OTHERS` handler. The functions `SQLCODE` and `SQLERRM` are especially useful in the `OTHERS` handler because they return the Oracle error code and message text. Alternatively, you can use the pragma `EXCEPTION_INIT` to associate exception names with Oracle error codes.

PL/SQL declares predefined exceptions globally in package `STANDARD`, which defines the PL/SQL environment. So, you need not declare them yourself. You can write handlers for predefined exceptions using the names in the following list:

Exception	Oracle Error	SQLCODE Value
<code>ACCESS_INTO_NULL</code>	<code>ORA-06530</code>	-6530
<code>CASE_NOT_FOUND</code>	<code>ORA-06592</code>	-6592
<code>COLLECTION_IS_NULL</code>	<code>ORA-06531</code>	-6531
<code>CURSOR_ALREADY_OPEN</code>	<code>ORA-06511</code>	-6511
<code>DUP_VAL_ON_INDEX</code>	<code>ORA-00001</code>	-1
<code>INVALID_CURSOR</code>	<code>ORA-01001</code>	-1001
<code>INVALID_NUMBER</code>	<code>ORA-01722</code>	-1722
<code>LOGIN_DENIED</code>	<code>ORA-01017</code>	-1017
<code>NO_DATA_FOUND</code>	<code>ORA-01403</code>	+100
<code>NOT_LOGGED_ON</code>	<code>ORA-01012</code>	-1012
<code>PROGRAM_ERROR</code>	<code>ORA-06501</code>	-6501
<code>ROWTYPE_MISMATCH</code>	<code>ORA-06504</code>	-6504
<code>SELF_IS_NULL</code>	<code>ORA-30625</code>	-30625
<code>STORAGE_ERROR</code>	<code>ORA-06500</code>	-6500
<code>SUBSCRIPT_BEYOND_COUNT</code>	<code>ORA-06533</code>	-6533
<code>SUBSCRIPT_OUTSIDE_LIMIT</code>	<code>ORA-06532</code>	-6532
<code>SYS_INVALID_ROWID</code>	<code>ORA-01410</code>	-1410
<code>TIMEOUT_ON_RESOURCE</code>	<code>ORA-00051</code>	-51
<code>TOO_MANY_ROWS</code>	<code>ORA-01422</code>	-1422
<code>VALUE_ERROR</code>	<code>ORA-06502</code>	-6502
<code>ZERO_DIVIDE</code>	<code>ORA-01476</code>	-1476

Brief descriptions of the predefined exceptions follow:

Exception	Raised when ...
ACCESS_INTO_NULL	Your program attempts to assign values to the attributes of an uninitialized (atomically null) object.
CASE_NOT_FOUND	None of the choices in the <code>WHEN</code> clauses of a <code>CASE</code> statement is selected, and there is no <code>ELSE</code> clause.
COLLECTION_IS_NULL	Your program attempts to apply collection methods other than <code>EXISTS</code> to an uninitialized (atomically null) nested table or varray, or the program attempts to assign values to the elements of an uninitialized nested table or varray.
CURSOR_ALREADY_OPEN	Your program attempts to open an already open cursor. A cursor must be closed before it can be reopened. A cursor <code>FOR</code> loop automatically opens the cursor to which it refers. So, your program cannot open that cursor inside the loop.
DUP_VAL_ON_INDEX	Your program attempts to store duplicate values in a database column that is constrained by a unique index.
INVALID_CURSOR	Your program attempts an illegal cursor operation such as closing an unopened cursor.
INVALID_NUMBER	In 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, <code>VALUE_ERROR</code> is raised.) This exception is also raised when the <code>LIMIT</code> -clause expression in a bulk <code>FETCH</code> statement does not evaluate to a positive number.
LOGIN_DENIED	Your program attempts to log on to Oracle with an invalid username and/or password.
NO_DATA_FOUND	A <code>SELECT INTO</code> statement returns no rows, or your program references a deleted element in a nested table or an uninitialized element in an index-by table. SQL aggregate functions such as <code>AVG</code> and <code>SUM</code> always return a value or a null. So, a <code>SELECT INTO</code> statement that calls an aggregate function never raises <code>NO_DATA_FOUND</code> . The <code>FETCH</code> statement is expected to return no rows eventually, so when that happens, no exception is raised.
NOT_LOGGED_ON	Your program issues a database call without being connected to Oracle.

Exception	Raised when ...
PROGRAM_ERROR	PL/SQL has an internal problem.
ROWTYPE_MISMATCH	The host cursor variable and PL/SQL cursor variable involved in an assignment have incompatible return types. For example, 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	Your program attempts to call a MEMBER method on a null instance. That is, the built-in parameter SELF (which is always the first parameter passed to a MEMBER method) is null.
STORAGE_ERROR	PL/SQL runs out of memory or memory has been corrupted.
SUBSCRIPT_BEYOND_COUNT	Your program references a nested table or varray element using an index number larger than the number of elements in the collection.
SUBSCRIPT_OUTSIDE_LIMIT	Your program references a nested table or varray element using an index number (-1 for example) that is outside the legal range.
SYS_INVALID_ROWID	The conversion of a character string into a universal rowid fails because the character string does not represent a valid rowid.
TIMEOUT_ON_RESOURCE	A time-out occurs while Oracle is waiting for a resource.
TOO_MANY_ROWS	A SELECT INTO statement returns more than one row.
VALUE_ERROR	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	Your 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. So, the sub-block cannot reference the global exception unless it was declared in a labeled block, in which case the following syntax is valid:

```
block_label.exception_name
```

The following example illustrates the scope rules:

```
DECLARE
    past_due EXCEPTION;
    acct_num NUMBER;
BEGIN
    DECLARE ----- sub-block begins
        past_due EXCEPTION; -- this declaration prevails
        acct_num NUMBER;
```

```
BEGIN
    ...
    IF ... THEN
        RAISE past_due; -- this is not handled
    END IF;
END; ----- sub-block ends
EXCEPTION
    WHEN past_due THEN -- does not handle RAISED exception
    ...
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. Therefore, 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 unnamed internal exceptions, you must use the `OTHERS` handler or the pragma `EXCEPTION_INIT`. A *pragma* is a compiler directive, which can be thought of as a parenthetical remark to the compiler. Pragas (also called *pseudoinstructions*) are processed at compile time, not at run time. For example, in the language Ada, the following pragma tells the compiler to optimize the use of storage space:

```
pragma OPTIMIZE(SPACE);
```

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.

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. The pragma must appear somewhere after the exception declaration in the same declarative section, as shown in the following example:

```
DECLARE
    deadlock_detected EXCEPTION;
    PRAGMA EXCEPTION_INIT(deadlock_detected, -60);
```



```

BEGIN
    ...
EXCEPTION
    WHEN deadlock_detected THEN
        -- handle the error
END;

```

Defining Your Own PL/SQL Error Messages: Procedure RAISE_APPLICATION_ERROR

Package `DBMS_STANDARD`, which is supplied with Oracle, provides language facilities that help your application interact with Oracle. For example, the procedure `raise_application_error` lets you issue user-defined 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. Package `DBMS_STANDARD` is an extension of package `STANDARD`, so you need not qualify references to its contents.

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 the following example, you call `raise_application_error` if an employee's salary is missing:

```

CREATE PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER) AS
    curr_sal NUMBER;
BEGIN
    SELECT sal INTO curr_sal FROM emp WHERE empno = emp_id;
    IF curr_sal IS NULL THEN
        /* Issue user-defined error message. */
        raise_application_error(-20101, 'Salary is missing');
    ELSE
        UPDATE emp SET sal = curr_sal + amount WHERE empno = emp_id;
    END IF;

```

```
END raise_salary;
```

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 my_emp_id and my_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(:my_emp_id, :my_amount);
  EXCEPTION
    WHEN null_salary THEN
      INSERT INTO emp_audit VALUES (:my_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 the following example, you alert your PL/SQL block to a user-defined exception named `out_of_stock`:

```
DECLARE
    out_of_stock    EXCEPTION;
    number_on_hand NUMBER(4);
BEGIN
    ...
    IF number_on_hand < 1 THEN
        RAISE out_of_stock;
    END IF;
EXCEPTION
    WHEN out_of_stock THEN
        -- handle the 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 the following example shows:

```
DECLARE
    acct_type INTEGER;
BEGIN
    ...
    IF acct_type NOT IN (1, 2, 3) THEN
        RAISE INVALID_NUMBER; -- raise predefined exception
    END IF;
EXCEPTION
    WHEN INVALID_NUMBER THEN
        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. In the latter case, PL/SQL returns an *unhandled exception* error to the host environment.

However, exceptions cannot propagate across remote procedure calls (RPCs). Therefore, a PL/SQL block cannot catch an exception raised by a remote subprogram. For a workaround, see "[Defining Your Own PL/SQL Error Messages: Procedure RAISE_APPLICATION_ERROR](#)" on page 7-9.

Figure 7-1, Figure 7-2, and Figure 7-3 illustrate the basic propagation rules.

Figure 7-1 Propagation Rules: Example 1

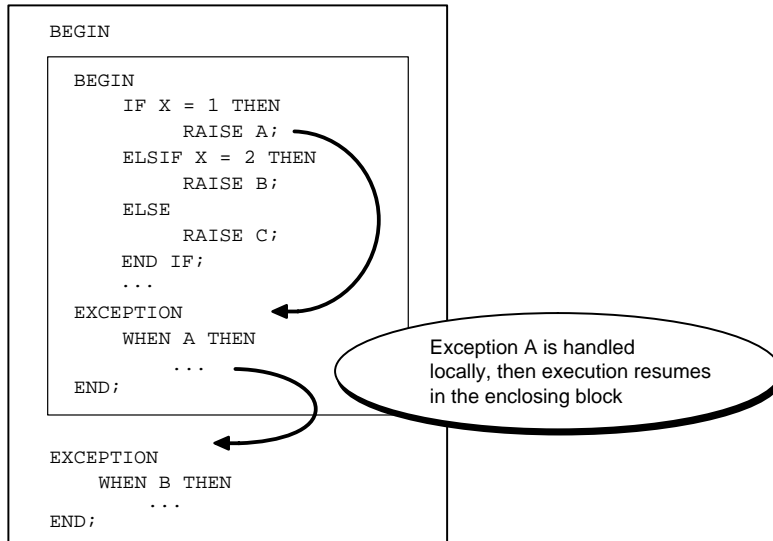


Figure 7–2 Propagation Rules: Example 2

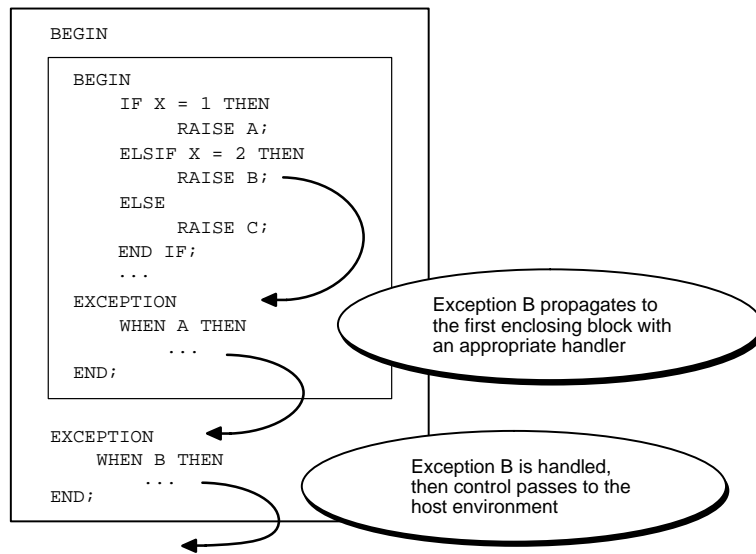
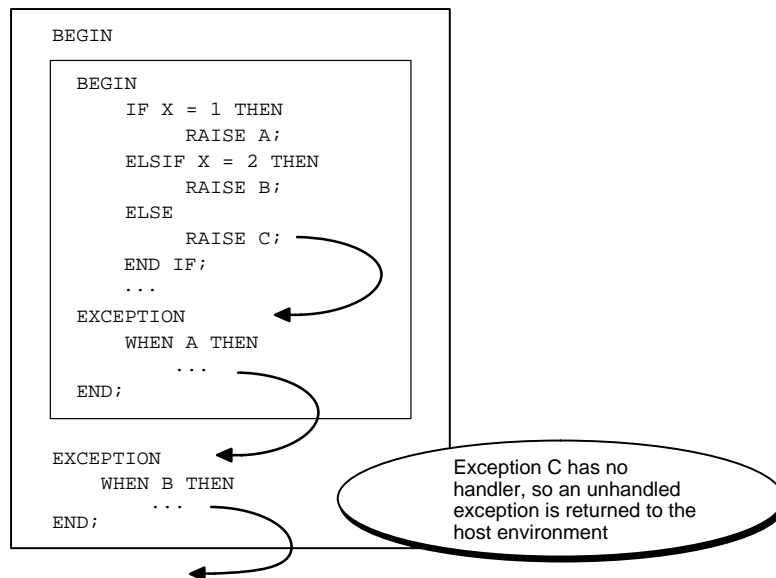


Figure 7–3 Propagation Rules: Example 3



An exception can propagate beyond its scope, that is, beyond the block in which it was declared. Consider the following example:

```
BEGIN
  ...
  DECLARE ----- sub-block begins
    past_due EXCEPTION;
  BEGIN
    ...
    IF ... THEN
      RAISE past_due;
    END IF;
  END; ----- sub-block ends
EXCEPTION
  ...
  WHEN OTHERS THEN
    ROLLBACK;
END;
```

Because the block in which exception `past_due` was declared has no handler for it, the exception propagates to the enclosing block. But, according to the scope rules, enclosing blocks cannot reference exceptions declared in a sub-block. So, only an `OTHERS` handler can catch the exception. If there is no handler for a user-defined exception, the calling application gets the following 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, simply place a `RAISE` statement in the local handler, as shown in the following example:

```
DECLARE
  out_of_balance EXCEPTION;
BEGIN
  ...
  BEGIN ----- sub-block begins
    ...
    IF ... THEN
      RAISE out_of_balance; -- raise the exception
    END IF;
  END;
```

```

EXCEPTION
    WHEN out_of_balance THEN
        -- handle the error
        RAISE; -- reraise the current exception
    END; ----- sub-block ends
EXCEPTION
    WHEN out_of_balance THEN
        -- handle the error differently
        ...
END;

```

Omitting the exception name in a `RAISE` statement—allowed only in an exception handler—reraises the current exception.

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 exception_name1 THEN -- handler
        sequence_of_statements1
    WHEN exception_name2 THEN -- another handler
        sequence_of_statements2
    ...
    WHEN OTHERS THEN -- optional handler
        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.

As the following example shows, use of the `OTHERS` handler guarantees that *no* exception will go unhandled:

```
EXCEPTION
  WHEN ... THEN
    -- handle the error
  WHEN ... THEN
    -- handle the error
  WHEN OTHERS THEN
    -- handle all other errors
END;
```

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.

Handling 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:

```
DECLARE
  credit_limit CONSTANT NUMBER(3) := 5000; -- raises an exception
BEGIN
  ...
```



```

EXCEPTION
  WHEN OTHERS THEN -- cannot catch the exception
    ...
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

Only one exception at a time can be active in the exception-handling part of a block or subprogram. So, an exception raised inside a handler propagates immediately to the enclosing block, which is searched to find a handler for the newly raised exception. From there on, the exception propagates normally. Consider the following 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 cannot branch into an exception handler. Also, a GOTO statement cannot branch from an exception handler into the current block. For example, the following GOTO statement is illegal:

```

DECLARE
  pe_ratio NUMBER(3,1);
BEGIN
  DELETE FROM stats WHERE symbol = 'XYZ';
  SELECT price / NVL(earnings, 0) INTO pe_ratio FROM stocks
    WHERE symbol = 'XYZ';
  <<my_label>>
  INSERT INTO stats (symbol, ratio) VALUES ('XYZ', pe_ratio);
EXCEPTION
  WHEN ZERO_DIVIDE THEN
    pe_ratio := 0;
    GOTO my_label; -- illegal branch into current block
END;

```

However, a GOTO statement can branch from an exception handler into an enclosing 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`. In the following example, you pass positive numbers and so get unwanted results:

```
DECLARE
    ...
    err_msg VARCHAR2(100);
BEGIN
    /* Get all Oracle error messages. */
    FOR err_num IN 1..9999 LOOP
        err_msg := SQLERRM(err_num); -- wrong; should be -err_num
        INSERT INTO errors VALUES (err_msg);
    END LOOP;
END;
```

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 the following example:

```

DECLARE
    err_num NUMBER;
    err_msg VARCHAR2(100);
BEGIN
    ...
EXCEPTION
    ...
    WHEN OTHERS THEN
        err_num := SQLCODE;
        err_msg := SUBSTR(SQLERRM, 1, 100);
        INSERT INTO errors VALUES (err_num, err_msg);
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.

Note: 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 three 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:

```
DECLARE
    pe_ratio NUMBER(3,1);
BEGIN
    DELETE FROM stats WHERE symbol = 'XYZ';
    SELECT price / NVL(earnings, 0) INTO pe_ratio FROM stocks
        WHERE symbol = 'XYZ';
    INSERT INTO stats (symbol, ratio) VALUES ('XYZ', pe_ratio);
EXCEPTION
    WHEN ZERO_DIVIDE THEN
        ...
END;
```

You can still handle an exception for a statement, then continue with the next statement. Simply 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 terminates, the enclosing block continues to execute at the point where the sub-block ends. Consider the following example:

```
DECLARE
    pe_ratio NUMBER(3,1);
BEGIN
    DELETE FROM stats WHERE symbol = 'XYZ';
    BEGIN ----- sub-block begins
        SELECT price / NVL(earnings, 0) INTO pe_ratio FROM stocks
            WHERE symbol = 'XYZ';
    EXCEPTION
        WHEN ZERO_DIVIDE THEN
            pe_ratio := 0;
    END; ----- sub-block ends
    INSERT INTO stats (symbol, ratio) VALUES ('XYZ', pe_ratio);
```

```

EXCEPTION
    WHEN OTHERS THEN
        ...
END;

```

In this example, if the `SELECT INTO` statement raises a `ZERO_DIVIDE` exception, the local handler catches it and sets `pe_ratio` to zero. Execution of the handler is complete, so the sub-block terminates, and execution continues with the `INSERT` statement.

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 5-38.

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.

Consider the example below. When the exception handler completes, the sub-block terminates, control transfers to the `LOOP` statement in the enclosing block, the sub-block starts executing again, and the transaction is retried. You might want to use a `FOR` or `WHILE` loop to limit the number of tries.

```

DECLARE
    name    VARCHAR2(20);
    ans1    VARCHAR2(3);
    ans2    VARCHAR2(3);
    ans3    VARCHAR2(3);
    suffix  NUMBER := 1;
BEGIN
    ...
    LOOP -- could be FOR i IN 1..10 LOOP to allow ten tries
        BEGIN -- sub-block begins
            SAVEPOINT start_transaction; -- mark a savepoint

```

```

        /* Remove rows from a table of survey results. */
        DELETE FROM results WHERE answer1 = 'NO';
        /* Add a survey respondent's name and answers. */
        INSERT INTO results VALUES (name, ans1, ans2, ans3);
            -- 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

Exceptions can mask the statement that caused an error, as the following example shows:

```

BEGIN
    SELECT ...
    SELECT ...
    SELECT ...
    ...
EXCEPTION
    WHEN NO_DATA_FOUND THEN ...
        -- Which SELECT statement caused the error?
END;

```

Normally, this is not a problem. But, if the need arises, you can use a *locator variable* to track statement execution, as follows:

```

DECLARE
    stmt INTEGER := 1; -- designates 1st SELECT statement
BEGIN
    SELECT ...
    stmt := 2; -- designates 2nd SELECT statement
    SELECT ...
    stmt := 3; -- designates 3rd SELECT statement
    SELECT ...
    ...
EXCEPTION

```

```
    WHEN NO_DATA_FOUND THEN
        INSERT INTO errors VALUES ('Error in statement ' || stmt);
END;
```

PL/SQL Subprograms

Civilization advances by extending the number of important operations that we can perform without thinking about them. —Alfred North Whitehead

This chapter shows you how to use subprograms, which let you name and encapsulate a sequence of statements. Subprograms aid application development by isolating operations. They are like building blocks, which you can use to construct modular, maintainable applications.

This chapter discusses the following topics:

- What Are Subprograms?
- Advantages of Subprograms
- Understanding PL/SQL Procedures
- Understanding PL/SQL Functions
- Declaring PL/SQL Subprograms
- Packaging PL/SQL Subprograms Together
- Actual Versus Formal Subprogram Parameters
- Positional Versus Named Notation for Subprogram Parameters
- Specifying Subprogram Parameter Modes
- Passing Large Data Structures with the NOCOPY Compiler Hint
- Using Default Values for Subprogram Parameters
- Understanding Subprogram Parameter Aliasing
- Overloading Subprogram Names
- How Subprogram Calls Are Resolved
- Accepting and Returning Multiple Rows with Table Functions
- Invoker Rights Versus Definer Rights
- Understanding and Using Recursion
- Calling External Subprograms

What Are Subprograms?

Subprograms are named PL/SQL blocks that can take parameters and be invoked. PL/SQL has two types of subprograms called *procedures* and *functions*. Generally, you use a procedure to perform an action and a function to compute a value.

Like unnamed or *anonymous* PL/SQL blocks, subprograms have a declarative part, an executable part, and an optional exception-handling part. The declarative part contains declarations of types, cursors, constants, variables, exceptions, and nested subprograms. These items are local and cease to exist when you exit the subprogram. The executable part contains statements that assign values, control execution, and manipulate Oracle data. The exception-handling part contains exception handlers, which deal with exceptions raised during execution.

Consider the following procedure named `debit_account`, which debits a bank account:

```
PROCEDURE debit_account (acct_id INTEGER, amount REAL) IS
    old_balance REAL;
    new_balance REAL;
    overdrawn    EXCEPTION;
BEGIN
    SELECT bal INTO old_balance FROM accts
        WHERE acct_no = acct_id;
    new_balance := old_balance - amount;
    IF new_balance < 0 THEN
        RAISE overdrawn;
    ELSE
        UPDATE accts SET bal = new_balance
            WHERE acct_no = acct_id;
    END IF;
EXCEPTION
    WHEN overdrawn THEN
        ...
END debit_account;
```

When invoked or *called*, this procedure accepts an account number and a debit amount. It uses the account number to select the account balance from the `accts` database table. Then, it uses the debit amount to compute a new balance. If the new balance is less than zero, an exception is raised; otherwise, the bank account is updated.

Advantages of Subprograms

Subprograms provide *extensibility*; that is, they let you tailor the PL/SQL language to suit your needs. For example, if you need a procedure that creates new departments, you can easily write one, as follows:

```
PROCEDURE create_dept (new_dname VARCHAR2, new_loc VARCHAR2) IS
BEGIN
    INSERT INTO dept VALUES (deptno_seq.NEXTVAL, new_dname, new_loc);
END create_dept;
```

Subprograms also provide *modularity*; that is, they let you break a program down into manageable, well-defined modules. This supports top-down design and the stepwise refinement approach to problem solving.

In addition, subprograms promote *reusability* and *maintainability*. Once validated, a subprogram can be used with confidence in any number of applications. If its definition changes, only the subprogram is affected. This simplifies maintenance.

Finally, subprograms aid *abstraction*, the mental process of deriving a universal from particulars. To use subprograms, you must know what they do, not how they work. Therefore, you can design applications from the top down without worrying about implementation details. Dummy subprograms (stubs) allow you to defer the definition of procedures and functions until you test and debug the main program.

Understanding PL/SQL Procedures

A procedure is a subprogram that performs a specific action. You write procedures using the syntax:

```
[CREATE [OR REPLACE]]
PROCEDURE procedure_name[(parameter[, parameter]...)]
    [AUTHID {DEFINER | CURRENT_USER}] {IS | AS}
    [PRAGMA AUTONOMOUS_TRANSACTION;]
    [local declarations]
BEGIN
    executable statements
[EXCEPTION
    exception handlers]
END [name];
```

where *parameter* stands for the following syntax:

```
parameter_name [IN | OUT [NOCOPY] | IN OUT [NOCOPY]] datatype
    [{:= | DEFAULT} expression]
```

The `CREATE` clause lets you create standalone procedures, which are stored in an Oracle database. You can execute the `CREATE PROCEDURE` statement interactively from SQL*Plus or from a program using native dynamic SQL (see [Chapter 11](#)).

The `AUTHID` clause determines whether a stored procedure 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`. For more information, see ["Invoker Rights Versus Definer Rights"](#) on page 8-47.

The pragma `AUTONOMOUS_TRANSACTION` instructs the PL/SQL compiler to mark a procedure 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. For more information, see ["Doing Independent Units of Work with Autonomous Transactions"](#) on page 6-53.

You cannot constrain the datatype of a parameter. For example, the following declaration of `acct_id` is illegal because the datatype `CHAR` is size-constrained:

```
PROCEDURE reconcile (acct_id CHAR(5)) IS ... -- illegal
```

However, you can use the following workaround to size-constrain parameter types indirectly:

```
DECLARE
    SUBTYPE Char5 IS CHAR(5);
    PROCEDURE reconcile (acct_id Char5) IS ...
```

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. 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: 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`, which introduces declarations in an anonymous PL/SQL block, is not used. 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. The `NULL`

statement meets this requirement. The exception-handling part contains exception handlers, which are placed between the keywords `EXCEPTION` and `END`.

Consider the procedure `raise_salary`, which increases the salary of an employee by a given amount:

```
PROCEDURE raise_salary (emp_id INTEGER, amount REAL) IS
    current_salary REAL;
    salary_missing EXCEPTION;
BEGIN
    SELECT sal INTO current_salary FROM emp
        WHERE empno = emp_id;
    IF current_salary IS NULL THEN
        RAISE salary_missing;
    ELSE
        UPDATE emp SET sal = sal + amount
            WHERE empno = emp_id;
    END IF;
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        INSERT INTO emp_audit VALUES (emp_id, 'No such number');
    WHEN salary_missing THEN
        INSERT INTO emp_audit VALUES (emp_id, 'Salary is null');
END raise_salary;
```

When called, this procedure accepts an employee number and a salary increase amount. It uses the employee number to select the current salary from the `emp` database table. If the employee number is not found or if the current salary is null, an exception is raised. Otherwise, the salary is updated.

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. You write (local) functions using the syntax:

```
[CREATE [OR REPLACE]]
FUNCTION function_name(parameter[, parameter]...) RETURN datatype
    [AUTHID {DEFINER | CURRENT_USER}]
    [PARALLEL_ENABLE

        [{[CLUSTER parameter BY (column_name [, column_name]...)]|

        [ORDER parameter BY (column_name [, column_name]...)]

        [(PARTITION parameter BY{[ {RANGE|HASH} (column_name [,
column_name]...)]|ANY})]

    ]
    [DETERMINISTIC] {IS | AS}

    [PIPELINED [USING implementation_type]]

    [AGGREGATE [UPDATE VALUE] {WITH EXTERNAL CONTEXT} USING
implementation_type]
    [PRAGMA AUTONOMOUS_TRANSACTION;]
    [local declarations]
BEGIN
    executable statements
[EXCEPTION
    exception handlers]
END [name];
```

The CREATE clause lets you create standalone functions, which are stored in an Oracle database. You can execute the CREATE FUNCTION statement interactively from SQL*Plus or from a program using native dynamic SQL.

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 hint `DETERMINISTIC` 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, see *Oracle9i 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`.

Consider the function `sal_ok`, which determines if a salary is out of range:

```
FUNCTION sal_ok (salary REAL, title VARCHAR2) RETURN BOOLEAN IS
    min_sal REAL;
    max_sal REAL;
BEGIN
    SELECT losal, hisal INTO min_sal, max_sal FROM sals
       WHERE job = title;
    RETURN (salary >= min_sal) AND (salary <= max_sal);
END sal_ok;
```

When called, this function accepts an employee salary and job title. It uses the job title to select range limits from the `sals` database table. The function identifier, `sal_ok`, is set to a Boolean value by the `RETURN` statement. If the salary is out of range, `sal_ok` is set to `FALSE`; otherwise, `sal_ok` is set to `TRUE`.

A function is called as part of an expression, as the example below shows. The function identifier `sal_ok` acts like a variable whose value depends on the parameters passed to it.

```
IF sal_ok(new_sal, new_title) THEN ...
```

Using the RETURN Statement

The `RETURN` statement immediately completes the execution of a subprogram and returns control to the caller. Execution then resumes 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 last lexical statement does not need to be a `RETURN` statement. Executing any `RETURN` statement completes the subprogram immediately. However, to have multiple exit points in a subprogram is a poor programming practice.

In procedures, a `RETURN` statement cannot return a value, and therefore cannot contain an expression. The statement simply returns control to the caller before the normal end of the procedure is reached.

However, 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. Observe how the function `balance` returns the balance of a specified bank account:

```
FUNCTION balance (acct_id INTEGER) RETURN REAL IS
    acct_bal REAL;
BEGIN
    SELECT bal INTO acct_bal FROM accts
        WHERE acct_no = acct_id;
    RETURN acct_bal;
END balance;
```

The following example shows that the expression in a function `RETURN` statement can be arbitrarily complex:

```
FUNCTION compound (
```



```

    years  NUMBER,
    amount NUMBER,
    rate   NUMBER) RETURN NUMBER IS
BEGIN
    RETURN amount * POWER((rate / 100) + 1, years);
END compound;

```

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.

Controlling Side Effects of PL/SQL Subprograms

To be callable from SQL statements, a stored function must obey the following "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 and/or write database tables and/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;

```

Note: 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 more information about the purity rules and pragma `RESTRICT_REFERENCES`, see *Oracle9i Application Developer's Guide - Fundamentals*.

Declaring PL/SQL Subprograms

You can declare subprograms in any PL/SQL block, subprogram, or package. But, you must declare subprograms at the end of a declarative section after all other program items.

PL/SQL requires that you declare an identifier before using it. Therefore, you must declare a subprogram before calling it. For example, the following declaration of procedure `award_bonus` is illegal because `award_bonus` calls procedure `calc_rating`, which is not yet declared when the call is made:

```
DECLARE
  ...
  PROCEDURE award_bonus IS
  BEGIN
    calc_rating(...); -- undeclared identifier
    ...
  END;

  PROCEDURE calc_rating (...) IS
  BEGIN
    ...
  END;
```

In this case, you can solve the problem easily by placing procedure `calc_rating` before procedure `award_bonus`. However, the easy solution does not always work. For example, suppose the procedures are mutually recursive (call each other) or you want to define them in logical or alphabetical order.

You can solve the problem by using a special subprogram declaration called a *forward declaration*, which consists of a subprogram spec terminated by a semicolon. In the following example, the forward declaration advises PL/SQL that the body of procedure `calc_rating` can be found later in the block.

```
DECLARE
  PROCEDURE calc_rating ( ... ); -- forward declaration
  ...
```

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.

Packaging PL/SQL Subprograms Together

You can group logically related subprograms in a package, which is stored in the database. That way, the subprograms can be shared by many applications. The subprogram specs go in the package spec, and the subprogram bodies go in the package body, where they are invisible to applications. Thus, packages allow you to hide implementation details. An example follows:

```
CREATE PACKAGE emp_actions AS -- package spec
    PROCEDURE hire_employee (emp_id INTEGER, name VARCHAR2, ...);
    PROCEDURE fire_employee (emp_id INTEGER);
    PROCEDURE raise_salary (emp_id INTEGER, amount REAL);
    ...
END emp_actions;

CREATE PACKAGE BODY emp_actions AS -- package body
    PROCEDURE hire_employee (emp_id INTEGER, name VARCHAR2, ...) IS
    BEGIN
        ...
        INSERT INTO emp VALUES (emp_id, name, ...);
    END hire_employee;

    PROCEDURE fire_employee (emp_id INTEGER) IS
    BEGIN
        DELETE FROM emp WHERE empno = emp_id;
    END fire_employee;

    PROCEDURE raise_salary (emp_id INTEGER, amount REAL) IS
    BEGIN
        UPDATE emp SET sal = sal + amount WHERE empno = emp_id;
    END raise_salary;
    ...
END emp_actions;
```

You can define subprograms in a package body without declaring their specs in the package spec. However, such subprograms can be called only from inside the package. For more information about packages, see [Chapter 9](#).

Actual Versus Formal Subprogram Parameters

Subprograms pass information using *parameters*. The variables or expressions referenced in the parameter list of a subprogram call are *actual* parameters. For example, the following procedure call lists two actual parameters named `emp_num` and `amount`:

```
raise_salary(emp_num, amount);
```

The next procedure call shows that expressions can be used as actual parameters:

```
raise_salary(emp_num, merit + cola);
```

The variables declared in a subprogram spec and referenced in the subprogram body are *formal* parameters. For example, the following procedure declares two formal parameters named `emp_id` and `amount`:

```
PROCEDURE raise_salary (emp_id INTEGER, amount REAL) IS
BEGIN
    UPDATE emp SET sal = sal + amount WHERE empno = emp_id;
END raise_salary;
```

A good programming practice is to use different names for actual and formal parameters.

When you call procedure `raise_salary`, 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, the following call to `raise_salary` is valid:

```
raise_salary(emp_num, '2500');
```

The actual parameter and its corresponding formal parameter must have compatible datatypes. For instance, PL/SQL cannot convert between the `DATE` and `REAL` datatypes. Also, the result must be convertible to the new datatype. The following procedure call raises the predefined exception `VALUE_ERROR` because PL/SQL cannot convert the second actual parameter to a number:

```
raise_salary(emp_num, '$2500'); -- note the dollar sign
```

Positional Versus Named Notation for Subprogram Parameters

When calling a subprogram, you can write the actual parameters using either positional or named notation. That is, you can indicate the association between an actual and formal parameter by position or name. So, given the declarations

```
DECLARE
  acct INTEGER;
  amt  REAL;
  PROCEDURE credit_acct (acct_no INTEGER, amount REAL) IS ...
```

you can call the procedure `credit_acct` in four logically equivalent ways:

```
BEGIN
  credit_acct(acct, amt);           -- positional notation
  credit_acct(amount => amt, acct_no => acct); -- named notation
  credit_acct(acct_no => acct, amount => amt); -- named notation
  credit_acct(acct, amount => amt);   -- mixed notation
```

Using Positional Notation

The first procedure call uses positional notation. The PL/SQL compiler associates the first actual parameter, `acct`, with the first formal parameter, `acct_no`. And, the compiler associates the second actual parameter, `amt`, with the second formal parameter, `amount`.

Using Named Notation

The second procedure call uses named notation. An arrow (`=>`) serves as the association operator, which associates the formal parameter to the left of the arrow with the actual parameter to the right of the arrow.

The third procedure call also uses named notation and shows that you can list the parameter pairs in any order. So, you need not know the order in which the formal parameters are listed.

Using Mixed Notation

The fourth procedure call shows that you can mix positional and named notation. In this case, the first parameter uses positional notation, and the second parameter uses named notation. Positional notation must precede named notation. The reverse is not allowed. For example, the following procedure call is illegal:

```
credit_acct(acct_no => acct, amt); -- illegal
```

Specifying Subprogram Parameter Modes

You use parameter modes to define the behavior of formal parameters. The three parameter modes, `IN` (the default), `OUT`, and `IN OUT`, can be used with any subprogram. However, avoid using the `OUT` and `IN OUT` modes with functions. The purpose of a function is to take zero or more arguments (actual parameters) and return a single value. 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. Therefore, it cannot be assigned a value. For example, the following assignment statement causes a compilation error:

```
PROCEDURE debit_account (acct_id IN INTEGER, amount IN REAL) IS
    minimum_purchase CONSTANT REAL DEFAULT 10.0;
    service_charge     CONSTANT REAL DEFAULT 0.50;
BEGIN
    IF amount < minimum_purchase THEN
        amount := amount + service_charge; -- causes compilation error
    END IF;
    ...
END debit_account;
```

The actual parameter that corresponds to an `IN` formal parameter can be a constant, literal, initialized variable, or expression. 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 8-19.

Using the OUT Mode

An `OUT` parameter lets you return values to the caller of a subprogram. Inside the subprogram, an `OUT` parameter acts like a variable. That means you can use an `OUT` formal parameter as if it were a local variable. You can change its value or reference the value in any way, as the following example shows:

```
PROCEDURE calc_bonus (emp_id IN INTEGER, bonus OUT REAL) IS
    hire_date     DATE;
    bonus_missing EXCEPTION;
BEGIN
    SELECT sal * 0.10, hiredate INTO bonus, hire_date FROM emp
        WHERE empno = emp_id;
```

```

    IF bonus IS NULL THEN
        RAISE bonus_missing;
    END IF;
    IF MONTHS_BETWEEN(SYSDATE, hire_date) > 60 THEN
        bonus := bonus + 500;
    END IF;
    ...
EXCEPTION
    WHEN bonus_missing THEN
        ...
END calc_bonus;

```

The actual parameter that corresponds to an OUT formal parameter must be a variable; it cannot be a constant or an expression. For example, the following procedure call is illegal:

```
calc_bonus(7499, salary + commission); -- causes compilation error
```

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` (see ["Passing Large Data Structures with the NOCOPY Compiler Hint"](#) on page 8-17) or the subprogram exits with an unhandled exception.

Like variables, OUT formal parameters are initialized to `NULL`. So, the datatype of an OUT formal parameter cannot be a subtype defined as `NOT NULL` (that includes the built-in subtypes `NATURALN` and `POSITIVEN`). Otherwise, when you call the subprogram, PL/SQL raises `VALUE_ERROR`. An example follows:

```

DECLARE
    SUBTYPE Counter IS INTEGER NOT NULL;
    rows Counter := 0;
    PROCEDURE count_emps (n OUT Counter) IS
    BEGIN
        SELECT COUNT(*) INTO n FROM emp;
    END;
BEGIN
    count_emps(rows); -- raises VALUE_ERROR

```

Before exiting a subprogram, explicitly 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. However, 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 lets you pass initial values to the subprogram being called and return updated values to the caller. Inside the subprogram, an `IN OUT` parameter acts like an initialized variable. Therefore, it can be assigned a value and its value can be assigned to another variable.

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. However, 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 a 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 <code>NOCOPY</code> is specified	actual parameter is passed by value (a copy of the value is passed in and out) unless <code>NOCOPY</code> is specified

Passing Large Data Structures with the NOCOPY Compiler Hint

Suppose a subprogram declares an `IN` parameter, an `OUT` parameter, and an `IN OUT` parameter. When you call the subprogram, the `IN` parameter is passed by reference. That is, a pointer to the `IN` actual parameter is passed to the corresponding formal parameter. So, both parameters reference the same memory location, which holds the value of the actual parameter.

By default, the `OUT` and `IN OUT` parameters are passed by value. That is, the value of the `IN OUT` actual parameter is copied into the corresponding formal parameter. Then, if the subprogram exits normally, the values assigned to the `OUT` and `IN OUT` formal parameters are copied into the corresponding actual parameters.

When the parameters hold large data structures such as collections, records, and instances of object types, all this copying slows down execution and uses up memory. To prevent that, you can specify the `NOCOPY` hint, which allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference.

In the following example, you ask the compiler to pass `IN OUT` parameter `my_staff` by reference instead of by value:

```
DECLARE
    TYPE Staff IS VARRAY(200) OF Employee;
    PROCEDURE reorganize (my_staff IN OUT NOCOPY Staff) IS ...
```

Remember, `NOCOPY` is a hint, not a directive. So, the compiler might pass `my_staff` by value despite your request. Usually, however, `NOCOPY` succeeds. So, it can benefit any PL/SQL application that passes around large data structures.

In the example below, 25000 records are loaded into a local nested table, which is passed to two local procedures that do nothing but execute `NULL` statements. However, a call to one procedure takes 21 seconds because of all the copying. With `NOCOPY`, a call to the other procedure takes much less than 1 second.

```
SQL> SET SERVEROUTPUT ON
SQL> GET test.sql
1  DECLARE
2      TYPE EmpTabTyp IS TABLE OF emp%ROWTYPE;
3      emp_tab EmpTabTyp := EmpTabTyp(NULL); -- initialize
4      t1 NUMBER(5);
5      t2 NUMBER(5);
6      t3 NUMBER(5);
7      PROCEDURE get_time (t OUT NUMBER) IS
8      BEGIN SELECT TO_CHAR(SYSDATE, 'SSSS') INTO t FROM dual; END;
9      PROCEDURE do_nothing1 (tab IN OUT EmpTabTyp) IS
10     BEGIN NULL; END;
```

```

11     PROCEDURE do_nothing2 (tab IN OUT NOCOPY EmpTabTyp) IS
12     BEGIN NULL; END;
13 BEGIN
14     SELECT * INTO emp_tab(1) FROM emp WHERE empno = 7788;
15     emp_tab.EXTEND(24999, 1); -- copy element 1 into 2..25000
16     get_time(t1);
17     do_nothing1(emp_tab); -- pass IN OUT parameter
18     get_time(t2);
19     do_nothing2(emp_tab); -- pass IN OUT NOCOPY parameter
20     get_time(t3);
21     dbms_output.put_line('Call Duration (secs)');
22     dbms_output.put_line('-----');
23     dbms_output.put_line('Just IN OUT: ' || TO_CHAR(t2 - t1));
24     dbms_output.put_line('With NOCOPY: ' || TO_CHAR(t3 - t2));
25* END;
SQL> /
Call Duration (secs)
-----
Just IN OUT: 21
With NOCOPY: 0
    
```

The Trade-Off for Better Performance with NOCOPY

NOCOPY lets you trade well-defined exception semantics for better performance. Its use affects exception handling in the following ways:

- Because NOCOPY is a hint, not a directive, the compiler can pass NOCOPY parameters to a subprogram by value or by reference. So, if the subprogram exits with an unhandled exception, you cannot rely on the values of the NOCOPY actual parameters.
- By default, if a subprogram exits with an unhandled exception, the values assigned to its OUT and IN OUT formal parameters are *not* copied into the corresponding actual parameters, and changes appear to roll back. However, when you specify NOCOPY, assignments to the formal parameters immediately affect the actual parameters as well. So, if the subprogram exits with an unhandled exception, the (possibly unfinished) changes are not "rolled back."
- Currently, RPC protocol lets you pass parameters only by value. So, exception semantics can change silently when you partition applications. For example, if you move a local procedure with NOCOPY parameters to a remote site, those parameters will no longer be passed by reference.

Also, the use of NOCOPY increases the likelihood of parameter aliasing. For more information, see ["Understanding Subprogram Parameter Aliasing"](#) on page 8-21.

Restrictions on NOCOPY

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 index-by table. This restriction does not apply to entire index-by tables.
- The actual parameter is constrained (by scale or NOT NULL for example). This restriction does not extend to constrained elements or attributes. Also, it does not apply to size-constrained character strings.
- 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 involved in an external or remote procedure call.

Using Default Values for Subprogram Parameters

As the example below shows, you can initialize IN parameters to default values. That way, you can pass different numbers of actual parameters to a subprogram, accepting or overriding the default values as you please. Moreover, you can add new formal parameters without having to change every call to the subprogram.

```
PROCEDURE create_dept (
    new_dname VARCHAR2 DEFAULT 'TEMP' ,
    new_loc   VARCHAR2 DEFAULT 'TEMP') IS
BEGIN
    INSERT INTO dept
        VALUES (deptno_seq.NEXTVAL, new_dname, new_loc);
    ...
END;
```

If an actual parameter is not passed, the default value of its corresponding formal parameter is used. Consider the following calls to create_dept:

```
create_dept;
create_dept('MARKETING');
create_dept('MARKETING', 'NEW YORK');
```

The first call passes no actual parameters, so both default values are used. The second call passes one actual parameter, so the default value for `new_loc` is used. The third call passes two actual parameters, so neither default value is used.

Usually, you can use positional notation to override the default values of formal parameters. However, you cannot skip a formal parameter by leaving out its actual parameter. For example, the following call incorrectly associates the actual parameter `'NEW YORK'` with the formal parameter `new_dname`:

```
create_dept('NEW YORK'); -- incorrect
```

You cannot solve the problem by leaving a placeholder for the actual parameter. For example, the following call is not allowed:

```
create_dept(, 'NEW YORK'); -- not allowed
```

In such cases, you must use named notation, as follows:

```
create_dept(new_loc => 'NEW YORK');
```

Also, you cannot assign a null to an uninitialized formal parameter by leaving out its actual parameter. For example, given the declaration

```
DECLARE
    FUNCTION gross_pay (
        emp_id    IN NUMBER,
        st_hours  IN NUMBER DEFAULT 40,
        ot_hours  IN NUMBER) RETURN REAL IS
    BEGIN
        ...
    END;
```

the following function call does not assign a null to `ot_hours`:

```
IF gross_pay(emp_num) > max_pay THEN ... -- not allowed
```

Instead, you must pass the null explicitly, as in

```
IF gross_pay(emp_num, ot_hour => NULL) > max_pay THEN ...
```

or you can initialize `ot_hours` to `NULL`, as follows:

```
ot_hours IN NUMBER DEFAULT NULL;
```

Finally, when creating a stored subprogram, you cannot use host variables (bind variables) in the `DEFAULT` clause. The following SQL*Plus example causes a *bad*

bind variable error because at the time of creation, `num` is just a placeholder whose value might change:

```
SQL> VARIABLE num NUMBER
SQL> CREATE FUNCTION gross_pay (emp_id IN NUMBER DEFAULT :num, ...
```

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, in which case 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 the example below, procedure `add_entry` refers to varray `lexicon` in two different ways: as a parameter and as a global variable. So, when `add_entry` is called, the identifiers `word_list` and `lexicon` name the same varray.

```
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);
    -- prints 'aardvark' if parameter was passed by value
    -- prints 'aardwolf' if parameter was passed by reference
END;
```

The result depends on the method of parameter passing chosen by the compiler. If the compiler chooses the by-value method, `word_list` and `lexicon` are separate copies of the same varray. So, changing one does not affect the other. But, if the compiler chooses the by-reference method, `word_list` and `lexicon` are just different names for the same varray. (Hence, the term "aliasing.") So, changing the value of `lexicon(1)` also changes the value of `word_list(1)`.

Aliasing can also occur when the same actual parameter appears more than once in a subprogram call. In the example below, `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.

```
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. Consider the example below. After the assignment, `emp_cv2` is an alias of `emp_cv1` because both point to the same query work area. So, both can alter its state. That is why the first fetch from `emp_cv2` fetches the third row (not the first) and why the second fetch from `emp_cv2` fails after you close `emp_cv1`.

```
PROCEDURE get_emp_data (
  emp_cv1 IN OUT EmpCurTyp,
  emp_cv2 IN OUT EmpCurTyp) IS
  emp_rec emp%ROWTYPE;
BEGIN
  OPEN emp_cv1 FOR SELECT * FROM emp;
  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;
    FETCH emp_cv2 INTO emp_rec; -- raises INVALID_CURSOR
    ...
END;
```

Overloading Subprogram Names

PL/SQL lets you *overload* subprogram names and type methods. That is, you can use the same name for several different subprograms as long as their formal parameters differ in number, order, or datatype family.

Suppose you want to initialize the first n rows in two index-by tables that were declared as follows:

```

DECLARE
    TYPE DateTabTyp IS TABLE OF DATE INDEX BY BINARY_INTEGER;
    TYPE RealTabTyp IS TABLE OF REAL INDEX BY BINARY_INTEGER;
    hiredate_tab DateTabTyp;
    sal_tab RealTabTyp;
BEGIN
    ...
END;
```

You might write the following procedure to initialize the index-by table named `hiredate_tab`:

```

PROCEDURE initialize (tab OUT DateTabTyp, n INTEGER) IS
BEGIN
    FOR i IN 1..n LOOP
        tab(i) := SYSDATE;
    END LOOP;
END initialize;
```

And, you might write the next procedure to initialize the index-by table named `sal_tab`:

```

PROCEDURE initialize (tab OUT RealTabTyp, n INTEGER) IS
BEGIN
    FOR i IN 1..n LOOP
        tab(i) := 0.0;
    END LOOP;
END initialize;
```

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, or package. PL/SQL determines which of the two procedures is being called by checking their formal parameters. In the following example, the version of `initialize` that PL/SQL uses depends on whether you call the procedure with a `DateTabTyp` or `RealTabTyp` parameter:

```
DECLARE
    TYPE DateTabTyp IS TABLE OF DATE INDEX BY BINARY_INTEGER;
    TYPE RealTabTyp IS TABLE OF REAL INDEX BY BINARY_INTEGER;
    hiredate_tab DateTabTyp;
    comm_tab RealTabTyp;
    indx BINARY_INTEGER;
    PROCEDURE initialize (tab OUT DateTabTyp, n INTEGER) IS
    BEGIN
        ...
    END;
    PROCEDURE initialize (tab OUT RealTabTyp, n INTEGER) IS
    BEGIN
        ...
    END;
BEGIN
    indx := 50;
    initialize(hiredate_tab, indx); -- calls first version
    initialize(comm_tab, indx);    -- calls second version
    ...
END;
```

Restrictions on Overloading

Only local or packaged subprograms, or type methods, can be overloaded. Therefore, you cannot overload standalone subprograms. Also, 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:

```
DECLARE
    ...
    PROCEDURE reconcile (acct_no IN INTEGER) IS
    BEGIN ... END;
    PROCEDURE reconcile (acct_no OUT INTEGER) IS
    BEGIN ... END;
```


You cannot overload two subprograms if their formal parameters differ only in datatype and the different datatypes are in the same family. For instance, you cannot overload the following procedures because the datatypes `INTEGER` and `REAL` are in the same family:

```
DECLARE
    ...
    PROCEDURE charge_back (amount INTEGER) IS
    BEGIN ... END;
    PROCEDURE charge_back (amount REAL) IS
    BEGIN ... END;
```

Likewise, you cannot overload two subprograms if their formal parameters differ only in subtype and the different subtypes are based on types in the same family. For example, you cannot overload the following procedures because the base types `CHAR` and `LONG` are in the same family:

```
DECLARE
    SUBTYPE Delimiter IS CHAR;
    SUBTYPE Text IS LONG;
    ...
    PROCEDURE scan (x Delimiter) IS
    BEGIN ... END;
    PROCEDURE scan (x Text) IS
    BEGIN ... END;
```

Finally, you cannot overload two functions that differ only in return type (the datatype of the return value) even if the types are in different families. For example, you cannot overload the following functions:

```
DECLARE
    ...
    FUNCTION acct_ok (acct_id INTEGER) RETURN BOOLEAN IS
    BEGIN ... END;
    FUNCTION acct_ok (acct_id INTEGER) RETURN INTEGER IS
    BEGIN ... END;
```

How Subprogram Calls Are Resolved

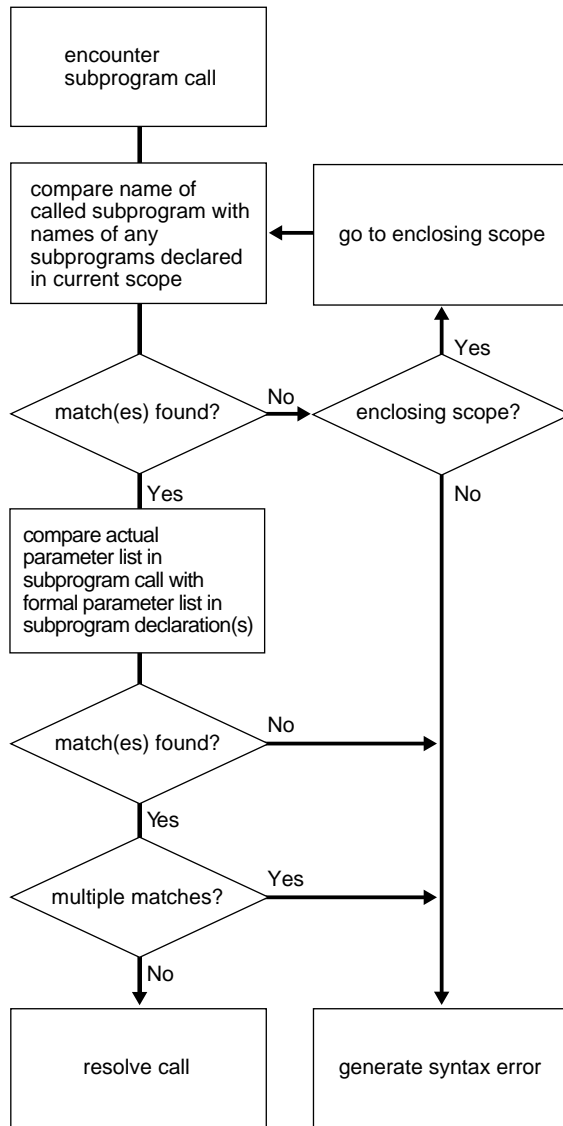
Figure 8–1 shows how the PL/SQL compiler resolves subprogram calls. When the compiler encounters a procedure or function call, it tries to find a declaration that matches the call. The compiler searches first in the current scope and then, if necessary, in successive enclosing scopes. The compiler stops searching if 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. That is, 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.

In the following example, you call the enclosing procedure `swap` from within the function `reconcile`. However, the compiler generates an error because neither declaration of `swap` within the current scope matches the procedure call:

```
PROCEDURE swap (n1 NUMBER, n2 NUMBER) IS
    num1 NUMBER;
    num2 NUMBER;
    FUNCTION balance (...) RETURN REAL IS
        PROCEDURE swap (d1 DATE, d2 DATE) IS
            BEGIN
                ...
            END;
        PROCEDURE swap (b1 BOOLEAN, b2 BOOLEAN) IS
            BEGIN
                ...
            END;
    BEGIN
        ...
        swap(num1, num2);
        RETURN ...
    END balance;
BEGIN
    ...
END;
```

Figure 8-1 How the PL/SQL Compiler Resolves Calls



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, here we create a type hierarchy with 3 levels:

```
CREATE 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);
```

We declare two overloaded instances of a function, where the only difference in argument types is their position in this type hierarchy:

```
CREATE PACKAGE p IS
  FUNCTION foo (arg super_t) RETURN NUMBER;
  FUNCTION foo (arg sub_t) RETURN NUMBER;
END;
/
CREATE PACKAGE BODY p IS
  FUNCTION foo (arg super_t) RETURN NUMBER IS BEGIN RETURN 1; END;
  FUNCTION foo (arg sub_t) RETURN NUMBER IS BEGIN RETURN 2; END;
END;
/
```

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.

```
SQL> set serveroutput on
SQL> declare
v final_t := final_t(1,2,3);
begin
  dbms_output.put_line(p.foo(v));
end;
/
2
```

In the previous example, the choice of which instance to call is made at compile time. In the following example, this choice is made dynamically.

```
CREATE TYPE super_t2 AS object
  (n NUMBER, MEMBER FUNCTION foo RETURN NUMBER) NOT final;
/
CREATE TYPE BODY super_t2 AS
  MEMBER FUNCTION foo RETURN NUMBER IS BEGIN RETURN 1; END; END;
/
CREATE OR replace TYPE sub_t2 under super_t2
  (n2 NUMBER,
   OVERRIDING MEMBER FUNCTION foo RETURN NUMBER) NOT final;
/
CREATE TYPE BODY sub_t2 AS
  OVERRIDING MEMBER FUNCTION foo RETURN NUMBER IS BEGIN RETURN 2;
END;
END;
/
CREATE OR replace TYPE final_t2 under sub_t2
  (n3 NUMBER);
/
```

We declare `v` as an instance of `super_t2`, but because we assign a value of `sub_t2` to it, the appropriate instance of the function is called. This feature is known as **dynamic dispatch**.

```
SQL> set serveroutput on

declare
  v super_t2 := final_t2(1,2,3);
begin
  dbms_output.put_line(v.foo);
```

```
end;  
/  
2
```

Accepting and Returning Multiple Rows with Table Functions

This section describes table functions. It also explains the generic datatypes `ANYTYPE`, `ANYDATA`, and `ANYDATASET`, which are likely to be used with table functions.

Major topics covered are:

- [Overview of Table Functions](#)
- [Writing a Pipelined Table Function](#)
- [Parallelizing Table Functions](#)
- [How Table Functions Stream their Input Data](#)

Overview of Table Functions

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. You use a table function like the name of a database table, in the `FROM` clause 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:

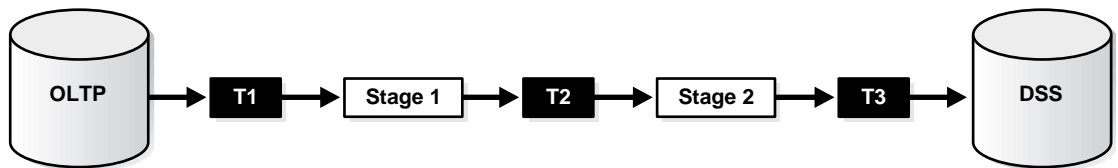
- By enabling multi-threaded, concurrent execution of table functions
- By eliminating intermediate staging between processes
- By improving query response time: With non-pipelined table functions, the entire collection returned by a table function must be constructed and returned to the server before 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

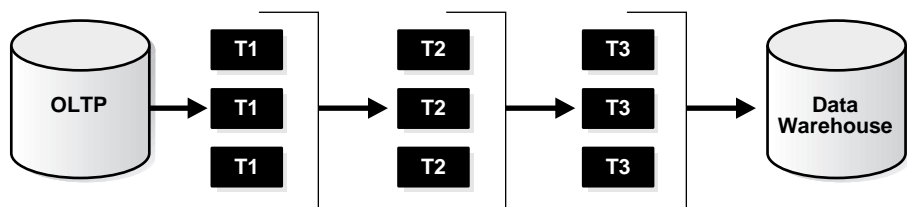
Figure 8–2 shows a typical data-processing scenario in which data goes through several (in this case, three) transformations, implemented by table functions, before finally being loaded into a database. In this scenario, the table functions are not parallelized, and the entire result collection must be staged using a temporary table after each transformation.

Figure 8–2 Typical Data Processing with Unparallelized, Unpipelined Table Functions



By contrast, Figure 8–3, below, shows how streaming and parallel execution can streamline the same scenario.

Figure 8–3 Data Processing Using Pipelining and Parallel Execution



What Are Table Functions?

Table functions return a collection type instance representing rows in a table, and can be queried like a table by calling the function in the `FROM` clause of a query. Table functions use the `TABLE` keyword.

The following example shows a table function `GetBooks` that takes a CLOB as input and returns an instance of the collection type `BookSet_t`. The CLOB column stores a catalog listing of books in some format (either proprietary or following a standard such as XML). The table function returns all the catalogs and their corresponding book listings.

The collection type `BookSet_t` is defined as:

```
CREATE TYPE Book_t AS OBJECT
( name VARCHAR2(100),
  author VARCHAR2(30),
  abstract VARCHAR2(1000));

CREATE TYPE BookSet_t AS TABLE OF Book_t;
```

The CLOBs are stored in a table `Catalogs`:

```
CREATE TABLE Catalogs
( name VARCHAR2(30),
  cat CLOB);
```

Function `GetBooks` is defined as follows:

```
CREATE FUNCTION GetBooks(a CLOB) RETURN BookSet_t;
```

The query below returns all the catalogs and their corresponding book listings.

```
SELECT c.name, Book.name, Book.author, Book.abstract
FROM Catalogs c, TABLE(GetBooks(c.cat)) Book;
```

What Are Pipelined Table Functions?

Data is said to be **pipelined** if it is consumed by a consumer (transformation) as soon as the producer (transformation) produces it, without being staged in tables or a cache before being input to the next transformation.

Pipelining enables a table function to return rows faster and can reduce the memory required to cache a table function's results.

A pipelined table function can return the table function's result collection in subsets. The returned collection behaves like a stream that can be fetched from on demand. This makes it possible to use a table function like a virtual table.

Pipelined table functions can be implemented in two ways:

- **Native PL/SQL approach:** The consumer and producers can run on separate execution threads (either in the same or different process context) and communicate through a pipe or queuing mechanism. This approach is similar to co-routine execution.
- **Interface approach:** The consumer and producers run on the same execution thread. Producer explicitly returns the control back to the consumer after producing a set of results. In addition, the producer caches the current state so that it can resume where it left off when the consumer invokes it again. The interface approach requires you to implement a set of well-defined interfaces in a procedural language. For details on the interface approach, see the Data Cartridges User's Guide.

In the rest of this chapter, the term **table function** is used to refer to a *pipelined* table function—that is, a table function that returns a collection in an iterative, pipelined way.

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 (using either the interface approach or the native PL/SQL approach).

For example, the following code sketches the declarations that define a `StockPivot` function. This function converts a row of the type (`Ticker`, `OpenPrice`, `ClosePrice`) into two rows of the form (`Ticker`, `PriceType`, `Price`). Calling `StockPivot` for the row ("ORCL", 41, 42) generates two rows: ("ORCL", "O", 41) and ("ORCL", "C", 42).

Input data for the table function might come from a source such as table `StockTable`:

```
CREATE TABLE StockTable (
  ticker VARCHAR(4),
  open_price NUMBER,
  close_price NUMBER
);
```

Here are the declarations. See "[PIPELINED IS...](#)" on page 8-35 for the function bodies.

```
-- Create the types for the table function's output collection
-- and collection elements
```

```

CREATE TYPE TickerType AS OBJECT
(
  ticker VARCHAR2(4),
  PriceType VARCHAR2(1),
  price NUMBER
);

CREATE TYPE TickerTypeSet AS TABLE OF TickerType;

-- Define the ref cursor type

CREATE PACKAGE refcur_pkg IS
  TYPE refcur_t IS REF CURSOR RETURN StockTable%ROWTYPE;
END refcur_pkg;
/

-- Create the table function

CREATE FUNCTION StockPivot(p refcur_pkg.refcur_t) RETURN TickerTypeSet
PIPELINED ... ;
/

```

Here is an example of a query that uses the `StockPivot` table function:

```
SELECT * FROM TABLE(StockPivot(CURSOR(SELECT * FROM StockTable)));
```

In the query above, the pipelined table function `StockPivot` fetches rows from the `CURSOR` subquery `SELECT * FROM StockTable`, 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 the example above, the referenced cursor is already open when the function begins executing.

Writing a Pipelined Table Function

You declare a pipelined table function by specifying the `PIPELINED` keyword. This keyword indicates that the function will return rows iteratively. The return type of the pipelined table function must be a collection type, such as a nested table or a varray. You can declare this collection at the schema level, or inside a package. Inside the function, you return individual elements of the collection type.

For example, here are declarations for two pipelined table functions. (The function bodies are shown in later examples.)

```
CREATE FUNCTION GetBooks(cat CLOB) RETURN BookSet_t
    PIPELINED IS ...;

CREATE FUNCTION StockPivot(p refcur_pkg.refcur_t) RETURN TickerTypeSet
    PIPELINED IS...;
```

Returning Results from Table Functions

In PL/SQL, the `PIPE ROW` statement causes a 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.) For example:

```
CREATE FUNCTION StockPivot(p refcur_pkg.refcur_t) RETURN TickerTypeSet
PIPELINED IS
    out_rec TickerType := TickerType(NULL,NULL,NULL);
    in_rec p%ROWTYPE;
BEGIN
    LOOP
        FETCH p INTO in_rec;
        EXIT WHEN p%NOTFOUND;
        -- first row
        out_rec.ticker := in_rec.Ticker;
        out_rec.PriceType := 'O';
        out_rec.price := in_rec.OpenPrice;
        PIPE ROW(out_rec);
        -- second row
        out_rec.PriceType := 'C';
        out_rec.Price := in_rec.ClosePrice;
        PIPE ROW(out_rec);
    END LOOP;
    CLOSE p;
    RETURN;
END;
```

In the example, 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 must 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.

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: *Oracle9i Supplied 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).

Querying Table Functions

Pipelined table functions are used in the `FROM` clause of `SELECT` statements. The result rows are retrieved by Oracle iteratively from the table function implementation. For example:

```
SELECT x.Ticker, x.Price
FROM TABLE(StockPivot(CURSOR(SELECT * FROM StockTable))) x
WHERE x.PriceType='C';
```

Note: A table function returns a collection. In some cases, such as when a ref cursor variable is passed to a table function from a PL/SQL block, you may need a `CAST` operator around the table function.

Optimizing Multiple Calls to Table Functions

Multiple invocations of a 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());
```

However, if the output of a table function is determined solely by the values passed into it as arguments, such that the function always produces exactly the same result value for each respective combination of values passed in, you can declare the function `DETERMINISTIC`, and Oracle will automatically buffer rows for it. Note, though, that the database has no way of knowing whether a function marked `DETERMINISTIC` really *is* `DETERMINISTIC`, and if one is not, results will be unpredictable.

Fetching from the Results of 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:

```
BEGIN
  OPEN r FOR SELECT * FROM TABLE(f(CURSOR(SELECT * FROM tab)));
  SELECT * BULK COLLECT INTO rec_tab FROM TABLE(g(r));
END;
```

```
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 empno FROM tab)));
```

In the example above, 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.

Using Multiple REF CURSOR Input Variables

PL/SQL functions can accept multiple `REF CURSOR` input variables:

```
CREATE FUNCTION g(p1 pkg.refcur_t1, p2 pkg.refcur_t2) RETURN...
  PIPELINED ... ;
```

Function `g` can be invoked as follows:

```
SELECT * FROM TABLE(g(CURSOR(SELECT empno FROM tab),
    CURSOR(SELECT * FROM emp)));
```

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(...)))));
```

Explicitly Opening a REF CURSOR for a Query

You can explicitly open a REF CURSOR for a query and pass it as a parameter to a table function:

```
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.

Performing DML Operations Inside Table Functions

To execute DML statements, a table function must be declared with the autonomous transaction pragma . This pragma causes the function to execute in an autonomous transaction not shared by other processes.

Use the following syntax to declare a table function with the autonomous transaction pragma:

```
CREATE FUNCTION f(p SYS_REFCURSOR) return CollType PIPELINED IS
  PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN ... END;
```

During parallel execution, each instance of the table function creates an independent transaction.

Performing DML Operations on Table Functions

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 Table Functions

Exception handling in table functions works just as it does with ordinary user-defined 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.

Parallelizing Table Functions

For a table function to be executed in parallel, it must have a partitioned input parameter. Parallelism is turned on for a table function if, and only if, both the following conditions are met:

- The function has a `PARALLEL_ENABLE` clause in its declaration

- Exactly one `REF CURSOR` argument is specified with a `PARTITION BY` clause
 If the `PARTITION BY` clause is not specified for any input `REF CURSOR` as part of the `PARALLEL_ENABLE` clause, the SQL compiler cannot determine how to partition the data correctly. Note that only strongly typed `REF CURSOR` arguments can be specified in the `PARTITION BY` clause, unless you use `PARTITION BY ANY`.

Parallel Execution of Table Functions

With parallel execution of a function that appears in the `SELECT` list, execution of the function is pushed down to and conducted by multiple slave **scan** processes. These each execute the function on a segment of the function's input data.

For example, the query

```
SELECT f(col1) FROM tab;
```

is parallelized if `f` is a pure function. The SQL executed by a slave scan process is similar to:

```
SELECT f(col1) FROM tab WHERE ROWID BETWEEN :b1 AND :b2;
```

Each slave scan operates on a range of rowids and applies function `f` to each contained row. Function `f` is then executed by the scan processes; it does not run independently of them.

Unlike a function that appears in the `SELECT` list, a table function is called in the `FROM` clause and returns a collection. This affects the way that table function input data is partitioned among slave scans because the partitioning approach must be appropriate for the operation that the table function performs. (For example, an `ORDER BY` operation requires input to be range-partitioned, whereas a `GROUP BY` operation requires input to be hash partitioned.)

A table function itself specifies in its declaration the partitioning approach that is appropriate for it. (See "[Input Data Partitioning](#)" on page 8-42.) The function is then executed in a two-stage operation. First, one set of slave processes partitions the data as directed in the function's declaration; then a second set of slave processes executes the table function in parallel on the partitioned data.

For example, the table function in the following query has a `REF CURSOR` parameter:

```
SELECT * FROM TABLE(f(CURSOR(SELECT * FROM tab)));
```

The scan is performed by one set of slave processes, which redistributes the rows (based on the partitioning method specified in the function declaration) to a second set of slave processes that actually executes function *f* in parallel.

Input Data Partitioning

The table function declaration can specify data partitioning for exactly one REF CURSOR parameter. The syntax to do this is as follows:

```
CREATE FUNCTION f(p ref cursor type) RETURN rec_tab_type PIPELINED
  PARALLEL_ENABLE(PARTITION p BY [{HASH | RANGE} (column list) | ANY ]) IS
BEGIN ... END;
```

The PARTITION...BY phrase in the PARALLEL_ENABLE clause specifies which one of the input cursors to partition and what columns to use for partitioning.

When explicit column names are specified in the column list, the partitioning method can be RANGE or HASH. The input rows will be hash- or range-partitioned on the columns specified.

The ANY keyword indicates that the function behavior is independent of the partitioning of the input data. When this keyword is used, the runtime system randomly partitions the data among the slaves. This keyword is appropriate for use with functions that take in one row, manipulate its columns, and generate output row(s) based on the columns of this row only.

For example, the pivot-like function `StockPivot` shown below takes as input a row of the type:

```
(Ticker varchar(4), OpenPrice number, ClosePrice number)
```

and generates rows of the type:

```
(Ticker varchar(4), PriceType varchar(1), Price number).
```

So the row ("ORCL", 41, 42) generates two rows ("ORCL", "O", 41) and ("ORCL", "C", 42).

```
CREATE FUNCTION StockPivot(p refcur_pkg.refcur_t) RETURN rec_tab_type PIPELINED
  PARALLEL_ENABLE(PARTITION p BY ANY) IS
  ret_rec rec_type;
BEGIN
  FOR rec IN p LOOP
    ret_rec.Ticker := rec.Ticker;
    ret_rec.PriceType := "O";
    ret_rec.Price := rec.OpenPrice;
```

```

PIPE ROW(ret_rec);

ret_rec.Ticker := rec.Ticker;  -- Redundant; not required
ret_rec.PriceType := "C";
ret_rec.Price := rec.ClosePrice;
push ret_rec;
END LOOP;
RETURN;
END;

```

The function `f` can be used to generate another table from `Stocks` table in the following manner:

```

INSERT INTO AlternateStockTable
  SELECT * FROM
  TABLE(StockPivot(CURSOR(SELECT * FROM StockTable)));

```

If the `StockTable` is scanned in parallel and partitioned on `OpenPrice`, then the function `StockPivot` is combined with the data-flow operator doing the scan of `StockTable` and thus sees the same partitioning.

If, on the other hand, the `StockTable` is not partitioned, and the scan on it does not execute in parallel, the insert into `AlternateStockTable` also runs sequentially. Here is a slightly more complex example:

```

INSERT INTO AlternateStockTable
  SELECT *
    FROM TABLE(f(CURSOR(SELECT * FROM Stocks))),
         TABLE(g(CURSOR( ... )))
  WHERE join_condition;

```

where `g` is defined to be:

```

CREATE FUNCTION g(p refcur_pkg.refcur_t) RETURN ... PIPELINED
  PARALLEL_ENABLE (PARTITION p BY ANY)
BEGIN ... END;

```

If function `g` runs in parallel and is partitioned by `ANY`, then the parallel insert can belong in the same data-flow operator as `g`.

Whenever the `ANY` keyword is specified, the data is partitioned randomly among the slaves. This effectively means that the function is executed in the same slave set which does the scan associated with the input parameter.

No redistribution or repartitioning of the data is required here. If the cursor `p` itself is not parallelized, the incoming data is randomly partitioned on the columns in the column list. The round-robin table queue is used for this partitioning.

Parallel Execution of Leaf-level Table Functions

To use parallel execution with a function that produces multiple rows, but does not need to accept multiple rows as input and so does not require a `REF CURSOR`, arrange things so as to create a need for a `REF CURSOR`. That way, the function will have some way to partition the work.

For example, suppose that you want a function to read a set of external files in parallel and return the records they contain. To provide work for a `REF CURSOR`, you might first create a table and populate it with the filenames. A `REF CURSOR` over this table can then be passed as a parameter to the table function (`readfiles`). The following code shows how this might be done:

```
CREATE TABLE filetab(filename VARCHAR(20));

INSERT INTO filetab VALUES('file0');
INSERT INTO filetab VALUES('file1');
...
INSERT INTO filetab VALUES('fileN');

SELECT * FROM
    TABLE(readfiles(CURSOR(SELECT filename FROM filetab)));

CREATE FUNCTION readfiles(p pkg.rc_t) RETURN coll_type
    PARALLEL_ENABLE(PARTITION p BY ANY) IS
    ret_rec rec_type;
BEGIN
    FOR rec IN p LOOP
        done := FALSE;
        WHILE (done = FALSE) LOOP
            done := readfilerecord(rec.filename, ret_rec);
            PIPE ROW(ret_rec);
        END LOOP;
    END LOOP;
    RETURN;
END;
```

How Table Functions Stream their Input Data

The way in which a table function orders or clusters rows that it fetches from cursor arguments is called **data streaming**. A function can stream its input data in any of the following ways:

- Place no restriction on the ordering of the incoming rows
- Order them on a particular key column or columns
- Cluster them on a particular key

Clustering causes rows that have the same key values to appear together but does not otherwise do any ordering of rows.

You control the behavior of the input stream using the following syntax:

```
FUNCTION f(p ref_cursor_type) RETURN tab_rec_type [PIPELINED]
    {[ORDER | CLUSTER] BY column_list}
    PARALLEL_ENABLE({PARTITION p BY
        [ANY | (HASH | RANGE) column_list]})
IS
BEGIN ... END;
```

Input streaming may be specified for either sequential or parallel execution of a function.

If an `ORDER BY` or `CLUSTER BY` clause is not specified, rows are input in a (random) order.

Note: The semantics of `ORDER BY` are different for parallel execution from the semantics of the `ORDER BY` clause in a SQL statement. In a SQL statement, the `ORDER BY` clause globally orders the entire data set. In a table function, the `ORDER BY` clause orders the respective rows local to each instance of the table function running on a slave.

The following example illustrates the syntax for ordering the input stream. In the example, function `f` takes in rows of the kind `(Region, Sales)` and returns rows of the form `(Region, AvgSales)`, showing average sales for each region.

```
CREATE FUNCTION f(p ref_cursor_type) RETURN tab_rec_type PIPELINED
    CLUSTER BY Region
    PARALLEL_ENABLE(PARTITION p BY Region) IS
ret_rec rec_type;
```

```
    cnt number;  
    sum number;  
BEGIN  
  FOR rec IN p LOOP  
    IF (first rec in the group) THEN  
      cnt := 1;  
      sum := rec.Sales;  
    ELSIF (last rec in the group) THEN  
      IF (cnt <> 0) THEN  
        ret_rec.Region := rec.Region;  
        ret_rec.AvgSales := sum/cnt;  
        PIPE ROW(ret_rec);  
      END IF;  
    ELSE  
      cnt := cnt + 1;  
      sum := sum + rec.Sales;  
    END IF;  
  END LOOP;  
  RETURN;  
END;
```

Choosing Between Partitioning and Clustering for Parallel Execution

Partitioning and clustering are easily confused, but they do different things. For example, sometimes partitioning can be sufficient without clustering in parallel execution.

Consider a function `SmallAggr` that performs in-memory aggregation of salary for each `department_id`, where `department_id` can be either 1, 2, or 3. The input rows to the function can be partitioned by `HASH` on `department_id` such that all rows with `department_id` equal to 1 go to one slave, all rows with `department_id` equal to 2 go to another slave, and so on.

The input rows do not need to be clustered on `department_id` to perform the aggregation in the function. Each slave could have a `1x3` array `SmallSum[1..3]` in which the aggregate sum for each `department_id` is added in memory into `SmallSum[department_id]`. On the other hand, if the number of unique values of `department_id` were very large, you would want to use clustering to compute department aggregates and write them to disk one `department_id` at a time.

Invoker Rights Versus Definer Rights

By default, stored procedures and SQL methods execute with the privileges of their owner, not their current user. Such *definer-rights* subprograms are bound to the schema in which they reside. For example, assume that `dept` tables reside in schemas `scott` and `blake`, and that the following standalone procedure resides in schema `scott`:

```
CREATE PROCEDURE create_dept (  
    my_deptno NUMBER,  
    my_dname  VARCHAR2,  
    my_loc    VARCHAR2) AS  
BEGIN  
    INSERT INTO dept VALUES (my_deptno, my_dname, my_loc);  
END;
```

Also assume that user `scott` has granted the `EXECUTE` privilege on this procedure to user `blake`. When user `blake` calls the procedure, the `INSERT` statement executes with the privileges of user `scott`. Also, the unqualified references to table `dept` is resolved in schema `scott`. So, even though user `blake` called the procedure, it updates the `dept` table in schema `scott`.

How can subprograms in one schema manipulate objects in another schema? One way is to fully qualify references to the objects, as in

```
INSERT INTO blake.dept ...
```

However, that hampers portability. As a workaround, you can define the schema name as a variable in SQL*Plus.

Another way is to copy the subprograms into the other schema. However, that hampers maintenance.

A better way is to use the `AUTHID` clause, which enables stored procedures and SQL methods to execute with the privileges and schema context of their current user.

Such *invoker-rights* subprograms are not bound to a particular schema. They can be run by a variety of users. The following version of procedure `create_dept` executes with the privileges of its current user and inserts rows into the `dept` table in that user's schema:

```
CREATE PROCEDURE create_dept (  
    my_deptno NUMBER,  
    my_dname  VARCHAR2,  
    my_loc    VARCHAR2) AUTHID CURRENT_USER AS  
BEGIN
```

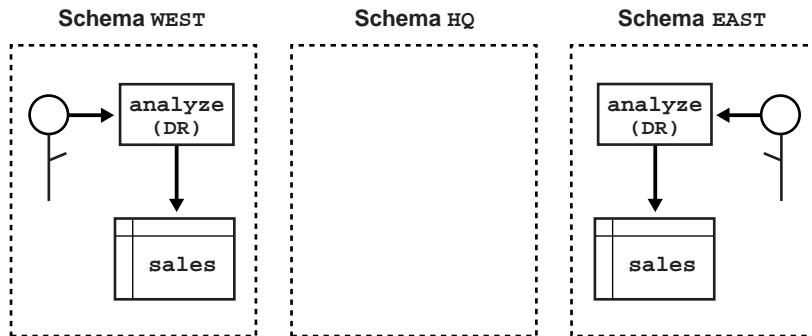
```
INSERT INTO dept VALUES (my_deptno, my_dname, my_loc);  
END;
```

Advantages of Invoker Rights

Invoker-rights subprograms let you reuse code and centralize application logic. They are especially useful in applications that store data in different schemas. In such cases, multiple users can manage their own data using a single code base.

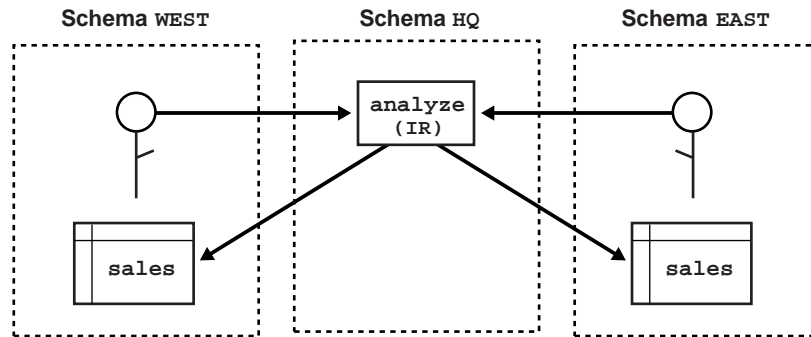
Consider a company that uses a definer-rights (DR) procedure to analyze sales. To provide local sales statistics, procedure `analyze` must access `sales` tables that reside at each regional site. So, as [Figure 8-4](#) shows, the procedure must also reside at each regional site. This causes a maintenance problem.

Figure 8-4 *Definer-Rights Problem: Multiple Copies of Identical Procedures*



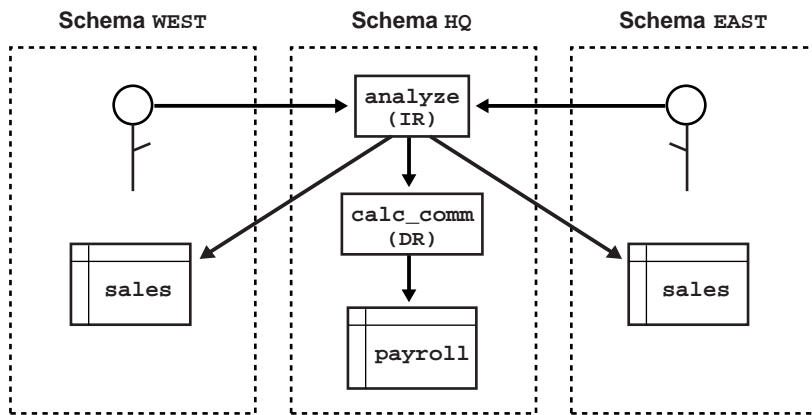
To solve the problem, the company installs an invoker-rights (IR) version of procedure `analyze` at headquarters. Now, as [Figure 8-5](#) shows, all regional sites can use the same procedure to query their own `sales` tables.

Figure 8–5 *Invoker-Rights Solution: Single Procedure that Operates on Multiple Schemas*



To restrict access to sensitive data, you can have an invoker-rights subprogram call a definer-rights subprogram. Suppose headquarters would like procedure `analyze` to calculate sales commissions and update a central `payroll` table.

That presents a problem because current users of `analyze` should not have direct access to the `payroll` table, which stores employee salaries and other sensitive data. As [Figure 8–6](#) shows, the solution is to have procedure `analyze` call definer-rights procedure `calc_comm`, which in turn updates the `payroll` table.

Figure 8–6 Controlled Access to an Invoker-Rights Subprogram

Specifying the Privileges for a Subprogram with the AUTHID Clause

To implement invoker 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. The header syntax is

```
-- standalone function
CREATE [OR REPLACE] FUNCTION [schema_name.]function_name
[(parameter_list)] RETURN datatype
[AUTHID {CURRENT_USER | DEFINER}] {IS | AS}

-- standalone procedure
CREATE [OR REPLACE] PROCEDURE [schema_name.]procedure_name
[(parameter_list)]
[AUTHID {CURRENT_USER | DEFINER}] {IS | AS}

-- package spec
CREATE [OR REPLACE] PACKAGE [schema_name.]package_name
[AUTHID {CURRENT_USER | DEFINER}] {IS | AS}

-- object type spec
CREATE [OR REPLACE] TYPE [schema_name.]object_type_name
[AUTHID {CURRENT_USER | DEFINER}] {IS | AS} OBJECT
```

where `DEFINER` is the default option. In a package or object type, the `AUTHID` clause applies to all subprograms.

Note: Most supplied PL/SQL packages (such as `DBMS_LOB`, `DBMS_PIPE`, `DBMS_ROWID`, `DBMS_SQL`, and `UTL_REF`) are invoker-rights packages.

Who Is the Current User During Subprogram Execution?

In a sequence of calls, if an invoker-rights subprogram is the first subprogram called, the current user is the session user. That remains true until a definer-rights subprogram is called, in which case the owner of that subprogram becomes the current user. If the definer-rights subprogram calls any invoker-rights subprograms, they execute with the privileges of the owner. When the definer-rights subprogram exits, control reverts to the previous current user.

How External References Are Resolved in Invoker-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 below refers to the packaged function `balance`. This external reference is resolved in the schema of the owner of procedure `reconcile`.

```
CREATE PROCEDURE reconcile (acc_id IN INTEGER)
  AUTHID CURRENT_USER AS
  bal NUMBER;
BEGIN
  bal := bank_ops.balance(acct_id);
  ...
END;
```

The Need for Template Objects in Invoker-Rights Subprograms

External references in an invoker-rights subprogram are resolved in the schema of the current user at run time. However, the PL/SQL compiler must resolve all references at compile time. So, the owner must create template objects in his or her schema beforehand. At run time, the template objects and the actual objects must match. Otherwise, you get an error or unexpected results.

For example, suppose user `scott` creates the following database table and standalone procedure:

```
CREATE TABLE emp (  
    empno NUMBER(4),  
    ename VARCHAR2(15));  
/  
CREATE PROCEDURE evaluate (my_empno NUMBER)  
    AUTHID CURRENT_USER AS  
    my_ename VARCHAR2(15);  
BEGIN  
    SELECT ename INTO my_ename FROM emp WHERE empno = my_empno;  
    ...  
END;  
/
```

Now, suppose user `blake` creates a similar database table, then calls procedure `evaluate`, as follows:

```
CREATE TABLE emp (  
    empno    NUMBER(4),  
    ename    VARCHAR2(15),  
    my_empno NUMBER(4)); -- note extra column  
/  
DECLARE  
    ...  
BEGIN  
    ...  
    scott.evaluate(7788);  
END;  
/
```

The procedure call executes without error but ignores column `my_empno` in the table created by user `blake`. That is because the actual table in the schema of the current user does not match the template table used at compile time.

Overriding Default Name Resolution in Invoker-Rights Subprograms

Occasionally, you might want to override the default invoker-rights behavior. Suppose user `scott` defines the standalone procedure below. Notice that the `SELECT` statement calls an external function. Normally, this external reference would be resolved in the schema of the current user.

```
CREATE PROCEDURE calc_bonus (emp_id INTEGER)
  AUTHID CURRENT_USER AS
  mid_sal REAL;
BEGIN
  SELECT median(sal) INTO mid_sal FROM emp;
  ...
END;
```

To have the reference resolved in the schema of the owner, create a public synonym for the function using the `CREATE SYNONYM` statement, as follows:

```
CREATE PUBLIC SYNONYM median FOR scott.median;
```

This works unless the current user has defined a function or private synonym named `median`. Alternatively, you can fully qualify the reference, as follows:

```
BEGIN
  SELECT scott.median(sal) INTO mid_sal FROM emp;
  ...
END;
```

This works unless the current user has defined a package named `scott` that contains a function named `median`.

Granting Privileges on Invoker-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-rights subprogram operates under the security domain of its owner, no matter who is executing it. So, 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 rights and others with invoker rights. Then, you can use the `EXECUTE` privilege to restrict program entry points (*controlled step-in*). That way, users of an entry-point subprogram can execute the other subprograms indirectly but not directly.

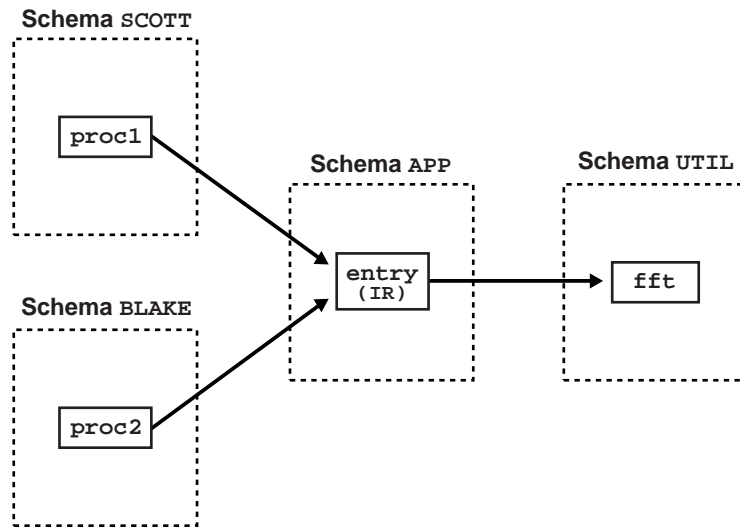
Granting Privileges on an Invoker-Rights Subprogram: Example

Suppose user `util` grants the `EXECUTE` privilege on subprogram `fft` to user `app`, as follows:

```
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. So, as [Figure 8-7](#) on page 8-55 shows, user `util` need not grant the `EXECUTE` privilege to every user who might call `fft` indirectly.

Notice that subprogram `util.fft` is called directly only from invoker-rights subprogram `app.entry`. So, 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 8–7 Indirect Calls to an Invoker-Rights Subprogram

Using Roles with Invoker-Rights Subprograms

The use of roles in a subprogram depends on whether it executes with definer rights or invoker rights. Within a definer-rights subprogram, all roles are disabled. Roles are not used for privilege checking, and you cannot set roles.

Within an invoker-rights subprogram, roles are enabled (unless the subprogram was called directly or indirectly by a definer-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-Rights Subprograms

For invoker-rights subprograms executed within a view expression, the view owner, not the view user, is considered to be the current user. For example, suppose user `scott` creates a view as shown below. The invoker-rights function `layout` always executes with the privileges of user `scott`, who is the view owner.

```
CREATE VIEW payroll AS SELECT layout(3) FROM dual;
```

This rule also applies to database triggers.

Using Database Links with Invoker-Rights Subprograms

Invoker rights affect only one kind of database link—current-user links, which are created as follows:

```
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-rights subprogram owned by user `blake` references the database link below. If global user `scott` calls the subprogram, it connects to the Dallas database as user `scott`, who is the current user.

```
CREATE DATABASE LINK dallas CONNECT TO CURRENT_USER USING ...
```

If it were a definer-rights subprogram, the current user would be `blake`. So, the subprogram would connect to the Dallas database as global user `blake`.

Using Object Types with Invoker-Rights Subprograms

To define object types for use in any schema, specify the `AUTHID CURRENT_USER` clause. (For more information about object types, see [Chapter 10](#).) Suppose user `blake` creates the following object type:

```
CREATE TYPE Num AUTHID CURRENT_USER AS OBJECT (
  x NUMBER,
  STATIC PROCEDURE new_num (
    n NUMBER, schema_name VARCHAR2, table_name VARCHAR2)
);

CREATE TYPE BODY Num AS
  STATIC PROCEDURE new_num (
    n NUMBER, schema_name VARCHAR2, table_name VARCHAR2) IS
    sql_stmt VARCHAR2(200);
  BEGIN
    sql_stmt := 'INSERT INTO ' || schema_name || '.'
      || table_name || ' VALUES (blake.Num(:1))';
    EXECUTE IMMEDIATE sql_stmt USING n;
  END;
END;
```

Then, user `blake` grants the `EXECUTE` privilege on object type `Num` to user `scott`:

```
GRANT EXECUTE ON Num TO scott;
```


Finally, user `scott` creates an object table to store objects of type `Num`, then calls procedure `new_num` to populate the table:

```
CONNECT scott/tiger;
CREATE TABLE num_tab OF blake.Num;
/
BEGIN
    blake.Num.new_num(1001, 'scott', 'num_tab');
    blake.Num.new_num(1002, 'scott', 'num_tab');
    blake.Num.new_num(1003, 'scott', 'num_tab');
END;
/
```

The calls succeed because the procedure executes with the privileges of its current user (`scott`), not its owner (`blake`).

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-Rights Instance Methods

An invoker-rights instance method executes with the privileges of the invoker, not the creator of the instance. Suppose that `Person` is an invoker-rights object type, and that user `scott` creates `p1`, an object of type `Person`. If user `blake` calls instance method `change_job` to operate on object `p1`, the current user of the method is `blake`, not `scott`. Consider the following example:

```
-- user blake creates a definer-rights procedure
CREATE PROCEDURE reassign (p Person, new_job VARCHAR2) AS
BEGIN
    -- user blake calls method change_job, so the
    -- method executes with the privileges of blake
    p.change_job(new_job);
    ...
END;

-- user scott passes a Person object to the procedure
DECLARE
    p1 Person;
```

```
BEGIN
    p1 := Person(...);
    blake.reassign(p1, 'CLERK');
    ...
END;
```

Understanding and Using Recursion

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, ...), which was first used to model the growth of a rabbit colony, 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. Think of a recursive call as a call to some other subprogram that does the same task as your subprogram. 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. As a result, your program 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 (theoretically) go on forever. In practice, if a recursive subprogram strays into infinite regress, PL/SQL eventually runs out of memory and raises the predefined exception `STORAGE_ERROR`.

Recursion Example: Computing the Factorial

To solve some programming problems, you must repeat a sequence of statements until a condition is met. You can use iteration or recursion to solve such problems.

Use recursion when the problem can be broken down into simpler versions of itself. For example, you can evaluate 3! as follows:

```
0! = 1 -- by definition
1! = 1 * 0! = 1
2! = 2 * 1! = 2
3! = 3 * 2! = 6
```

To implement this algorithm, you might write the following recursive function, which returns the factorial of a positive integer:

```
FUNCTION fac (n POSITIVE) RETURN INTEGER IS -- returns n!
BEGIN
  IF n = 1 THEN -- terminating condition
    RETURN 1;
  ELSE
    RETURN n * fac(n - 1); -- recursive call
  END IF;
END fac;
```

At each recursive call, *n* is decremented. Eventually, *n* becomes 1 and the recursion stops.

Recursion Example: Traversing Tree-Structured Data

Consider the procedure below, which finds the staff of a given manager. The procedure declares two formal parameters, *mgr_no* and *tier*, which represent the manager's employee number and a tier in his or her departmental organization. Staff members reporting directly to the manager occupy the first tier.

```
PROCEDURE find_staff (mgr_no NUMBER, tier NUMBER := 1) IS
  boss_name VARCHAR2(10);
  CURSOR c1 (boss_no NUMBER) IS
    SELECT empno, ename FROM emp WHERE mgr = boss_no;
BEGIN
  /* Get manager's name. */
  SELECT ename INTO boss_name FROM emp WHERE empno = mgr_no;
  IF tier = 1 THEN
    INSERT INTO staff -- single-column output table
      VALUES (boss_name || ' manages the staff');
  END IF;
  /* Find staff members who report directly to manager. */
  FOR ee IN c1 (mgr_no) LOOP
    INSERT INTO staff
      VALUES (boss_name || ' manages ' || ee.ename
```

```
        || ' on tier ' || TO_CHAR(tier));
    /* Drop to next tier in organization. */
    find_staff(ee.empno, tier + 1); -- recursive call
END LOOP;
COMMIT;
END;
```

When called, the procedure accepts a value for `mgr_no` but uses the default value of `tier`. For example, you might call the procedure as follows:

```
find_staff(7839);
```

The procedure passes `mgr_no` to a cursor in a cursor `FOR` loop, which finds staff members at successively lower tiers in the organization. At each recursive call, a new instance of the `FOR` loop is created and another cursor is opened, but prior cursors stay positioned on the next row in their result sets.

When a fetch fails to return a row, the cursor is closed automatically and the `FOR` loop is exited. Since the recursive call is inside the `FOR` loop, the recursion stops. Unlike the initial call, each recursive call passes a second actual parameter (the next tier) to the procedure.

Tip: Perform Recursive Queries with the `CONNECT BY` Clause

The last example illustrates recursion, not the efficient use of set-oriented SQL statements. You might want to compare the performance of the recursive procedure to that of the following SQL statement, which does the same task:

```
INSERT INTO staff
  SELECT PRIOR ename || ' manages ' || ename
         || ' on tier ' || TO_CHAR(LEVEL - 1)
  FROM emp
  START WITH empno = 7839
  CONNECT BY PRIOR empno = mgr;
```

The SQL statement is appreciably faster. However, the procedure is more flexible. For example, a multi-table query cannot contain the `CONNECT BY` clause. So, unlike the procedure, the SQL statement cannot be modified to do joins. (A *join* combines rows from two or more database tables.) In addition, a procedure can process data in ways that a single SQL statement cannot.

Using Mutual Recursion

Subprograms are *mutually recursive* if they directly or indirectly call each other. In the example below, the Boolean functions `odd` and `even`, which determine whether a number is odd or even, call each other directly. The forward declaration of `odd` is necessary because `even` calls `odd`, which is not yet declared when the call is made.

```

FUNCTION odd (n NATURAL) RETURN BOOLEAN; -- forward declaration

FUNCTION even (n NATURAL) RETURN BOOLEAN IS
BEGIN
    IF n = 0 THEN
        RETURN TRUE;
    ELSE
        RETURN odd(n - 1); -- mutually recursive call
    END IF;
END even;

FUNCTION odd (n NATURAL) RETURN BOOLEAN IS
BEGIN
    IF n = 0 THEN
        RETURN FALSE;
    ELSE
        RETURN even(n - 1); -- mutually recursive call
    END IF;
END odd;

```

When a positive integer `n` is passed to `odd` or `even`, the functions call each other by turns. At each call, `n` is decremented. Ultimately, `n` becomes zero and the final call returns `TRUE` or `FALSE`. For instance, passing the number 4 to `odd` results in this sequence of calls:

```

odd(4)
even(3)
odd(2)
even(1)
odd(0) -- returns FALSE

```

On the other hand, passing the number 4 to `even` results in this sequence of calls:

```

even(4)
odd(3)
even(2)
odd(1)
even(0) -- returns TRUE

```

Recursion Versus Iteration

Unlike iteration, recursion is not essential to PL/SQL programming. Any problem that can be solved using recursion can be solved using iteration. Also, the iterative version of a subprogram is usually easier to design than the recursive version. However, the recursive version is usually simpler, smaller, and therefore easier to debug. Compare the following functions, which compute the n th Fibonacci number:

```
-- recursive version
FUNCTION fib (n POSITIVE) RETURN INTEGER IS
BEGIN
    IF (n = 1) OR (n = 2) THEN
        RETURN 1;
    ELSE
        RETURN fib(n - 1) + fib(n - 2);
    END IF;
END fib;

-- iterative version
FUNCTION fib (n POSITIVE) RETURN INTEGER IS
    pos1 INTEGER := 1;
    pos2 INTEGER := 0;
    cum INTEGER;
BEGIN
    IF (n = 1) OR (n = 2) THEN
        RETURN 1;
    ELSE
        cum := pos1 + pos2;
        FOR i IN 3..n LOOP
            pos2 := pos1;
            pos1 := cum;
            cum := pos1 + pos2;
        END LOOP;
        RETURN cum;
    END IF;
END fib;
```

The recursive version of `fib` is more elegant than the iterative version. However, the iterative version is more efficient; it runs faster and uses less storage. That is because each recursive call requires additional time and memory. As the number of recursive calls gets larger, so does the difference in efficiency. Still, if you expect the number of recursive calls to be small, you might choose the recursive version for its readability.

Calling External Subprograms

PL/SQL is a powerful development tool; you can use it for almost any purpose. However, it is specialized for SQL transaction processing. So, some tasks are more quickly done in a lower-level language such as C, which is very efficient at machine-precision calculations. Other tasks are more easily done in a fully object-oriented, standardized language such as Java.

To support such special-purpose processing, you can use PL/SQL call specs to invoke *external subprograms* (that is, subprograms written in other languages). This makes the strengths and capabilities of those languages available to you from PL/SQL.

For example, you can call Java stored procedures from any PL/SQL block, subprogram, or package. Suppose you store the following Java class in the database:

```
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 emp SET sal = sal * ? WHERE empno = ?";
        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 this call spec:

```
CREATE PROCEDURE raise_salary (empno NUMBER, pct NUMBER)
AS LANGUAGE JAVA
NAME 'Adjuster.raiseSalary(int, float)';
```

Later, you might call procedure `raise_salary` from an anonymous PL/SQL block, as follows:

```
DECLARE
    emp_id NUMBER;
    percent NUMBER;
BEGIN
    -- get values for emp_id and percent
    raise_salary(emp_id, percent); -- call external subprogram
```

Typically, 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 let you extend the functionality of the database server, and move computation-bound programs from client to server, where they execute faster.

For more information about Java stored procedures, see *Oracle9i Java Stored Procedures Developer's Guide*. For more information about external C subprograms, see *Oracle9i Application Developer's Guide - Fundamentals*.

Creating Dynamic Web Pages with 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.

For more information about creating and using PSPs, see *Oracle9i Application Developer's Guide - Fundamentals*.

PL/SQL Packages

Goods which are not shared are not goods. —Fernando de Rojas

This chapter shows you how to bundle related PL/SQL programming resources into a package. The resources might include a collection of procedures or a pool of type definitions and variable declarations. For example, a Human Resources package might contain hiring and firing procedures. Once written, your general-purpose package is compiled, then stored in an Oracle database, where its contents can be shared by many applications.

This chapter discusses the following topics:

[What Is a PL/SQL Package?](#)

[Advantages of PL/SQL Packages](#)

[Understanding The Package Spec](#)

[Understanding The Package Body](#)

[Some Examples of Package Features](#)

[Private Versus Public Items in Packages](#)

[Overloading Packaged Subprograms](#)

[How Package STANDARD Defines the PL/SQL Environment](#)

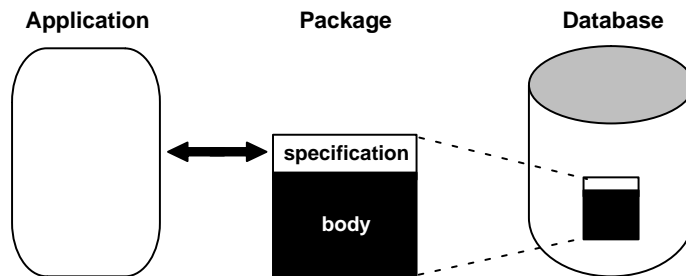
[Overview of Product-Specific Packages](#)

What Is a PL/SQL Package?

A **package** is a schema object that groups logically related PL/SQL types, items, and subprograms. Packages usually have two parts, a specification and a body, although sometimes the body is unnecessary. The **specification (spec for short)** 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.

As [Figure 9–1](#) shows, you can think of the spec as an operational interface and of the body as a "black box." You can debug, enhance, or replace a package body without changing the interface (package spec) to the package.

Figure 9–1 Package Interface



To create packages, use the `CREATE PACKAGE` statement, which you can execute interactively from SQL*Plus. Here is the syntax:

```
CREATE [OR REPLACE] PACKAGE package_name
  [AUTHID {CURRENT_USER | DEFINER}]
  {IS | AS}
  [PRAGMA SERIALLY_REUSABLE;]
  [collection_type_definition ...]
  [record_type_definition ...]
  [subtype_definition ...]
  [collection_declaration ...]
  [constant_declaration ...]
  [exception_declaration ...]
  [object_declaration ...]
  [record_declaration ...]
  [variable_declaration ...]
```

```

    [cursor_spec ...]
    [function_spec ...]
    [procedure_spec ...]
    [call_spec ...]
    [PRAGMA RESTRICT_REFERENCES(assertions) ...]
END [package_name];

[CREATE [OR REPLACE] PACKAGE BODY package_name {IS | AS}
    [PRAGMA SERIALLY_REUSABLE;]
    [collection_type_definition ...]
    [record_type_definition ...]
    [subtype_definition ...]
    [collection_declaration ...]
    [constant_declaration ...]
    [exception_declaration ...]
    [object_declaration ...]
    [record_declaration ...]
    [variable_declaration ...]
    [cursor_body ...]
    [function_spec ...]
    [procedure_spec ...]
    [call_spec ...]
[BEGIN
    sequence_of_statements]
END [package_name];]

```

The spec holds **public declarations**, which are visible to your application. 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 your application. Following the declarative part of the package body is the optional initialization part, which typically holds statements that initialize package variables.

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 ["Invoker Rights Versus Definer Rights"](#) on page 8-47.

A **call spec** lets you publish a Java method or external C function in the Oracle data dictionary. The call spec publishes the routine by mapping its name, parameter types, and return type to their SQL counterparts. To learn how to write Java call specs, see *Oracle9i Java Stored Procedures Developer's Guide*. To learn how to write C call specs, see *Oracle9i Application Developer's Guide - Fundamentals*.

Example of a PL/SQL Package

In the example below, you package a record type, a cursor, and two employment procedures. Notice that the procedure `hire_employee` uses the database sequence `empno_seq` and the function `SYSDATE` to insert a new employee number and hire date, respectively.

```
CREATE OR REPLACE PACKAGE emp_actions AS -- spec
    TYPE EmpRecTyp IS RECORD (emp_id INT, salary REAL);
    CURSOR desc_salary RETURN EmpRecTyp;
    PROCEDURE hire_employee (
        ename VARCHAR2,
        job   VARCHAR2,
        mgr   NUMBER,
        sal   NUMBER,
        comm  NUMBER,
        deptno NUMBER);
    PROCEDURE fire_employee (emp_id NUMBER);
END emp_actions;

CREATE OR REPLACE PACKAGE BODY emp_actions AS -- body
    CURSOR desc_salary RETURN EmpRecTyp IS
        SELECT empno, sal FROM emp ORDER BY sal DESC;
    PROCEDURE hire_employee (
        ename VARCHAR2,
        job   VARCHAR2,
        mgr   NUMBER,
        sal   NUMBER,
        comm  NUMBER,
        deptno NUMBER) IS
    BEGIN
        INSERT INTO emp VALUES (empno_seq.NEXTVAL, ename, job,
            mgr, SYSDATE, sal, comm, deptno);
    END hire_employee;

    PROCEDURE fire_employee (emp_id NUMBER) IS
    BEGIN
        DELETE FROM emp WHERE empno = emp_id;
    END fire_employee;
END emp_actions;
```

Only the declarations in the package spec are visible and accessible to applications. Implementation details in the package body are hidden and inaccessible. So, you can change the body (implementation) without having to recompile calling programs.

Advantages of PL/SQL Packages

Packages offer several advantages: modularity, easier application design, information hiding, added functionality, and better performance.

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. So, they can be shared by all subprograms that execute in the environment. Also, they allow you to maintain data across transactions without having to store it in the database.

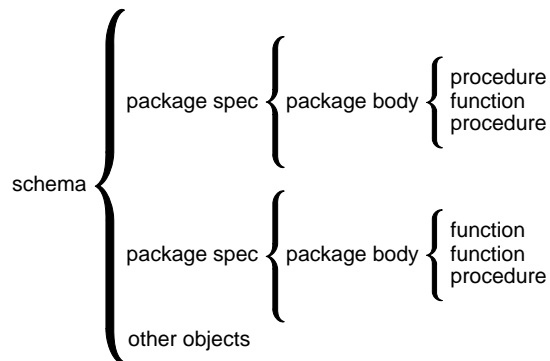
Better Performance

When you call a packaged subprogram for the first time, the whole package is loaded into memory. So, later calls to related subprograms in the package require no disk I/O. Also, packages stop cascading dependencies and thereby avoid unnecessary recompiling. For example, if you change the implementation of a packaged function, Oracle need not recompile the calling subprograms because they do not depend on the package body.

Understanding The Package Spec

The package spec contains public declarations. The scope of these declarations is local to your database schema and global to the package. So, the declared items are accessible from your application and from anywhere in the package. [Figure 9–2](#) illustrates the scoping.

Figure 9–2 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 `fac` takes one argument of type `INTEGER` and returns a value of type `INTEGER`:

```
FUNCTION fac (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).

Only subprograms and cursors have an underlying implementation. So, if a spec declares only types, constants, variables, exceptions, and call specs, the package body is unnecessary. Consider the following bodiless package:

```
CREATE PACKAGE trans_data AS -- bodiless package
    TYPE TimeRec IS RECORD (
        minutes SMALLINT,
        hours    SMALLINT);
    TYPE TransRec IS RECORD (
        category VARCHAR2,
        account  INT,
        amount   REAL,
        time_of  TimeRec);
```

```

    minimum_balance    CONSTANT REAL := 10.00;
    number_processed   INT;
    insufficient_funds EXCEPTION;
END trans_data;

```

The package `trans_data` needs no body because types, constants, variables, and exceptions do not have an underlying implementation. Such packages let you define global variables—usable by subprograms and database triggers—that persist throughout a session.

Referencing Package Contents

To reference the types, items, subprograms, and call specs declared within a package spec, use dot notation, as follows:

```

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 might call the packaged procedure `hire_employee` from SQL*Plus, as follows:

```
SQL> CALL emp_actions.hire_employee('TATE', 'CLERK', ...);
```

In the example below, you call the same procedure from an anonymous PL/SQL block embedded in a Pro*C program. The actual parameters `emp_name` and `job_title` are host variables (that is, variables declared in a host environment).

```

EXEC SQL EXECUTE
    BEGIN
        emp_actions.hire_employee(:emp_name, :job_title, ...);

```

Restrictions

You cannot reference remote packaged variables directly or indirectly. For example, you cannot call the following procedure remotely because it references a packaged variable in a parameter initialization clause:

```

CREATE PACKAGE random AS
    seed NUMBER;
    PROCEDURE initialize (starter IN NUMBER := seed, ...);

```

Also, inside a package, you cannot reference host variables.

Understanding The Package Body

The package body implements the package spec. That is, the package body contains the implementation of every cursor and subprogram declared in the package spec. Keep in mind that subprograms defined in a package body are accessible outside the package only if their specs also appear in the package spec.

To match subprogram specs and bodies, PL/SQL does a token-by-token comparison of their headers. So, except for white space, the headers must match word for word. Otherwise, PL/SQL raises an exception, as the following example shows:

```
CREATE PACKAGE emp_actions AS
    ...
    PROCEDURE calc_bonus (date_hired emp.hiredate%TYPE, ...);
END emp_actions;

CREATE PACKAGE BODY emp_actions AS
    ...
    PROCEDURE calc_bonus (date_hired DATE, ...) IS
        -- parameter declaration raises an exception because 'DATE'
        -- does not match 'emp.hiredate%TYPE' word for word
    BEGIN ... END;
END emp_actions;
```

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 package below named `emp_actions`. The package spec declares the following types, items, and subprograms:

- Types `EmpRecTyp` and `DeptRecTyp`
- 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 general use.

```
CREATE PACKAGE emp_actions AS
  /* Declare externally visible types, cursor, exception. */
  TYPE EmpRecTyp IS RECORD (emp_id INT, salary REAL);
  TYPE DeptRecTyp IS RECORD (dept_id INT, location VARCHAR2);
  CURSOR desc_salary RETURN EmpRecTyp;
  invalid_salary EXCEPTION;

  /* Declare externally callable subprograms. */
  FUNCTION hire_employee (
    ename  VARCHAR2,
    job    VARCHAR2,
    mgr    REAL,
    sal    REAL,
    comm   REAL,
    deptno REAL) RETURN INT;
  PROCEDURE fire_employee (emp_id INT);
  PROCEDURE raise_salary (emp_id INT, grade INT, amount REAL);
  FUNCTION nth_highest_salary (n INT) RETURN EmpRecTyp;
END emp_actions;

CREATE PACKAGE BODY emp_actions AS
  number_hired INT; -- visible only in this package

  /* Fully define cursor specified in package. */
  CURSOR desc_salary RETURN EmpRecTyp IS
    SELECT empno, sal FROM emp ORDER BY sal DESC;
```

```
/* Fully define subprograms specified in package. */
FUNCTION hire_employee (
    ename VARCHAR2,
    job   VARCHAR2,
    mgr   REAL,
    sal   REAL,
    comm  REAL,
    deptno REAL) RETURN INT IS
    new_empno INT;
BEGIN
    SELECT empno_seq.NEXTVAL INTO new_empno FROM dual;
    INSERT INTO emp VALUES (new_empno, ename, job,
        mgr, SYSDATE, sal, comm, deptno);
    number_hired := number_hired + 1;
    RETURN new_empno;
END hire_employee;

PROCEDURE fire_employee (emp_id INT) IS
BEGIN
    DELETE FROM emp WHERE empno = emp_id;
END fire_employee;

/* Define local function, available only inside package. */
FUNCTION sal_ok (rank INT, salary REAL) RETURN BOOLEAN IS
    min_sal REAL;
    max_sal REAL;
BEGIN
    SELECT losal, hisal INTO min_sal, max_sal FROM salgrade
        WHERE grade = rank;
    RETURN (salary >= min_sal) AND (salary <= max_sal);
END sal_ok;

PROCEDURE raise_salary (emp_id INT, grade INT, amount REAL) IS
    salary REAL;
BEGIN
    SELECT sal INTO salary FROM emp WHERE empno = emp_id;
    IF sal_ok(grade, salary + amount) THEN
        UPDATE emp SET sal = sal + amount WHERE empno = emp_id;
    ELSE
        RAISE invalid_salary;
    END IF;
END raise_salary;
```

```

FUNCTION nth_highest_salary (n INT) 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_ACTIONS');
    number_hired := 0;
END emp_actions;

```

Remember, the initialization part of a package is run just once, the first time you reference the package. So, in the last example, only one row is inserted into the database table `emp_audit`. Likewise, 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.

In the next example, you package some typical bank transactions. Assume that debit and credit transactions are entered after business hours through automatic teller machines, then applied to accounts the next morning.

```

CREATE PACKAGE bank_transactions AS
    /* Declare externally visible constant. */
    minimum_balance CONSTANT REAL := 100.00;
    /* Declare externally callable procedures. */
    PROCEDURE apply_transactions;
    PROCEDURE enter_transaction (
        acct INT,
        kind CHAR,
        amount REAL);
END bank_transactions;

```

```
CREATE PACKAGE BODY bank_transactions AS
    /* Declare global variable to hold transaction status. */
    new_status VARCHAR2(70) := 'Unknown';

    /* Use forward declarations because apply_transactions
       calls credit_account and debit_account, which are not
       yet declared when the calls are made. */
    PROCEDURE credit_account (acct INT, credit REAL);
    PROCEDURE debit_account (acct INT, debit REAL);

    /* Fully define procedures specified in package. */
    PROCEDURE apply_transactions IS
    /* Apply pending transactions in transactions table
       to accounts table. Use cursor to fetch rows. */
        CURSOR trans_cursor IS
            SELECT acct_id, kind, amount FROM transactions
                WHERE status = 'Pending'
                ORDER BY time_tag
                FOR UPDATE OF status; -- to lock rows
    BEGIN
        FOR trans IN trans_cursor LOOP
            IF trans.kind = 'D' THEN
                debit_account(trans.acct_id, trans.amount);
            ELSIF trans.kind = 'C' THEN
                credit_account(trans.acct_id, trans.amount);
            ELSE
                new_status := 'Rejected';
            END IF;
            UPDATE transactions SET status = new_status
                WHERE CURRENT OF trans_cursor;
        END LOOP;
    END apply_transactions;

    PROCEDURE enter_transaction (
    /* Add a transaction to transactions table. */
        acct INT,
        kind CHAR,
        amount REAL) IS
    BEGIN
        INSERT INTO transactions
            VALUES (acct, kind, amount, 'Pending', SYSDATE);
    END enter_transaction;
```

```
/* Define local procedures, available only in package. */
PROCEDURE do_journal_entry (
/* Record transaction in journal. */
    acct    INT,
    kind    CHAR,
    new_bal REAL) IS
BEGIN
    INSERT INTO journal
        VALUES (acct, kind, new_bal, sysdate);
    IF kind = 'D' THEN
        new_status := 'Debit applied';
    ELSE
        new_status := 'Credit applied';
    END IF;
END do_journal_entry;

PROCEDURE credit_account (acct INT, credit REAL) IS
/* Credit account unless account number is bad. */
    old_balance REAL;
    new_balance REAL;
BEGIN
    SELECT balance INTO old_balance FROM accounts
        WHERE acct_id = acct
        FOR UPDATE OF balance; -- to lock the row
    new_balance := old_balance + credit;
    UPDATE accounts SET balance = new_balance
        WHERE acct_id = acct;
    do_journal_entry(acct, 'C', new_balance);
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        new_status := 'Bad account number';
    WHEN OTHERS THEN
        new_status := SUBSTR(SQLERRM,1,70);
END credit_account;

PROCEDURE debit_account (acct INT, debit REAL) IS
/* Debit account unless account number is bad or
account has insufficient funds. */
    old_balance REAL;
    new_balance REAL;
    insufficient_funds EXCEPTION;
BEGIN
    SELECT balance INTO old_balance FROM accounts
        WHERE acct_id = acct
        FOR UPDATE OF balance; -- to lock the row
```

```
new_balance := old_balance - debit;
IF new_balance >= minimum_balance THEN
    UPDATE accounts SET balance = new_balance
        WHERE acct_id = acct;
    do_journal_entry(acct, 'D', new_balance);
ELSE
    RAISE insufficient_funds;
END IF;
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        new_status := 'Bad account number';
    WHEN insufficient_funds THEN
        new_status := 'Insufficient funds';
    WHEN OTHERS THEN
        new_status := SUBSTR(SQLERRM,1,70);
END debit_account;
END bank_transactions;
```

In this package, the initialization part is not used.

Private Versus Public Items in Packages

Look again at the package `emp_actions`. The package body declares a variable named `number_hired`, which is initialized to zero. Unlike items declared in the spec of `emp_actions`, items declared in the body are restricted to use within the package. Therefore, PL/SQL code outside the package cannot reference the variable `number_hired`. Such items are called **private**.

However, items declared in the spec of `emp_actions`, such as the exception `invalid_salary`, are visible outside the package. Therefore, any PL/SQL code can reference the exception `invalid_salary`. Such items are called **public**.

When you must 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.

If you must also make the items public, place them in the package spec. For example, the constant `minimum_balance` declared in the spec of the package `bank_transactions` is available for general use.

Overloading Packaged Subprograms

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 following package defines two procedures named `journalize`:

```
CREATE PACKAGE journal_entries AS
...
    PROCEDURE journalize (amount REAL, trans_date VARCHAR2);
    PROCEDURE journalize (amount REAL, trans_date INT);
END journal_entries;

CREATE PACKAGE BODY journal_entries AS
...
    PROCEDURE journalize (amount REAL, trans_date VARCHAR2) IS
    BEGIN
        INSERT INTO journal
            VALUES (amount, TO_DATE(trans_date, 'DD-MON-YYYY'));
    END journalize;

    PROCEDURE journalize (amount REAL, trans_date INT) IS
    BEGIN
        INSERT INTO journal
            VALUES (amount, TO_DATE(trans_date, 'J'));
    END journalize;
END journal_entries;
```

The first procedure accepts `trans_date` as a character string, while the second procedure accepts it as a number (the Julian day). Each procedure handles the data appropriately. For the rules that apply to overloaded subprograms, see ["Overloading Subprogram Names"](#) on page 8-23.

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 redeclare `ABS` in a PL/SQL program, your local declaration overrides the global declaration. However, you can still call the built-in function by qualifying the reference to `ABS`, as follows:

```
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 help you build PL/SQL-based applications. For example, Oracle is supplied with many utility packages, a few of which are highlighted below. For more information, see *Oracle9i Supplied 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 and subprograms, which makes it easier to test and debug them. The procedure `put_line` outputs information to a buffer in the SGA. You display the information

by calling the procedure `get_line` or by setting `SERVEROUTPUT ON` in SQL*Plus. For example, suppose you create the following stored procedure:

```
CREATE PROCEDURE calc_payroll (payroll OUT NUMBER) AS
  CURSOR c1 IS SELECT sal, comm FROM emp;
BEGIN
  payroll := 0;
  FOR clrec IN c1 LOOP
    clrec.comm := NVL(clrec.comm, 0);
    payroll := payroll + clrec.sal + clrec.comm;
  END LOOP;
  /* Display debug info. */
  dbms_output.put_line('Value of payroll: ' || TO_CHAR(payroll));
END;
```

When you issue the following commands, SQL*Plus displays the value assigned by the procedure to parameter `payroll`:

```
SQL> SET SERVEROUTPUT ON
SQL> VARIABLE num NUMBER
SQL> CALL calc_payroll(:num);
Value of payroll: 31225
```

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.

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 routines in C that allow external programs to collect information, then send it through pipes to procedures stored in an Oracle database.

About the UTL_FILE Package

Package `UTL_FILE` allows your PL/SQL programs to 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.

Guidelines for Writing Packages

When writing packages, keep them as general as possible so they can be reused in future applications. Avoid writing packages that duplicate some feature already provided by Oracle.

Package specs reflect the design of your application. So, define them before the package bodies. Place in a spec only the types, items, and subprograms that must be visible to users of the package. That way, other developers cannot misuse the package by basing their code on irrelevant 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 Oracle to recompile dependent procedures. However, changes to a package spec require Oracle to recompile every stored subprogram that references the package.

PL/SQL Object Types

*... It next will be right
To describe each particular batch:
Distinguishing those that have feathers, and bite,
From those that have whiskers, and scratch. —Lewis Carroll*

Object-oriented programming is rapidly gaining acceptance because it can reduce the cost and time required to build complex applications. In PL/SQL, object-oriented programming is based on object types. They provide abstract templates for real-world objects, and so are an ideal modeling tool. They also provide black-box encapsulation like an integrated component that can be plugged into various electronic devices. To plug an object type into your programs, you need to know only what it does, not how it works.

This chapter discusses the following topics:

- The Role of Abstraction
- What Is an Object Type?
- Why Use Object Types?
- Structure of an Object Type
- Components of an Object Type
- Defining Object Types
- Declaring and Initializing Objects
- Accessing Attributes
- Calling Constructors
- Calling Methods
- Sharing Objects
- Manipulating Objects

The Role of Abstraction

An **abstraction** is a high-level description or model of a real-world entity. Abstractions keep our daily lives manageable. They help us reason about an object, event, or relationship by suppressing irrelevant detail. For example, to drive a car, you need not know how its engine works. A simple interface consisting of a gearshift, steering wheel, accelerator, and brake, lets you use the car effectively. The details of what happens under the hood are not important for day-to-day driving.

Abstractions are central to the discipline of programming. For example, you use **procedural abstraction** when you suppress the details of a complex algorithm by writing a procedure and passing it parameters. A single procedure call hides the details of your implementation. To try a different implementation, you simply replace the procedure with another having the same name and parameters. Thanks to abstraction, programs that call the procedure need not be modified.

You use **data abstraction** when you specify the datatype of a variable. The datatype stipulates a set of values and a set of operations appropriate for those values. For instance, a variable of type `POSITIVE` can hold only positive integers, and can only be added, subtracted, multiplied, and so on. To use the variable, you need not know how PL/SQL stores integers or implements arithmetic operations; you simply accept the programming interface.

Object types are a generalization of the built-in datatypes found in most programming languages. PL/SQL provides a variety of built-in scalar and composite datatypes, each of which is associated with a set of predefined operations. A **scalar** type (such as `CHAR`) has no internal components. A **composite** type (such as `RECORD`) has internal components that can be manipulated individually. Like the `RECORD` type, an object type is a composite type. However, its operations are user-defined, not predefined.

Currently, you cannot define object types within PL/SQL. They must be `CREATED` and stored in an Oracle database, where they can be shared by many programs. A program that uses object types is called a **client program**. It can declare and manipulate an object without knowing how the object type represents data or implements operations. This lets you write the program and object type separately, and to change the implementation of the object type without affecting the program. Thus, object types support both procedural and data abstraction.

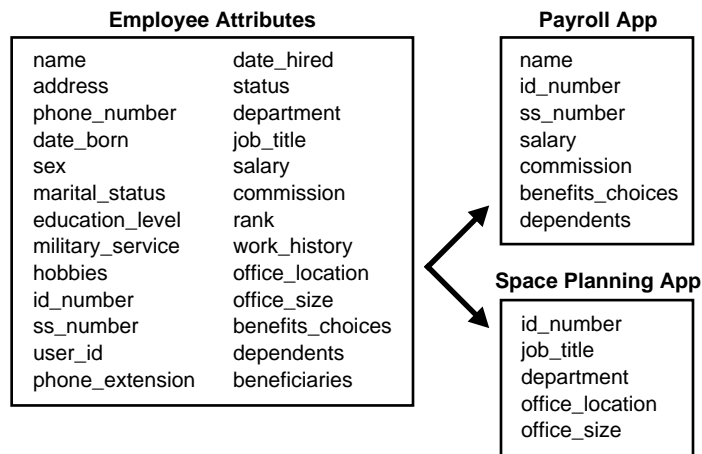
What Is an Object Type?

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**.

We usually think of an object (such as a person, car, or bank account) as having attributes and behaviors. For example, a baby has the attributes gender, age, and weight, and the behaviors eat, drink, and sleep. Object types let you maintain this perspective when you sit down to write an application.

When you define an object type using the `CREATE TYPE` statement, you create an abstract template for some real-world object. The template specifies only those attributes and behaviors the object will need in the application environment. For example, an employee has many attributes, but usually only a few are needed to fill the requirements of an application (see [Figure 10-1](#)).

Figure 10-1 Form Follows Function



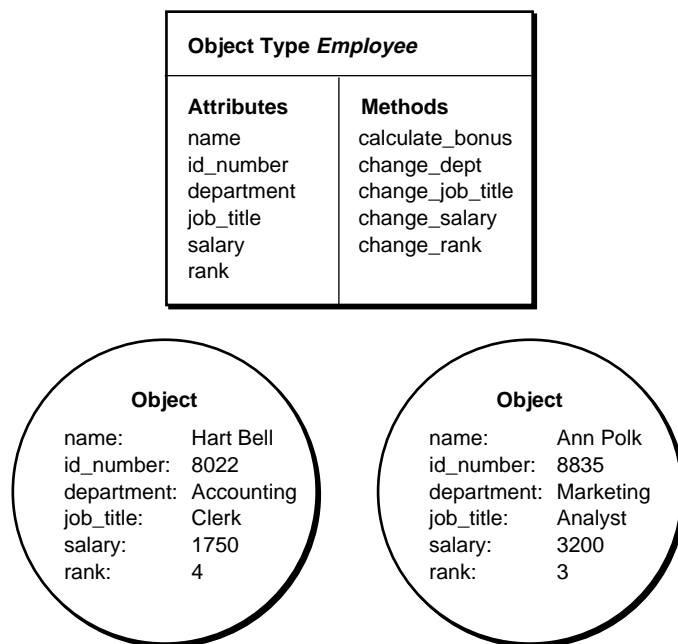
Suppose you must write a program to allocate employee bonuses. Not all employee attributes are needed to solve this problem. So, you design an abstract employee who has the following problem-specific attributes: name, ID number, department, job title, salary, and rank. Then, you identify the operations needed to handle an abstract employee. For example, you need an operation that lets Management change the rank of an employee.

Next, you define a set of variables (attributes) to represent the data, and a set of subprograms (methods) to perform the operations. Finally, you encapsulate the attributes and methods in an object type.

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. That way, the employee data is kept in a proper state.

At run time, when the data structure is filled with values, you have created an **instance** of an abstract employee. You can create as many instances (usually called **objects**) as you need. Each object has the name, number, job title, and so on of an actual employee (see [Figure 10-2](#)). This data is accessed or changed only by the methods associated with it. Thus, object types let you create objects with well-defined attributes and behavior.

Figure 10-2 Object Type and Objects (Instances) of that Type



Why Use Object Types?

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. It also allows different teams of programmers to develop software components concurrently.

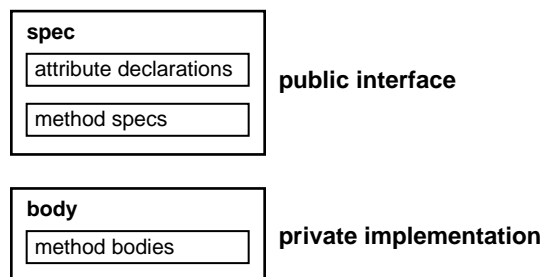
By encapsulating operations with data, object types let you move data-maintenance code out of SQL scripts and PL/SQL blocks into methods. Object types minimize side effects by allowing access to data only through approved operations. Also, object types hide implementation details, so that you can change the details without affecting client programs.

Object types allow for realistic data modeling. Complex real-world entities and relationships map directly into object types. Moreover, object types map directly into classes defined in object-oriented languages such as Java and C++. Now your programs can better reflect the world they are trying to simulate.

Structure of an Object Type

Like a package, an object type has two parts: a specification and a body (refer to [Figure 10-3](#)). The **specification** (or **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.

Figure 10-3 Object Type Structure



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—and without affecting client programs.

In an object type spec, all attributes must be declared before any methods. Only subprograms have an underlying implementation. So, if an object type spec declares only attributes, 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).

To understand the structure better, study the example below, in which an object type for complex numbers is defined. For now, it is enough to know that a complex number has two parts, a real part and an imaginary part, and that several arithmetic operations are defined for complex numbers.

```
CREATE TYPE Complex AS OBJECT (  
    rpart REAL, -- attribute  
    ipart REAL,  
    MEMBER FUNCTION plus (x Complex) RETURN Complex, -- method  
    MEMBER FUNCTION less (x Complex) RETURN Complex,  
    MEMBER FUNCTION times (x Complex) RETURN Complex,  
    MEMBER FUNCTION divby (x Complex) RETURN Complex  
);
```

```
CREATE TYPE BODY Complex AS  
    MEMBER FUNCTION plus (x Complex) RETURN Complex IS  
    BEGIN  
        RETURN Complex(rpart + x.rpart, ipart + x.ipart);  
    END plus;  
  
    MEMBER FUNCTION less (x Complex) RETURN Complex IS  
    BEGIN  
        RETURN Complex(rpart - x.rpart, ipart - x.ipart);  
    END less;  
  
    MEMBER FUNCTION times (x Complex) RETURN Complex IS  
    BEGIN  
        RETURN Complex(rpart * x.rpart - ipart * x.ipart,  
            rpart * x.ipart + ipart * x.rpart);  
    END times;  
  
    MEMBER FUNCTION divby (x Complex) RETURN Complex IS  
        z REAL := x.rpart**2 + x.ipart**2;  
    BEGIN  
        RETURN Complex((rpart * x.rpart + ipart * x.ipart) / z,  
            (ipart * x.rpart - rpart * x.ipart) / z);  
    END divby;  
END;
```


Components of an Object Type

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. You must declare at least one attribute (the maximum is 1000). Methods are optional.

Attributes

Like a variable, an attribute is declared with a name and datatype. The name must be unique within the object type (but can be reused in other object types). The datatype can be any Oracle type except

- LONG and LONG RAW
- NCHAR, NCLOB, and NVARCHAR2
- ROWID and UROWID
- The PL/SQL-specific types BINARY_INTEGER (and its subtypes), BOOLEAN, PLS_INTEGER, RECORD, REF CURSOR, %TYPE, and %ROWTYPE
- Types defined inside a PL/SQL package

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. However, objects can be stored in database tables on which you can impose constraints.

The kind of data structure formed by a set of attributes depends on the real-world object being modeled. For example, to represent a rational number, which has a numerator and a denominator, you need only two INTEGER variables. On the other hand, to represent a college student, you need several VARCHAR2 variables to hold a name, address, phone number, status, and so on, plus a VARRAY variable to hold courses and grades.

The data structure can be very complex. For example, the datatype of an attribute can be another object type (called a **nested** object type). That lets you build a complex object type from simpler object types. Some object types such as queues, lists, and trees are dynamic, meaning that they can grow as they are used. Recursive object types, which contain direct or indirect references to themselves, allow for highly sophisticated data models.

Methods

In general, a method is a subprogram declared in an object type spec using the keyword `MEMBER` or `STATIC`. The method cannot have the same name as the object type or any of its attributes. `MEMBER` methods are invoked on instances, as in

```
instance_expression.method()
```

However, `STATIC` methods are invoked on the object type, not its instances, as in

```
object_type_name.method()
```

Like packaged subprograms, methods have two parts: a specification and a body. The **specification** (**spec** for short) consists of a method name, an optional parameter list, and, for functions, a return type. The **body** is the code that executes to perform a specific task.

For each method spec in an object type spec, there must either be a corresponding method body in the object type body, or the method must be declared `NOT INSTANTIABLE` to indicate that the body is only present in subtypes of this type. To match method specs and bodies, the PL/SQL compiler does a token-by-token comparison of their headers. The headers must match exactly.

Like an attribute, a formal parameter is declared with a name and datatype. However, the datatype of a parameter cannot be size-constrained. The datatype can be any Oracle type except those disallowed for attributes. (See "[Attributes](#)" on page 10-7.) The same restrictions apply to return types.

Allowed Languages for Methods

Oracle lets you implement object methods in PL/SQL, Java or C. You can implement type methods in Java or C by providing a call specification in your type. A 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. To learn how to write Java call specs, see *Oracle9i Java Stored Procedures Developer's Guide*. To learn how to write C call specs, see *Oracle9i Application Developer's Guide - Fundamentals*.

Parameter SELF

`MEMBER` methods accept a built-in parameter named `SELF`, which is an instance of the object type. Whether declared implicitly or explicitly, it is always the first parameter passed to a `MEMBER` method. However, `STATIC` methods cannot accept or reference `SELF`.

In the method body, `SELF` denotes the object whose method was invoked. For example, method `transform` declares `SELF` as an IN OUT parameter:

```
CREATE TYPE Complex AS OBJECT (
    MEMBER FUNCTION transform (SELF IN OUT Complex) ...
```

You cannot specify a different datatype for `SELF`. In `MEMBER` functions, if `SELF` is not declared, its parameter mode defaults to `IN`. However, in `MEMBER` procedures, if `SELF` is not declared, its parameter mode defaults to `IN OUT`. You cannot specify the `OUT` parameter mode for `SELF`.

As the following example shows, methods can reference the attributes of `SELF` without a qualifier:

```
CREATE FUNCTION gcd (x INTEGER, y INTEGER) RETURN INTEGER AS
-- find greatest common divisor of x and y
ans INTEGER;
BEGIN
    IF (y <= x) AND (x MOD y = 0) THEN ans := y;
    ELSIF x < y THEN ans := gcd(y, x);
    ELSE ans := gcd(y, x MOD y);
    END IF;
    RETURN ans;
END;
```

```
CREATE TYPE Rational AS OBJECT (
    num INTEGER,
    den INTEGER,
    MEMBER PROCEDURE normalize,
    ...
);
```

```
CREATE TYPE BODY Rational AS
MEMBER PROCEDURE normalize IS
    g INTEGER;
BEGIN
    g := gcd(SELF.num, SELF.den);
    g := gcd(num, den); -- equivalent to previous statement
    num := num / g;
    den := den / g;
END normalize;
...
END;
```

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.

Overloading

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. When you call one of the methods, PL/SQL finds it by comparing the list of actual parameters with each list of formal parameters.

A subtype can also overload methods it inherits from its supertype. In this case, the methods can have exactly the same formal parameters.

You cannot overload two methods if their formal parameters differ only in parameter mode. Also, you cannot overload two member functions that differ only in return type. For more information, see "[Overloading Subprogram Names](#)" on page 8-23.

MAP and ORDER Methods

The values of a scalar datatype such as `CHAR` or `REAL` have a predefined order, which allows them to be compared. But instances of an object type have no predefined order. To put them in order for comparison or sorting purposes, PL/SQL calls a **MAP method** supplied by you. In the following example, the keyword `MAP` indicates that method `convert()` orders `Rational` objects by mapping them to `REAL` values:

```
CREATE TYPE Rational AS OBJECT (  
    num INTEGER,  
    den INTEGER,  
    MAP MEMBER FUNCTION convert RETURN REAL,  
    ...  
);  
  
CREATE TYPE BODY Rational AS  
    MAP MEMBER FUNCTION convert RETURN REAL IS  
    BEGIN  
        RETURN num / den;  
    END convert;  
    ...  
END;
```

PL/SQL uses the ordering to evaluate Boolean expressions such as $x > y$, and to do comparisons implied by the `DISTINCT`, `GROUP BY`, and `ORDER BY` clauses. `MAP` method `convert()` returns the relative position of an object in the ordering of all Rational objects.

An object type can contain only one `MAP` method. It accepts the built-in parameter `SELF` and returns one of the following scalar types: `DATE`, `NUMBER`, `VARCHAR2`, or an ANSI SQL type such as `CHARACTER` or `REAL`.

Alternatively, you can supply PL/SQL with an **ORDER method**. An object type can contain only one `ORDER` method, which must be a function that returns a numeric result. In the following example, the keyword `ORDER` indicates that method `match()` compares two objects:

```
CREATE TYPE Customer AS OBJECT (
    id    NUMBER,
    name  VARCHAR2(20),
    addr  VARCHAR2(30),
    ORDER MEMBER FUNCTION match (c Customer) RETURN INTEGER
);

CREATE TYPE BODY Customer AS
    ORDER MEMBER FUNCTION match (c Customer) RETURN INTEGER IS
    BEGIN
        IF id < c.id THEN
            RETURN -1; -- any negative number will do
        ELSIF id > c.id THEN
            RETURN 1;  -- any positive number will do
        ELSE
            RETURN 0;
        END IF;
    END;
END;
```

Every `ORDER` method takes just two parameters: the built-in parameter `SELF` and another object of the same type. If `c1` and `c2` are `Customer` objects, a comparison such as `c1 > c2` calls method `match` automatically. The method returns a negative number, zero, or a positive number signifying that `SELF` is respectively less than, equal to, or greater than the other parameter. If either parameter passed to an `ORDER` method is null, the method returns a null.

Guidelines A `MAP` method, acting like a hash function, maps object values into scalar values, which are then compared using operators such as `<`, `=`, and so on. An `ORDER` method simply compares one object value to another.

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.)

When sorting or merging a large number of objects, use a `MAP` method. One call maps all the objects into scalars, then sorts the scalars. An `ORDER` method is less efficient because it must be called repeatedly (it can compare only two objects at a time). You must use a `MAP` method for hash joins because PL/SQL hashes on the object value.

Constructor Methods

Every object type has a **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.

Oracle generates a default constructor for every object type. The formal parameters of the constructor match the attributes of the object type. That is, the parameters and attributes are declared in the same order and have the same names and datatypes. PL/SQL never calls a constructor implicitly, so you must call it explicitly. For more information, see ["Calling Constructors"](#) on page 10-28.

Changing Attributes and Methods of an Existing Object Type (Type Evolution)

You can use the `ALTER TYPE` statement to add, modify, or drop attributes, and add or drop methods of an existing object type:

```
CREATE TYPE Person_typ AS OBJECT
( name CHAR(20),
  ssn CHAR(12),
  address VARCHAR2(100));
CREATE TYPE Person_nt IS TABLE OF Person_typ;
CREATE TYPE dept_typ AS OBJECT
( mgr Person_typ,
  emps Person_nt);
CREATE TABLE dept OF dept_typ;

-- Add new attributes to Person_typ and propagate the change
-- to Person_nt and dept_typ
ALTER TYPE Person_typ ADD ATTRIBUTE (picture BLOB, dob DATE)
CASCADE NOT INCLUDING TABLE DATA;

CREATE TYPE mytype AS OBJECT (attr1 NUMBER, attr2 NUMBER);
```

```
ALTER TYPE mytype ADD ATTRIBUTE (attr3 NUMBER),
DROP ATTRIBUTE attr2,
ADD ATTRIBUTE attr4 NUMBER CASCADE;
```

When a procedure is compiled, it always uses the current version of any object types it references. Existing procedures on the server that reference an object type are invalidated when the type is altered, and are automatically recompiled the next time the procedure is called. You must manually recompile any procedures on the client side that reference types that are altered.

If you drop a method from a supertype, you might have to make changes to subtypes that override that method. You can find if any subtypes are affected by using the `CASCADE` option of `ALTER TYPE`; the statement is rolled back if any subtypes override the method. To successfully drop the method from the supertype, you can:

- Drop the method permanently from the subtype first.
- Drop the method in the subtype, then add it back later using `ALTER TYPE` without the `OVERRIDING` keyword.

For more information about the `ALTER TYPE` statement, see *Oracle9i SQL Reference*. For guidelines about using type evolution in your applications, and options for changing other types and data that rely on see *Oracle9i Application Developer's Guide - Object-Relational Features*.

Defining Object Types

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. This section gives several complete examples, which teach you a lot about the design of object types and prepare you to start writing your own.

Currently, you cannot define object types in a PL/SQL block, subprogram, or package. However, you can define them interactively in SQL*Plus using the following syntax:

```
CREATE [OR REPLACE] TYPE type_name
  [AUTHID {CURRENT_USER | DEFINER}]
  { {IS | AS} OBJECT | UNDER supertype_name }
(
  attribute_name datatype[, attribute_name datatype]...
  [{MAP | ORDER} MEMBER function_spec,]
  [{FINAL| NOT FINAL} MEMBER function_spec,]
```

```
[{INSTANTIABLE| NOT INSTANTIABLE} MEMBER function_spec,]
[ {MEMBER | STATIC} {subprogram_spec | call_spec}
[, {MEMBER | STATIC} {subprogram_spec | call_spec}]... ]
) [ {FINAL| NOT FINAL} ] [ {INSTANTIABLE| NOT INSTANTIABLE} ] ;

[CREATE [OR REPLACE] TYPE BODY type_name {IS | AS}
  { {MAP | ORDER} MEMBER function_body;
    | {MEMBER | STATIC} {subprogram_body | call_spec}; }
  [ {MEMBER | STATIC} {subprogram_body | call_spec}; ]... ]
END;
```

The `AUTHID` clause determines whether all member methods 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 ["Invoker Rights Versus Definer Rights"](#) on page 8-47.

Overview of PL/SQL Type Inheritance

PL/SQL supports a single-inheritance model. You can define subtypes of object types. These subtypes contain all the attributes and methods of the parent type (or supertype). The subtypes can also contain additional attributes and additional methods, and can override methods from the supertype.

You can define whether or not subtypes can be derived from a particular type. You can also define types and methods that cannot be instantiated directly, only by declaring subtypes that instantiate them.

Some of the type properties can be changed dynamically with the `ALTER TYPE` statement. When changes are made to the supertype, either through `ALTER TYPE` or by redefining the supertype, the subtypes automatically reflect those changes.

You can use the `TREAT` operator in queries to return only those objects that are of a specified subtype. You can use the `IS OF` predicate to test whether an object is a member of one or more specified types or their subtypes.

The values from the `REF` and `DEREF` functions can represent either the declared type of the table or view, or one or more of its subtypes.

See the *Oracle9i Application Developer's Guide - Object-Relational Features* for more detail on all these object-relational features.

Examples of PL/SQL Type Inheritance

```
-- Create a supertype from which several subtypes will be derived.
CREATE TYPE Person_typ AS OBJECT ( ssn NUMBER, name VARCHAR2(30),
```



```
address VARCHAR2(100)) NOT FINAL;

-- Derive a subtype that has all the attributes of the supertype,
-- plus some additional attributes.
CREATE TYPE Student_typ UNDER Person_typ ( deptid NUMBER, major
VARCHAR2(30)) NOT FINAL;

-- Because Student_typ is declared NOT FINAL, you can derive
-- further subtypes from it.
CREATE TYPE PartTimeStudent_typ UNDER Student_typ( numhours NUMBER);

-- Derive another subtype. Because it has the default attribute
-- FINAL, you cannot use Employee_typ as a supertype and derive
-- subtypes from it.
CREATE TYPE Employee_typ UNDER Person_typ( empid NUMBER, mgr
VARCHAR2(30));

-- Define an object type that can be a supertype. Because the
-- member function is FINAL, it cannot be overridden in any
-- subtypes.

CREATE TYPE T AS OBJECT (... , MEMBER PROCEDURE Print(), FINAL MEMBER
FUNCTION foo(x NUMBER)... ) NOT FINAL;

-- We never want to create an object of this supertype. By using
-- NOT INSTANTIABLE, we force all objects to use one of the subtypes
-- instead, with specific implementations for the member functions.
CREATE TYPE Address_typ AS OBJECT(...) NOT INSTANTIABLE NOT FINAL;

-- These subtypes can provide their own implementations of
-- member functions, such as for validating phone numbers and
-- postal codes. Because there is no "generic" way of doing these
-- things, only objects of these subtypes can be instantiated.
CREATE TYPE USAddress_typ UNDER Address_typ(...);
CREATE TYPE IntlAddress_typ UNDER Address_typ(...);

-- Return REFS for those Person_typ objects that are instances of
-- the Student_typ subtype, and NULL REFS otherwise.
SELECT TREAT(REF(p) AS REF Student_typ) FROM Person_v p;

-- Example of using TREAT for assignment...

-- Return REFS for those Person_type objects that are instances of
-- Employee_typ or Student_typ, or any of their subtypes.
```

```

SELECT REF(p) FROM Person_v P WHERE VALUE(p) IS OF (Employee_typ,
Student_typ);

-- Similar to above, but do not allow any subtypes of Student_typ.
SELECT REF(p) FROM Person_v p WHERE VALUE(p) IS OF(ONLY
Student_typ);

-- The results of REF and Deref can include objects of Person_typ
-- and its subtypes such as Employee_typ and Student_typ.
SELECT REF(p) FROM Person_v p;
SELECT Deref(REF(p)) FROM Person_v p;

```

Object Type Example: Stack

A **stack** holds an ordered collection of data items. Stacks have a top and a bottom. Items can be added or removed only at the top. So, the last item added to a stack is the first item removed. (Think of the stack of clean serving trays in a cafeteria.) The operations **push** and **pop** update the stack while preserving last in, first out (LIFO) behavior.

Stacks have many applications. For example, they are used in systems programming to prioritize interrupts and to manage recursion. The simplest implementation of a stack uses an integer array, with one end of the array representing the top of the stack.

PL/SQL provides the datatype `VARRAY`, which lets you declare variable-size arrays (varrays for short). To declare a varray attribute, you must first define its type. However, you cannot define types in an object type spec. So, you define a standalone varray type, specifying its maximum size, as follows:

```
CREATE TYPE IntArray AS VARRAY(25) OF INTEGER;
```

Now, you can write the object type spec:

```

CREATE TYPE Stack AS OBJECT (
    max_size INTEGER,
    top      INTEGER,
    position IntArray,
    MEMBER PROCEDURE initialize,
    MEMBER FUNCTION full RETURN BOOLEAN,
    MEMBER FUNCTION empty RETURN BOOLEAN,
    MEMBER PROCEDURE push (n IN INTEGER),
    MEMBER PROCEDURE pop (n OUT INTEGER)
);

```

Finally, you write the object type body:

```
CREATE TYPE BODY Stack AS
  MEMBER PROCEDURE initialize IS
  BEGIN
    top := 0;
    /* Call constructor for varray and set element 1 to NULL. */
    position := IntArray(NULL);
    max_size := position.LIMIT; -- get varray size constraint
    position.EXTEND(max_size - 1, 1); -- copy element 1 into 2..25
  END initialize;

  MEMBER FUNCTION full RETURN BOOLEAN IS
  BEGIN
    RETURN (top = max_size); -- return TRUE if stack is full
  END full;

  MEMBER FUNCTION empty RETURN BOOLEAN IS
  BEGIN
    RETURN (top = 0); -- return TRUE if stack is empty
  END empty;

  MEMBER PROCEDURE push (n IN INTEGER) IS
  BEGIN
    IF NOT full THEN
      top := top + 1; -- push integer onto stack
      position(top) := n;
    ELSE -- stack is full
      RAISE_APPLICATION_ERROR(-20101, 'stack overflow');
    END IF;
  END push;

  MEMBER PROCEDURE pop (n OUT INTEGER) IS
  BEGIN
    IF NOT empty THEN
      n := position(top);
      top := top - 1; -- pop integer off stack
    ELSE -- stack is empty
      RAISE_APPLICATION_ERROR(-20102, 'stack underflow');
    END IF;
  END pop;
END;
```

In member procedures `push` and `pop`, you use the built-in procedure `raise_application_error` to issue user-defined error messages. That way, you report errors to the client program and avoid returning unhandled exceptions to the host environment. The client program gets a PL/SQL exception, which it can process using the error-reporting functions `SQLCODE` and `SQLERRM` in an `OTHERS` exception handler. In the following example, when an exception is raised, you print the corresponding Oracle error message:

```
DECLARE
    ...
BEGIN
    ...
EXCEPTION
    WHEN OTHERS THEN
        dbms_output.put_line(SQLERRM);
END;
```

Alternatively, the program can use `pragma EXCEPTION_INIT` to map the error numbers returned by `raise_application_error` to named exceptions, as the following example shows:

```
DECLARE
    stack_overflow EXCEPTION;
    stack_underflow EXCEPTION;
    PRAGMA EXCEPTION_INIT(stack_overflow, -20101);
    PRAGMA EXCEPTION_INIT(stack_underflow, -20102);
BEGIN
    ...
EXCEPTION
    WHEN stack_overflow THEN
        ...
END;
```

Object Type Example: Ticket_Booth

Consider a chain of movie theaters, each theater with three screens. Each theater has a ticket booth where tickets for three different movies are sold. All tickets are priced at \$3.00. Periodically, ticket receipts are collected and the stock of tickets is replenished.

Before defining an object type that represents a ticket booth, you must consider the data and operations needed. For a simple ticket booth, the object type needs attributes for the ticket price, quantity of tickets on hand, and receipts. It also needs

methods for the following operations: purchase ticket, take inventory, replenish stock, and collect receipts.

For receipts, you use a three-element varray. Elements 1, 2, and 3 record the ticket receipts for movies 1, 2, and 3, respectively. To declare a varray attribute, you must first define its type, as follows:

```
CREATE TYPE RealArray AS VARRAY(3) OF REAL;
```

Now, you can write the object type spec:

```
CREATE TYPE Ticket_Booth AS OBJECT (
    price          REAL,
    qty_on_hand    INTEGER,
    receipts       RealArray,
    MEMBER PROCEDURE initialize,
    MEMBER PROCEDURE purchase (
        movie      INTEGER,
        amount     REAL,
        change     OUT REAL),
    MEMBER FUNCTION inventory RETURN INTEGER,
    MEMBER PROCEDURE replenish (quantity INTEGER),
    MEMBER PROCEDURE collect (movie INTEGER, amount OUT REAL)
);
```

Finally, you write the object type body:

```
CREATE TYPE BODY Ticket_Booth AS
    MEMBER PROCEDURE initialize IS
    BEGIN
        price := 3.00;
        qty_on_hand := 5000; -- provide initial stock of tickets
        -- call constructor for varray and set elements 1..3 to zero
        receipts := RealArray(0,0,0);
    END initialize;

    MEMBER PROCEDURE purchase (
        movie      INTEGER,
        amount     REAL,
        change     OUT REAL) IS
    BEGIN
        IF qty_on_hand = 0 THEN
            RAISE_APPLICATION_ERROR(-20103, 'out of stock');
        END IF;
        IF amount >= price THEN
            qty_on_hand := qty_on_hand - 1;
```

```
        receipts(movie) := receipts(movie) + price;
        change := amount - price;
    ELSE -- amount is not enough
        change := amount; -- so return full amount
    END IF;
END purchase;

MEMBER FUNCTION inventory RETURN INTEGER IS
BEGIN
    RETURN qty_on_hand;
END inventory;

MEMBER PROCEDURE replenish (quantity INTEGER) IS
BEGIN
    qty_on_hand := qty_on_hand + quantity;
END replenish;

MEMBER PROCEDURE collect (movie INTEGER, amount OUT REAL) IS
BEGIN
    amount := receipts(movie); -- get receipts for a given movie
    receipts(movie) := 0; -- reset receipts to zero
END collect;
END;
```

Object Type Example: Bank_Account

Before defining an object type that represents a bank account, you must consider the data and operations needed. For a simple bank account, the object type needs attributes for an account number, balance, and status. It also needs methods for the following operations: open account, verify account number, close account, deposit money, withdraw money, and return balance.

First, you write the object type spec, as follows:

```
CREATE TYPE Bank_Account AS OBJECT (
    acct_number INTEGER(5),
    balance     REAL,
    status      VARCHAR2(10),
    MEMBER PROCEDURE open (amount IN REAL),
    MEMBER PROCEDURE verify_acct (num IN INTEGER),
    MEMBER PROCEDURE close (num IN INTEGER, amount OUT REAL),
    MEMBER PROCEDURE deposit (num IN INTEGER, amount IN REAL),
    MEMBER PROCEDURE withdraw (num IN INTEGER, amount IN REAL),
    MEMBER FUNCTION curr_bal (num IN INTEGER) RETURN REAL
);
```

Then, you write the object type body:

```
CREATE TYPE BODY Bank_Account AS
  MEMBER PROCEDURE open (amount IN REAL) IS
  -- open account with initial deposit
  BEGIN
    IF NOT amount > 0 THEN
      RAISE_APPLICATION_ERROR(-20104, 'bad amount');
    END IF;
    SELECT acct_sequence.NEXTVAL INTO acct_number FROM dual;
    status := 'open';
    balance := amount;
  END open;

  MEMBER PROCEDURE verify_acct (num IN INTEGER) IS
  -- check for wrong account number or closed account
  BEGIN
    IF (num <> acct_number) THEN
      RAISE_APPLICATION_ERROR(-20105, 'wrong number');
    ELSIF (status = 'closed') THEN
      RAISE_APPLICATION_ERROR(-20106, 'account closed');
    END IF;
  END verify_acct;

  MEMBER PROCEDURE close (num IN INTEGER, amount OUT REAL) IS
  -- close account and return balance
  BEGIN
    verify_acct(num);
    status := 'closed';
    amount := balance;
  END close;

  MEMBER PROCEDURE deposit (num IN INTEGER, amount IN REAL) IS
  BEGIN
    verify_acct(num);
    IF NOT amount > 0 THEN
      RAISE_APPLICATION_ERROR(-20104, 'bad amount');
    END IF;
    balance := balance + amount;
  END deposit;

  MEMBER PROCEDURE withdraw (num IN INTEGER, amount IN REAL) IS
  -- if account has enough funds, withdraw
  -- given amount; else, raise an exception
```

```

BEGIN
    verify_acct(num);
    IF amount <= balance THEN
        balance := balance - amount;
    ELSE
        RAISE_APPLICATION_ERROR(-20107, 'insufficient funds');
    END IF;
END withdraw;

MEMBER FUNCTION curr_bal (num IN INTEGER)
    RETURN REAL IS
BEGIN
    verify_acct(num);
    RETURN balance;
END curr_bal;
END;
```

Object Type Example: Rational Numbers

A rational number is a number expressible as the quotient of two integers, a numerator and a denominator. Like most languages, PL/SQL does not have a rational number type or predefined operations on rational numbers. Let us remedy that omission by defining object type `Rational`. First, you write the object type spec, as follows:

```

CREATE TYPE Rational AS OBJECT (
    num INTEGER,
    den INTEGER,
    MAP MEMBER FUNCTION convert RETURN REAL,
    MEMBER PROCEDURE normalize,
    MEMBER FUNCTION reciprocal RETURN Rational,
    MEMBER FUNCTION plus (x Rational) RETURN Rational,
    MEMBER FUNCTION less (x Rational) RETURN Rational,
    MEMBER FUNCTION times (x Rational) RETURN Rational,
    MEMBER FUNCTION divby (x Rational) RETURN Rational,
    PRAGMA RESTRICT_REFERENCES (DEFAULT, RNDS,WNDS,RNPS,WNPS)
);
```

PL/SQL does not allow the overloading of operators. So, you must define methods named `plus()`, `less()` (the word `minus` is reserved), `times()`, and `divby()` instead of overloading the infix operators `+`, `-`, `*`, and `/`.

Next, you create the following standalone stored function, which will be called by method `normalize()`:


```

CREATE FUNCTION gcd (x INTEGER, y INTEGER) RETURN INTEGER AS
-- find greatest common divisor of x and y
  ans INTEGER;
BEGIN
  IF (y <= x) AND (x MOD y = 0) THEN
    ans := y;
  ELSIF x < y THEN
    ans := gcd(y, x); -- recursive call
  ELSE
    ans := gcd(y, x MOD y); -- recursive call
  END IF;
  RETURN ans;
END;

```

Then, you write the object type body, as follows:

```

CREATE TYPE BODY Rational AS
  MAP MEMBER FUNCTION convert RETURN REAL IS
  -- convert rational number to real number
  BEGIN
    RETURN num / den;
  END convert;

  MEMBER PROCEDURE normalize IS
  -- reduce fraction num / den to lowest terms
  g INTEGER;
  BEGIN
    g := gcd(num, den);
    num := num / g;
    den := den / g;
  END normalize;

  MEMBER FUNCTION reciprocal RETURN Rational IS
  -- return reciprocal of num / den
  BEGIN
    RETURN Rational(den, num); -- call constructor
  END reciprocal;

  MEMBER FUNCTION plus (x Rational) RETURN Rational IS
  -- return sum of SELF + x
  r Rational;
  BEGIN
    r := Rational(num * x.den + x.num * den, den * x.den);
    r.normalize;
    RETURN r;
  END plus;

```

```
END plus;

MEMBER FUNCTION less (x Rational) RETURN Rational IS
-- return difference of SELF - x
  r Rational;
BEGIN
  r := Rational(num * x.den - x.num * den, den * x.den);
  r.normalize;
  RETURN r;
END less;

MEMBER FUNCTION times (x Rational) RETURN Rational IS
-- return product of SELF * x
  r Rational;
BEGIN
  r := Rational(num * x.num, den * x.den);
  r.normalize;
  RETURN r;
END times;

MEMBER FUNCTION divby (x Rational) RETURN Rational IS
-- return quotient of SELF / x
  r Rational;
BEGIN
  r := Rational(num * x.den, den * x.num);
  r.normalize;
  RETURN r;
END divby;
END;
```

Declaring and Initializing Objects

Once 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.

Declaring Objects

You can use object types wherever built-in types such as `CHAR` or `NUMBER` can be used. In the block below, you declare object `r` of type `Rational`. Then, you call the constructor for object type `Rational` to initialize the object. The call assigns the values 6 and 8 to attributes `num` and `den`, respectively.

```
DECLARE
    r Rational;
BEGIN
    r := Rational(6, 8);
    dbms_output.put_line(r.num); -- prints 6
```

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 `Account` to specify the datatype of a formal parameter:

```
DECLARE
    ...
    PROCEDURE open_acct (new_acct IN OUT Account) IS ...
```

In the following example, you use object type `Account` to specify the return type of a function:

```
DECLARE
    ...
    FUNCTION get_acct (acct_id IN INTEGER) RETURN Account IS ...
```

Initializing 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. Consider the following example:

```
DECLARE
    r Rational; -- r becomes atomically null
BEGIN
    r := Rational(2,3); -- r becomes 2/3
```

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, as the following example shows:

```

DECLARE
    r Rational;
BEGIN
    r Rational := Rational(1,2); -- r becomes 1/2
    r := NULL; -- r becomes atomically null
    IF r IS NULL THEN ... -- condition yields TRUE

```

A good programming practice is to initialize an object in its declaration, as shown in the following example:

```

DECLARE
    r Rational := Rational(2,3); -- r becomes 2/3

```

How PL/SQL Treats Uninitialized Objects

In an expression, attributes of an uninitialized object evaluate to NULL. Trying to assign values to attributes of an uninitialized object raises the predefined exception `ACCESS_INTO_NULL`. When applied to an uninitialized object or its attributes, the `IS NULL` comparison operator yields TRUE.

The following example illustrates the difference between null objects and objects with null attributes:

```

DECLARE
    r Rational; -- r is atomically null
BEGIN
    IF r IS NULL THEN ... -- yields TRUE
    IF r.num IS NULL THEN ... -- yields TRUE
    r := Rational(NULL, NULL); -- initializes r
    r.num := 4; -- succeeds because r is no longer atomically null
                -- even though all its attributes are null
    r := NULL; -- r becomes atomically null again
    r.num := 4; -- raises ACCESS_INTO_NULL
EXCEPTION
    WHEN ACCESS_INTO_NULL THEN
        ...
END;

```

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.

Accessing Attributes

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. In the example below, you assign the value of attribute `den` to variable `denominator`. Then, you assign the value stored in variable `numerator` to attribute `num`.

```
DECLARE
    r Rational := Rational(NULL, NULL);
    numerator   INTEGER;
    denominator INTEGER;
BEGIN
    ...
    denominator := r.den;
    r.num := numerator;

```

Attribute names can be chained, which lets you access the attributes of a nested object type. For example, suppose you define object types `Address` and `Student`, as follows:

```
CREATE TYPE Address AS OBJECT (
    street   VARCHAR2(30),
    city     VARCHAR2(20),
    state    CHAR(2),
    zip_code VARCHAR2(5)
);

CREATE TYPE Student AS OBJECT (
    name           VARCHAR2(20),
    home_address  Address,
    phone_number  VARCHAR2(10),
    status        VARCAHR2(10),
    advisor_name  VARCHAR2(20),
    ...
);'
```

Notice that `zip_code` is an attribute of object type `Address` and that `Address` is the datatype of attribute `home_address` in object type `Student`. If `s` is a `Student` object, you access the value of its `zip_code` attribute as follows:

```
s.home_address.zip_code
```

Calling Constructors

Calls to a constructor are allowed wherever function calls are allowed. Like all functions, a constructor is called as part of an expression, as the following example shows:

```
DECLARE
    r1 Rational := Rational(2, 3);
    FUNCTION average (x Rational, y Rational) RETURN Rational IS
    BEGIN
        ...
    END;
BEGIN
    r1 := average(Rational(3, 4), Rational(7, 11));
    IF (Rational(5, 8) > r1) THEN
        ...
    END IF;
END;
```

When you pass parameters to a constructor, the call assigns initial values to the attributes of the object being instantiated. You must supply a parameter for every attribute because, unlike constants and variables, attributes cannot have default values. As the following example shows, the *n*th parameter assigns a value to the *n*th attribute:

```
DECLARE
    r Rational;
BEGIN
    r := Rational(5, 6); -- assign 5 to num, 6 to den
    -- now r is 5/6
```

The next example shows that you can call a constructor using named notation instead of positional notation:

```
BEGIN
    r := Rational(den => 6, num => 5); -- assign 5 to num, 6 to den
```

Calling Methods

Like packaged subprograms, methods are called using dot notation. In the following example, you call method `normalize()`, which divides attributes `num` and `den` (for "numerator" and "denominator") by their greatest common divisor:

```
DECLARE
    r Rational;
```

```

BEGIN
  r := Rational(6, 8);
  r.normalize;
  dbms_output.put_line(r.num);  -- prints 3
END;

```

As the example below shows, you can chain method calls. Execution proceeds from left to right. First, member function `reciprocal()` is called, then member procedure `normalize()` is called.

```

DECLARE
  r Rational := Rational(6, 8);
BEGIN
  r.reciprocal().normalize;
  dbms_output.put_line(r.num);  -- prints 4
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. For example, the following statement is not allowed:

```
r.normalize().reciprocal;  -- not allowed
```

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*.

Sharing Objects

Most real-world objects are considerably larger and more complex than objects of type `Rational`. Consider the following object types:

```
CREATE TYPE Address AS OBJECT (
```

```
        street_address VARCHAR2(35),
        city            VARCHAR2(15),
        state           CHAR(2),
        zip_code        INTEGER
    );

CREATE TYPE Person AS OBJECT (
    first_name  VARCHAR2(15),
    last_name   VARCHAR2(15),
    birthday    DATE,
    home_address Address, -- nested object type
    phone_number VARCHAR2(15),
    ss_number   INTEGER,
    ...
);
```

Address objects have twice as many attributes as Rational objects, and Person objects have still more attributes including one of type Address. When an object is large, it is inefficient to pass copies of it from subprogram to subprogram. It makes more sense to share the object. You can do that if the object has an object identifier. To share the object, you use references (refs for short). A *ref* is a pointer to an object.

Sharing has two important advantages. First, data is not replicated unnecessarily. Second, when a shared object is updated, the change occurs in only one place, and any ref can retrieve the updated values instantly.

In the following example, you gain the advantages of sharing by defining object type Home and then creating a table that stores instances of that object type:

```
CREATE TYPE Home AS OBJECT (
    address  VARCHAR2(35),
    owner    VARCHAR2(25),
    age      INTEGER,
    style    VARCHAR(15),
    floor plan BLOB,
    price    REAL(9,2),
    ...
);
...
CREATE TABLE homes OF Home;
```


Using Refs

By revising object type `Person`, you can model a community in which several people might share the same home. You use the type modifier `REF` to declare refs, which hold pointers to objects.

```
CREATE TYPE Person AS OBJECT (
  first_name  VARCHAR2(10),
  last_name   VARCHAR2(15),
  birthday    DATE,
  home_address REF Home, -- can be shared by family
  phone_number VARCHAR2(15),
  ss_number   INTEGER,
  mother      REF Person, -- family members refer to each other
  father      REF Person,
  ...
);
```

Notice how references from persons to homes and between persons model real-world relationships.

You can declare refs as variables, parameters, fields, or attributes. And, you can use refs as input or output variables in SQL data manipulation statements. However, you cannot navigate through refs. Given an expression such as `x.attribute`, where `x` is a ref, PL/SQL cannot navigate to the table in which the referenced object is stored. For example, the following assignment is illegal:

```
DECLARE
  p_ref    REF Person;
  phone_no VARCHAR2(15);
BEGIN
  phone_no := p_ref.phone_number; -- illegal
```

Instead, you must use the function `DEREF` or make calls to the package `UTL_REF` to access the object. For some examples, see ["Using Function DEREF"](#) on page 10-36.

Forward Type Definitions

You can refer only to schema objects that already exist. In the following example, the first `CREATE TYPE` statement is illegal because it refers to object type `Department`, which does not yet exist:

```
CREATE TYPE Employee AS OBJECT (
  name VARCHAR2(20),
  dept REF Department, -- illegal
```

```

    ...
);

CREATE TYPE Department AS OBJECT (
    number INTEGER,
    manager Employee,
    ...
);

```

Switching the `CREATE TYPE` statements does not help because the object types are **mutually dependent**. Object type `Employee` has an attribute that refers to object type `Department`, and object type `Department` has an attribute of type `Employee`. To solve this problem, you use a special `CREATE TYPE` statement called a forward type definition, which lets you define mutually dependent object types.

To debug the last example, simply precede it with the following statement:

```

CREATE TYPE Department; -- forward type definition
-- at this point, Department is an incomplete object type

```

The object type created by a forward type definition is called an **incomplete object type** because (until it is defined fully) it has no attributes or methods.

An **impure** incomplete object type has attributes but causes compilation errors because it refers to an undefined type. For example, the following `CREATE TYPE` statement causes an error because object type `Address` is undefined:

```

CREATE TYPE Customer AS OBJECT (
    id    NUMBER,
    name  VARCHAR2(20),
    addr  Address, -- not yet defined
    phone VARCHAR2(15)
);

```

This lets you defer the definition of object type `Address`. Moreover, the incomplete type `Customer` can be made available to other application developers for use in refs.

Manipulating Objects

You can use an object type in the `CREATE TABLE` statement to specify the datatype of a column. Once the table is created, you can use SQL statements to insert an object, select its attributes, call its methods, and update its state.

Note: Access to remote or distributed objects is not allowed.

In the SQL*Plus script below, the `INSERT` statement calls the constructor for object type `Rational`, then inserts the resulting object. The `SELECT` statement retrieves the value of attribute `num`. The `UPDATE` statement calls member method `reciprocal()`, which returns a `Rational` value after swapping attributes `num` and `den`. Notice that a table alias is required when you reference an attribute or method. (For an explanation, see [Appendix D](#).)

```
CREATE TABLE numbers (rn Rational, ...)
/
INSERT INTO numbers (rn) VALUES (Rational(3, 62)) -- inserts 3/62
/
SELECT n.rn.num INTO my_num FROM numbers n ... -- returns 3
/
UPDATE numbers n SET n.rn = n.rn.reciprocal() ... -- yields 62/3
```

When you instantiate an object this way, it has no identity outside the database table. However, the object type exists independently of any table, and can be used to create objects in other ways.

In the next example, you create a table that stores objects of type `Rational` in its rows. Such tables, having rows of objects, are called **object tables**. Each column in a row corresponds to an attribute of the object type. Rows can have different column values.

```
CREATE TABLE rational_nums OF Rational;
```

Each row in an object table has an **object identifier**, which uniquely identifies the object stored in that row and serves as a reference to the object.

Selecting Objects

Assume that you have run the following SQL*Plus script, which creates object type `Person` and object table `persons`, and that you have populated the table:

```
CREATE TYPE Person AS OBJECT (
    first_name  VARCHAR2(15),
    last_name   VARCHAR2(15),
    birthday    DATE,
    home_address Address,
    phone_number VARCHAR2(15))
/
CREATE TABLE persons OF Person
/
```

The following subquery produces a result set of rows containing only the attributes of `Person` objects:

```
BEGIN
  INSERT INTO employees -- another object table of type Person
    SELECT * FROM persons p WHERE p.last_name LIKE '%Smith';
```

To return a result set of objects, you must use the function `VALUE`, which is discussed in the next section.

Using Function `VALUE`

As you might expect, the function `VALUE` 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.) For example, to return a result set of `Person` objects, use `VALUE` as follows:

```
BEGIN
  INSERT INTO employees
    SELECT VALUE(p) FROM persons p
    WHERE p.last_name LIKE '%Smith';
```

In the next example, you use `VALUE` to return a specific `Person` object:

```
DECLARE
  p1 Person;
  p2 Person;
  ...
BEGIN
  SELECT VALUE(p) INTO p1 FROM persons p
    WHERE p.last_name = 'Kroll';
  p2 := p1;
  ...
END;
```

At this point, `p1` holds a local `Person` object, which is a copy of the stored object whose last name is `'Kroll'`, and `p2` holds another local `Person` object, which is a copy of `p1`. As the following example shows, you can use these variables to access and update the objects they hold:

```
BEGIN
  p1.last_name := p1.last_name || ' Jr';
```

Now, the local `Person` object held by `p1` has the last name `'Kroll Jr'`.

Using Function REF

You can retrieve refs using the function `REF`, which, like `VALUE`, takes as its argument a correlation variable. In the following example, you retrieve one or more refs to `Person` objects, then insert the refs into table `person_refs`:

```
BEGIN
  INSERT INTO person_refs
    SELECT REF(p) FROM persons p
      WHERE p.last_name LIKE '%Smith';
```

In the next example, you retrieve a ref and attribute at the same time:

```
DECLARE
  p_ref          REF Person;
  taxpayer_id    VARCHAR2(9);
BEGIN
  SELECT REF(p), p.ss_number INTO p_ref, taxpayer_id
    FROM persons p
      WHERE p.last_name = 'Parker'; -- must return one row
  ...
END;
```

In the final example, you update the attributes of a `Person` object:

```
DECLARE
  p_ref          REF Person;
  my_last_name   VARCHAR2(15);
BEGIN
  SELECT REF(p) INTO p_ref FROM persons p
    WHERE p.last_name = my_last_name;
  UPDATE persons p
    SET p = Person('Jill', 'Anders', '11-NOV-67', ...)
    WHERE REF(p) = p_ref;
END;
```

Testing for Dangling Refs

If the object to which a ref points is deleted, the ref is left **dangling** (pointing to a nonexistent object). To test for this condition, you can use the SQL predicate `IS DANGLING`. For example, suppose column `manager` in relational table `department` holds refs to `Employee` objects stored in an object table. You can use the following `UPDATE` statement to convert any dangling refs into nulls:

```
UPDATE department SET manager = NULL WHERE manager IS DANGLING;
```

Using Function Deref

You cannot navigate through refs within PL/SQL procedural statements. Instead, you must use the function `Deref` in a SQL statement. (`Deref` is short for dereference. When you **dereference** a pointer, you get the value to which it points.) `Deref` takes as its argument a reference to an object, then returns the value of that object. If the ref is dangling, `Deref` returns a null object.

In the example below, you dereference a ref to a `Person` object. Notice that you select the ref from dummy table `dual`. You need not specify an object table and search criteria because each object stored in an object table has a unique, immutable object identifier, which is part of every ref to that object.

```
DECLARE
    p1    Person;
    p_ref REF Person;
    name  VARCHAR2(15);
BEGIN
    ...
    /* Assume that p_ref holds a valid reference
       to an object stored in an object table. */
    SELECT Deref(p_ref) INTO p1 FROM dual;
    name := p1.last_name;
```

You can use `Deref` in successive SQL statements to dereference refs, as the following example shows:

```
CREATE TYPE PersonRef AS OBJECT (p_ref REF Person)
/
DECLARE
    name  VARCHAR2(15);
    pr_ref REF PersonRef;
    pr    PersonRef;
    p     Person;
BEGIN
    ...
    /* Assume pr_ref holds a valid reference. */
    SELECT Deref(pr_ref) INTO pr FROM dual;
    SELECT Deref(pr.p_ref) INTO p FROM dual;
    name := p.last_name;
    ...
END
/
```

The next example shows that you cannot use function `Deref` within procedural statements:

```
BEGIN
  ...
  pl := Deref(p_ref); -- not allowed
```

Within SQL statements, you can use dot notation to navigate through object columns to ref attributes and through one ref attribute to another. You can also navigate through ref columns to attributes if you use a table alias. For example, the following syntax is valid:

```
table_alias.object_column.ref_attribute
table_alias.object_column.ref_attribute.attribute
table_alias.ref_column.attribute
```

Assume that you have run the following SQL*Plus script, which creates object types `Address` and `Person` and object table `persons`:

```
CREATE TYPE Address AS OBJECT (
  street  VARCHAR2(35),
  city    VARCHAR2(15),
  state   CHAR(2),
  zip_code INTEGER)
/
CREATE TYPE Person AS OBJECT (
  first_name  VARCHAR2(15),
  last_name   VARCHAR2(15),
  birthday    DATE,
  home_address REF Address, -- shared with other Person objects
  phone_number VARCHAR2(15))
/
CREATE TABLE persons OF Person
/
```

Ref attribute `home_address` corresponds to a column in object table `persons` that holds refs to `Address` objects stored in some other table. After populating the tables, you can select a particular address by dereferencing its ref, as follows:

```
DECLARE
  addr1 Address,
  addr2 Address,
  ...
BEGIN
  SELECT Deref(home_address) INTO addr1 FROM persons p
  WHERE p.last_name = 'Derringer';
```

In the example below, you navigate through ref column `home_address` to attribute `street`. In this case, a table alias is required.

```
DECLARE
    my_street VARCHAR2(25),
    ...
BEGIN
    SELECT p.home_address.street INTO my_street FROM persons p
        WHERE p.last_name = 'Lucas';
```

Inserting Objects

You use the `INSERT` statement to add objects to an object table. In the following example, you insert a `Person` object into object table `persons`:

```
BEGIN
    INSERT INTO persons
        VALUES ('Jenifer', 'Lapidus', ...);
```

Alternatively, you can use the constructor for object type `Person` to insert an object into object table `persons`:

```
BEGIN
    INSERT INTO persons
        VALUES (Person('Albert', 'Brooker', ...));
```

In the next example, you use the `RETURNING` clause to store `Person` refs in local variables. Notice how the clause mimics a `SELECT` statement. You can also use the `RETURNING` clause in `UPDATE` and `DELETE` statements.

```
DECLARE
    p1_ref REF Person;
    p2_ref REF Person;
BEGIN
    INSERT INTO persons p
        VALUES (Person('Paul', 'Chang', ...))
        RETURNING REF(p) INTO p1_ref;
    INSERT INTO persons p
        VALUES (Person('Ana', 'Thorne', ...))
        RETURNING REF(p) INTO p2_ref;
```

To insert objects into an object table, you can use a subquery that returns objects of the same type. An example follows:

```
BEGIN
    INSERT INTO persons2
```



```
SELECT VALUE(p) FROM persons p
      WHERE p.last_name LIKE '%Jones';
```

The rows copied to object table `persons2` are given new object identifiers. No object identifiers are copied from object table `persons`.

The script below creates a relational table named `department`, which has a column of type `Person`, then inserts a row into the table. Notice how constructor `Person()` provides a value for column `manager`.

```
CREATE TABLE department (
    dept_name VARCHAR2(20),
    manager   Person,
    location  VARCHAR2(20))
/
INSERT INTO department
    VALUES ('Payroll', Person('Alan', 'Tsai', ...), 'Los Angeles')
/
```

The new `Person` object stored in column `manager` cannot be referenced because it is stored in a column (not a row) and therefore has no object identifier.

Updating Objects

To modify the attributes of objects in an object table, you use the `UPDATE` statement, as the following example shows:

```
BEGIN
    UPDATE persons p SET p.home_address = '341 Oakdene Ave'
        WHERE p.last_name = 'Brody';
    UPDATE persons p SET p = Person('Beth', 'Steinberg', ...)
        WHERE p.last_name = 'Steinway';
END;
```

Deleting Objects

You use the `DELETE` statement to remove objects (rows) from an object table. To remove objects selectively, you use the `WHERE` clause, as follows:

```
BEGIN
    DELETE FROM persons p
        WHERE p.home_address = '108 Palm Dr';
END;
```

Native Dynamic SQL

A happy and gracious flexibility ... —Matthew Arnold

This chapter shows you how to use native dynamic SQL (dynamic SQL for short), a PL/SQL interface that makes your applications more flexible and versatile. You learn simple ways to write programs that can build and process SQL statements "on the fly" at run time.

Within PL/SQL, you can execute any kind of SQL statement (even data definition and data control statements) without resorting to cumbersome programmatic approaches. Dynamic SQL blends seamlessly into your programs, making them more efficient, readable, and concise.

This chapter discusses the following topics:

[What Is Dynamic SQL?](#)

[The Need for Dynamic SQL](#)

[Using the EXECUTE IMMEDIATE Statement](#)

[Using the OPEN-FOR, FETCH, and CLOSE Statements](#)

[Tips and Traps for Dynamic SQL](#)

What Is Dynamic SQL?

Most PL/SQL programs do a specific, predictable job. For example, a stored procedure might accept an employee number and salary increase, then update the `sal` column in the `emp` table. In this case, the full text of the `UPDATE` statement is known at compile time. Such statements do not change from execution to execution. So, they are called *static* SQL statements.

However, some programs must build and process a variety of SQL statements at run time. For example, a general-purpose report writer must build different `SELECT` statements for the various reports it generates. In this case, the full text of the statement is unknown until run time. Such statements can, and probably will, change from execution to execution. So, they are called *dynamic* SQL statements.

Dynamic SQL statements are stored in character strings built by your program at run time. Such strings must contain the text of a valid SQL statement or PL/SQL block. They can also contain placeholders for bind arguments. A *placeholder* is an undeclared identifier, so its name, to which you must prefix a colon, does not matter. For example, PL/SQL makes no distinction between the following strings:

```
'DELETE FROM emp WHERE sal > :my_sal AND comm < :my_comm'  
'DELETE FROM emp WHERE sal > :s AND comm < :c'
```

To process most dynamic SQL statements, you use the `EXECUTE IMMEDIATE` statement. However, to process a multi-row query (`SELECT` statement), you must use the `OPEN-FOR`, `FETCH`, and `CLOSE` statements.

The Need for Dynamic SQL

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`). In PL/SQL, such statements cannot be executed statically.
- You want more flexibility. For example, you might want to defer your choice of schema objects until run time. Or, you might want your program to build different search conditions for the `WHERE` clause of a `SELECT` statement. A more complex program might choose from various SQL operations, clauses, etc.
- You use package `DBMS_SQL` to execute SQL statements dynamically, but you want better performance, something easier to use, or functionality that `DBMS_SQL` lacks such as support for objects and collections. (For a comparison with `DBMS_SQL`, see *Oracle9i Application Developer's Guide - Fundamentals*.)

Using the EXECUTE IMMEDIATE Statement

The EXECUTE IMMEDIATE statement prepares (parses) and immediately executes a dynamic SQL statement or an anonymous PL/SQL block. The syntax is

```
EXECUTE IMMEDIATE dynamic_string
[INTO {define_variable[, define_variable]... | record}]
[USING [IN | OUT | IN OUT] bind_argument
      [, [IN | OUT | IN OUT] bind_argument]...]
[ {RETURNING | RETURN} INTO bind_argument[, bind_argument]...];
```

where `dynamic_string` is a string expression that represents a SQL statement or PL/SQL block, `define_variable` is a variable that stores a selected column value, and `record` is a user-defined or %ROWTYPE record that stores a selected row. An input `bind_argument` is an expression whose value is passed to the dynamic SQL statement or PL/SQL block. An output `bind_argument` is a variable that stores a value returned by the dynamic SQL statement or PL/SQL block.

Except for multi-row queries, the dynamic string can contain any SQL statement (*without* the terminator) or any PL/SQL block (with 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. For the right way, see ["Making Procedures Work on Arbitrarily Named Schema Objects"](#) on page 11-15.

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, 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. So, 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"](#) on page 11-17.

Dynamic SQL supports all the SQL datatypes. So, for example, define variables and bind arguments can be collections, LOBs, instances of an object type, and refs. As a rule, dynamic SQL does not support PL/SQL-specific types. So, 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. However, you incur some overhead because EXECUTE IMMEDIATE re-prepares the dynamic string before every execution.

Some Examples of Dynamic SQL

The following PL/SQL block contains several examples of dynamic SQL:

```

DECLARE
    sql_stmt      VARCHAR2(200);
    plsql_block  VARCHAR2(500);
    emp_id       NUMBER(4) := 7566;
    salary       NUMBER(7,2);
    dept_id      NUMBER(2) := 50;
    dept_name    VARCHAR2(14) := 'PERSONNEL';
    location     VARCHAR2(13) := 'DALLAS';
    emp_rec      emp%ROWTYPE;
BEGIN
    EXECUTE IMMEDIATE 'CREATE TABLE bonus (id NUMBER, amt NUMBER)';

    sql_stmt := 'INSERT INTO dept VALUES (:1, :2, :3)';
    EXECUTE IMMEDIATE sql_stmt USING dept_id, dept_name, location;

    sql_stmt := 'SELECT * FROM emp WHERE empno = :id';
    EXECUTE IMMEDIATE sql_stmt INTO emp_rec USING emp_id;

    plsql_block := 'BEGIN emp_pkg.raise_salary(:id, :amt); END;';
    EXECUTE IMMEDIATE plsql_block USING 7788, 500;

    sql_stmt := 'UPDATE emp SET sal = 2000 WHERE empno = :1
                RETURNING sal INTO :2';
    EXECUTE IMMEDIATE sql_stmt USING emp_id RETURNING INTO salary;

    EXECUTE IMMEDIATE 'DELETE FROM dept WHERE deptno = :num'
        USING dept_id;

    EXECUTE IMMEDIATE 'ALTER SESSION SET SQL_TRACE TRUE';
END;

```

In the example below, a standalone procedure accepts the name of a database table (such as 'emp') and an optional WHERE-clause condition (such as 'sal > 2000'). If you omit the condition, the procedure deletes all rows from the table. Otherwise, the procedure deletes only those rows that meet the condition.

```
CREATE PROCEDURE delete_rows (
    table_name IN VARCHAR2,
    condition IN VARCHAR2 DEFAULT NULL) AS
    where_clause VARCHAR2(100) := ' WHERE ' || condition;
BEGIN
    IF condition IS NULL THEN where_clause := NULL; END IF;
    EXECUTE IMMEDIATE 'DELETE FROM ' || table_name || where_clause;
EXCEPTION
    ...
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. For example, both of the following EXECUTE IMMEDIATE statements are legal:

```
DECLARE
    sql_stmt VARCHAR2(200);
    my_empno NUMBER(4) := 7902;
    my_ename VARCHAR2(10);
    my_job VARCHAR2(9);
    my_sal NUMBER(7,2) := 3250.00;
BEGIN
    sql_stmt := 'UPDATE emp SET sal = :1 WHERE empno = :2
        RETURNING ename, job INTO :3, :4';

    /* Bind returned values through USING clause. */
    EXECUTE IMMEDIATE sql_stmt
        USING my_sal, my_empno, OUT my_ename, OUT my_job;

    /* Bind returned values through RETURNING INTO clause. */
    EXECUTE IMMEDIATE sql_stmt
        USING my_sal, my_empno RETURNING INTO my_ename, my_job;
    ...
END;
```


Specifying Parameter Modes

With the `USING` clause, you need not specify a parameter mode for input bind arguments because the mode defaults to `IN`. With the `RETURNING INTO` clause, you cannot specify a parameter mode for output bind arguments because, by definition, the mode is `OUT`. An example follows:

```
DECLARE
    sql_stmt VARCHAR2(200);
    dept_id  NUMBER(2) := 30;
    old_loc  VARCHAR2(13);
BEGIN
    sql_stmt :=
        'DELETE FROM dept WHERE deptno = :1 RETURNING loc INTO :2';
    EXECUTE IMMEDIATE sql_stmt USING dept_id RETURNING INTO old_loc;
    ...
END;
```

When appropriate, you must specify the `OUT` or `IN OUT` mode for bind arguments passed as parameters. For example, suppose you want to call the following standalone procedure:

```
CREATE PROCEDURE create_dept (
    deptno IN OUT NUMBER,
    dname  IN VARCHAR2,
    loc    IN VARCHAR2) AS
BEGIN
    SELECT deptno_seq.NEXTVAL INTO deptno FROM dual;
    INSERT INTO dept VALUES (deptno, dname, loc);
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 `deptno`, as follows:

```
DECLARE
    plsqli_block VARCHAR2(500);
    new_deptno  NUMBER(2);
    new_dname   VARCHAR2(14) := 'ADVERTISING';
    new_loc     VARCHAR2(13) := 'NEW YORK';
BEGIN
    plsqli_block := 'BEGIN create_dept(:a, :b, :c); END;';
    EXECUTE IMMEDIATE plsqli_block
        USING IN OUT new_deptno, new_dname, new_loc;
    IF new_deptno > 90 THEN ...
END;
```

Using the OPEN-FOR, FETCH, and CLOSE Statements

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"](#) on page 6-16.)

Opening the Cursor Variable

The OPEN-FOR statement associates a cursor variable with a multi-row query, executes the query, identifies the result set, positions the cursor on the first row in the result set, then zeroes the rows-processed count kept by %ROWCOUNT.

Unlike the static form of OPEN-FOR, the dynamic form has an optional USING clause. At run time, bind arguments in the USING clause replace corresponding placeholders in the dynamic SELECT statement. The syntax is

```
OPEN {cursor_variable | :host_cursor_variable} FOR dynamic_string
    [USING bind_argument[, bind_argument]...];
```

where `cursor_variable` is a weakly typed cursor variable (one without a return type), `host_cursor_variable` is a cursor variable declared in a PL/SQL host environment such as an OCI program, and `dynamic_string` is a string expression that represents a multi-row query.

In the following example, you declare a cursor variable, then associate it with a dynamic SELECT statement that returns rows from the emp table:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR; -- define weak REF CURSOR type
    emp_cv EmpCurTyp; -- declare cursor variable
    my_ename VARCHAR2(15);
    my_sal NUMBER := 1000;
BEGIN
    OPEN emp_cv FOR -- open cursor variable
        'SELECT ename, sal FROM emp WHERE sal > :s' USING my_sal;
    ...
END;
```

Any bind arguments in the query are evaluated only when the cursor variable is opened. So, to fetch from the cursor using different bind values, you must reopen the cursor variable with the bind arguments set to their new values.

Fetching from the Cursor Variable

The `FETCH` statement returns a row from the result set of a multi-row query, assigns the values of select-list items to corresponding variables or fields in the `INTO` clause, increments the count kept by `%ROWCOUNT`, and advances the cursor to the next row. The syntax follows:

```
FETCH {cursor_variable | :host_cursor_variable}
      INTO {define_variable[, define_variable]... | record};
```

Continuing the example, you fetch rows from cursor variable `emp_cv` into define variables `my_ename` and `my_sal`:

```
LOOP
  FETCH emp_cv INTO my_ename, my_sal; -- fetch next row
  EXIT WHEN emp_cv%NOTFOUND; -- exit loop when last row is fetched
  -- process row
END LOOP;
```

For each column value returned by the query associated with the cursor variable, there must be a corresponding, type-compatible variable or field in the `INTO` clause. 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.

If you try to fetch from a closed or never-opened cursor variable, PL/SQL raises the predefined exception `INVALID_CURSOR`.

Closing the Cursor Variable

The `CLOSE` statement disables a cursor variable. After that, the associated result set is undefined. The syntax follows:

```
CLOSE {cursor_variable | :host_cursor_variable};
```

In this example, when the last row is processed, you close cursor variable `emp_cv`:

```
LOOP
  FETCH emp_cv INTO my_ename, my_sal;
  EXIT WHEN emp_cv%NOTFOUND;
  -- process row
END LOOP;
CLOSE emp_cv; -- close cursor variable
```

If you try to close an already-closed or never-opened cursor variable, PL/SQL raises `INVALID_CURSOR`.

Examples of Dynamic SQL for Records, Objects, and Collections

As the following example shows, you can fetch rows from the result set of a dynamic multi-row query into a record:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR;
    emp_cv    EmpCurTyp;
    emp_rec   emp%ROWTYPE;
    sql_stmt  VARCHAR2(200);
    my_job    VARCHAR2(15) := 'CLERK';
BEGIN
    sql_stmt := 'SELECT * FROM emp WHERE job = :j';
    OPEN emp_cv FOR sql_stmt USING my_job;
    LOOP
        FETCH emp_cv INTO emp_rec;
        EXIT WHEN emp_cv%NOTFOUND;
        -- process record
    END LOOP;
    CLOSE emp_cv;
END;
```

The next example illustrates the use of objects and collections. Suppose you define object type `Person` and VARRAY type `Hobbies`, as follows:

```
CREATE TYPE Person AS OBJECT (name VARCHAR2(25), age NUMBER);
CREATE TYPE Hobbies IS VARRAY(10) OF VARCHAR2(25);
```

Now, using dynamic SQL, you can write a package of procedures that uses these types, as follows:

```
CREATE PACKAGE teams AS
    PROCEDURE create_table (tab_name VARCHAR2);
    PROCEDURE insert_row (tab_name VARCHAR2, p Person, h Hobbies);
    PROCEDURE print_table (tab_name VARCHAR2);
END;

CREATE PACKAGE BODY teams AS
    PROCEDURE create_table (tab_name VARCHAR2) IS
    BEGIN
        EXECUTE IMMEDIATE 'CREATE TABLE ' || tab_name ||
            ' (pers Person, hobbs Hobbies)';
    END;
```

```

PROCEDURE insert_row (
    tab_name VARCHAR2,
    p Person,
    h Hobbies) 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;
    cv RefCurTyp;
    p Person;
    h Hobbies;
BEGIN
    OPEN cv FOR 'SELECT pers, hobbs FROM ' || tab_name;
    LOOP
        FETCH cv INTO p, h;
        EXIT WHEN cv%NOTFOUND;
        -- print attributes of 'p' and elements of 'h'
    END LOOP;
    CLOSE cv;
END;
END;

```

From an anonymous PL/SQL block, you might call the procedures in package teams, as follows:

```

DECLARE
    team_name VARCHAR2(15);
    ...
BEGIN
    ...
    team_name := 'Notables';
    teams.create_table(team_name);
    teams.insert_row(team_name, Person('John', 31),
        Hobbies('skiing', 'coin collecting', 'tennis'));
    teams.insert_row(team_name, Person('Mary', 28),
        Hobbies('golf', 'quilting', 'rock climbing'));
    teams.print_table(team_name);
END;

```

Using Bulk Dynamic SQL

In this section, you learn how to add the power of bulk binding to dynamic SQL. Bulk binding improves performance by minimizing the number of context switches between the PL/SQL and SQL engines. With bulk binding, entire collections, not just individual elements, are passed back and forth.

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 Collections with Bulk Binds"](#) on page 5-32. Refer to that section for background information.

Syntax for Dynamic Bulk Binds

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). However, 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.

Bulk EXECUTE IMMEDIATE

This statement lets you bulk-bind define variables or OUT bind arguments passed as parameters to a dynamic SQL statement. The syntax follows:

```
EXECUTE IMMEDIATE dynamic_string
  [[BULK COLLECT] INTO define_variable[, define_variable ...]]
  [USING bind_argument[, bind_argument ...]]
  [{RETURNING | RETURN}
  BULK COLLECT INTO bind_argument[, bind_argument ...]];
```

With a dynamic multi-row query, you can use the BULK COLLECT INTO clause to bind define variables. The values in each column are stored in a collection.

With a dynamic INSERT, UPDATE, or DELETE statement that returns multiple rows, you can use the RETURNING BULK COLLECT INTO clause to bulk-bind output variables. The returned rows of values are stored in a set of collections.

Bulk FETCH

This statement lets you fetch from a dynamic cursor the same way you fetch from a static cursor. The syntax follows:

```
FETCH dynamic_cursor
      BULK COLLECT INTO define_variable[, define_variable ...];
```

If the number of define variables in the BULK COLLECT INTO list exceeds the number of columns in the query select-list, Oracle generates an error.

Bulk FORALL

This statement lets you bulk-bind input variables in a dynamic SQL statement. In addition, you can use the EXECUTE IMMEDIATE statement inside a FORALL loop. The syntax follows:

```
FORALL index IN lower bound..upper bound
      EXECUTE IMMEDIATE dynamic_string
      USING bind_argument | bind_argument(index)
          [, bind_argument | bind_argument(index)] ...
      [{RETURNING | RETURN} BULK COLLECT
      INTO bind_argument[, bind_argument ... ]];
```

The dynamic string must represent an INSERT, UPDATE, or DELETE statement (not a SELECT statement).

Examples of Dynamic Bulk Binds

You can bind define variables in a dynamic query using the BULK COLLECT INTO clause. As the following example shows, you can use that clause in a bulk FETCH or bulk EXECUTE IMMEDIATE statement:

```
DECLARE
  TYPE EmpCurTyp IS REF CURSOR;
  TYPE NumList IS TABLE OF NUMBER;
  TYPE NameList IS TABLE OF VARCHAR2(15);
  emp_cv EmpCurTyp;
  empnos NumList;
  enames NameList;
  sals   NumList;
```

```
BEGIN
  OPEN emp_cv FOR 'SELECT empno, ename FROM emp';
  FETCH emp_cv BULK COLLECT INTO empnos, enames;
  CLOSE emp_cv;

  EXECUTE IMMEDIATE 'SELECT sal FROM emp'
    BULK COLLECT INTO sals;
END;
```

Only the INSERT, UPDATE, and DELETE statements can have output bind variables. To bulk-bind them, you use the BULK RETURNING INTO clause, which can appear only in an EXECUTE IMMEDIATE. An example follows:

```
DECLARE
  TYPE NameList IS TABLE OF VARCHAR2(15);
  enames      NameList;
  bonus_amt  NUMBER := 500;
  sql_stmt   VARCHAR(200);
BEGIN
  sql_stmt := 'UPDATE emp SET bonus = :1 RETURNING ename 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 below. However, the SQL statement cannot be a query.

```
DECLARE
  TYPE NumList IS TABLE OF NUMBER;
  TYPE NameList IS TABLE OF VARCHAR2(15);
  empnos NumList;
  enames NameList;
BEGIN
  empnos := NumList(1,2,3,4,5);
  FORALL i IN 1..5
    EXECUTE IMMEDIATE
      'UPDATE emp SET sal = sal * 1.1 WHERE empno = :1
      RETURNING ename INTO :2'
      USING empnos(i) RETURNING BULK COLLECT INTO enames;
  ...
END;
```


Tips and Traps for Dynamic SQL

This section shows you how to take full advantage of dynamic SQL and how to avoid some common pitfalls.

Improving Performance

In the example below, Oracle opens a different cursor for each distinct value of `emp_id`. This can lead to resource contention and poor performance.

```
CREATE PROCEDURE fire_employee (emp_id NUMBER) AS
BEGIN
    EXECUTE IMMEDIATE
        'DELETE FROM emp WHERE empno = ' || TO_CHAR(emp_id);
END;
```

You can improve performance by using a bind variable, as shown below. This 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 emp WHERE empno = :num' USING emp_id;
END;
```

Making Procedures Work on Arbitrarily Named Schema Objects

Suppose you need a procedure that accepts the name of any database table, then drops that table from your schema. Using dynamic SQL, you might write the following standalone procedure:

```
CREATE PROCEDURE drop_table (table_name IN VARCHAR2) AS
BEGIN
    EXECUTE IMMEDIATE 'DROP TABLE :tab' USING table_name;
END;
```

However, at run time, this procedure fails with an *invalid table name* error. That is because you cannot use bind arguments to pass the names of schema objects to a dynamic SQL statement. Instead, you must embed parameters in the dynamic string, then pass the names of schema objects to those parameters.

To debug the last example, you must revise the `EXECUTE IMMEDIATE` statement. Instead of using a placeholder and bind argument, you embed parameter `table_name` in the dynamic string, as follows:

```
CREATE PROCEDURE drop_table (table_name IN VARCHAR2) AS
BEGIN
    EXECUTE IMMEDIATE 'DROP TABLE ' || table_name;
END;
```

Now, you can pass the name of any database table to the dynamic SQL statement.

Using Duplicate Placeholders

Placeholders in a dynamic SQL statement are associated with bind arguments in the `USING` clause by position, not by name. So, if the same placeholder appears two or more times in the SQL statement, each appearance must correspond to a bind argument in the `USING` clause. For example, given the dynamic string

```
sql_stmt := 'INSERT INTO payroll VALUES (:x, :x, :y, :x)';
```

you might code the corresponding `USING` clause as follows:

```
EXECUTE IMMEDIATE sql_stmt USING a, a, b, a;
```

However, only the unique placeholders in a dynamic PL/SQL block are associated with bind arguments in the `USING` clause by position. So, if the same placeholder appears two or more times in a PL/SQL block, all appearances correspond to one bind argument in the `USING` clause. In the example below, the first unique placeholder (`x`) is associated with the first bind argument (`a`). Likewise, the second unique placeholder (`y`) is associated with the second bind argument (`b`).

```
DECLARE
    a NUMBER := 4;
    b NUMBER := 7;
BEGIN
    plsqli_block := 'BEGIN calc_stats(:x, :x, :y, :x); END;';
    EXECUTE IMMEDIATE plsqli_block USING a, b;
    ...
END;
```

Using Cursor Attributes

Every explicit cursor has four attributes: %FOUND, %ISOPEN, %NOTFOUND, and %ROWCOUNT. When appended to the cursor name, they return useful information about the execution of static and dynamic SQL statements.

To process SQL data manipulation statements, Oracle opens an implicit cursor named SQL. Its attributes return information about the most recently executed INSERT, UPDATE, DELETE, or single-row SELECT statement. For example, the following standalone function uses %ROWCOUNT to return the number of rows deleted from a database table:

```
CREATE FUNCTION rows_deleted (
    table_name IN VARCHAR2,
    condition IN VARCHAR2) RETURN INTEGER AS
BEGIN
    EXECUTE IMMEDIATE
        'DELETE FROM ' || table_name || ' WHERE ' || condition;
    RETURN SQL%ROWCOUNT; -- return number of rows deleted
END;
```

Likewise, when appended to a cursor variable name, the cursor attributes return information about the execution of a multi-row query. For more information about cursor attributes, see ["Using Cursor Attributes"](#) on page 6-34.

Passing Nulls

Suppose you want to pass nulls to a dynamic SQL statement. For example, you might write the following EXECUTE IMMEDIATE statement:

```
EXECUTE IMMEDIATE 'UPDATE emp SET comm = :x' USING NULL;
```

However, this statement fails with a *bad expression* error because the literal NULL is not allowed in the USING clause. To work around this restriction, simply replace the keyword NULL with an uninitialized variable, as follows:

```
DECLARE
    a_null CHAR(1); -- set to NULL automatically at run time
BEGIN
    EXECUTE IMMEDIATE 'UPDATE emp SET comm = :x' USING a_null;
END;
```

Doing Remote Operations

As the following example shows, PL/SQL subprograms can execute dynamic SQL statements that refer to objects on a remote database:

```
PROCEDURE delete_dept (db_link VARCHAR2, dept_id INTEGER) IS
BEGIN
    EXECUTE IMMEDIATE 'DELETE FROM dept@' || db_link ||
        ' WHERE deptno = :num' USING dept_id;
END;
```

Also, 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 Chicago database:

```
CREATE FUNCTION row_count (tab_name VARCHAR2) RETURN INTEGER AS
    rows INTEGER;
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@chicago('emp');
```

Using Invoker Rights

By default, a stored procedure executes with the privileges of its definer, not its invoker. Such procedures are bound to the schema in which they reside. For example, assume that the following standalone procedure, which can drop any kind of database object, resides in schema `scott`:

```
CREATE PROCEDURE drop_it (kind IN VARCHAR2, name IN VARCHAR2) AS
BEGIN
    EXECUTE IMMEDIATE 'DROP ' || kind || ' ' || name;
END;
```

Also assume that user `jones` has been granted the `EXECUTE` privilege on this procedure. When user `jones` calls `drop_it`, as follows, the dynamic `DROP` statement executes with the privileges of user `scott`:

```
SQL> CALL drop_it('TABLE', 'dept');
```

Also, the unqualified reference to table `dept` is resolved in schema `scott`. So, the procedure drops the table from schema `scott`, not from schema `jones`.

However, the `AUTHID` clause enables a stored procedure to execute with the privileges of its invoker (current user). Such procedures are not bound to a particular schema. For example, the following version of `drop_it` executes with the privileges of its invoker:

```
CREATE PROCEDURE drop_it (kind IN VARCHAR2, name IN VARCHAR2)
  AUTHID CURRENT_USER AS
BEGIN
  EXECUTE IMMEDIATE 'DROP ' || kind || ' ' || name;
END;
```

Also, the unqualified reference to the database object is resolved in the schema of the invoker. For details, see "[Invoker Rights Versus Definer Rights](#)" on page 8-47.

Using Pragma RESTRICT_REFERENCES

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 8-9.) To check for violations of the rules, you can use the pragma `RESTRICT_REFERENCES`. The pragma asserts that a function does not read and/or write database tables and/or package variables. (For more information, See *Oracle9i Application Developer's Guide - Fundamentals*.)

However, 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`). That is 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

In a few situations, executing a SQL data definition statement results in a deadlock. For example, the procedure below 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 PROCEDURE calc_bonus (emp_id NUMBER) AS
BEGIN
  . . .
  EXECUTE IMMEDIATE 'DROP PROCEDURE calc_bonus';
```

Tuning PL/SQL Applications

Every day, in every way, I am getting better and better. —Émile Coué

Over time, even the performance of well-designed applications can degrade. So, periodic tuning is an important part of application maintenance. This chapter shows you how to make small adjustments that improve performance. By tuning your applications, you can make sure they continue to deliver the required response time and throughput.

This chapter discusses the following topics:

[Reasons for PL/SQL Performance Problems](#)

[Identifying PL/SQL Performance Problems](#)

[PL/SQL Features for Performance Tuning](#)

Reasons for 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.

Badly Written SQL Statements in a PL/SQL Program

PL/SQL programs look relatively simple because their complexity is hidden in SQL statements, which do most of the work. That is why badly written SQL statements are the main reason for slow execution. If a program contains many badly written SQL statements, no number of well-written PL/SQL statements will help.

If badly written SQL statements are slowing down your program, analyze their execution plans and performance using the methods listed below. Then, rewrite the SQL statements. For example, hints to the query optimizer can eliminate problems such as unnecessary full-table scans.

- `EXPLAIN PLAN` statement
- SQL Trace facility with TKPROF utility
- Oracle Trace facility

For more information about these methods, see *Oracle9i Database Performance Methods*.

Poor Programming Practices

Often, poor programming practices are a side effect of schedule crunches. In such circumstances, even experienced programmers might write code that hampers performance.

No matter how suitable a programming language is for a given task, badly written subprograms (for example, a slow sort or search function) can ruin performance. Suppose the subprogram called most often by an application is a lookup function with hundreds of possible targets. If that function could be written as a hash or a binary search but, instead, is written as a linear search, overall performance suffers.

Other poor practices include declaring variables that are never used, passing unneeded parameters to functions and procedures, placing initializations or computations inside a loop needlessly, and so on.

Duplication of Built-in Functions

PL/SQL provides many highly optimized functions such as `REPLACE`, `TRANSLATE`, `SUBSTR`, `INSTR`, `RPAD`, and `LTRIM`. Do not hand code your own versions. Built-in

functions are more efficient. Even when a built-in function has more power than you need, use it rather than hand-coding a subset of its functionality.

Inefficient Conditional Control Statements

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. For example, in the following OR expression, when the value of `sal` is less than 1500, the left operand yields TRUE, so PL/SQL need not evaluate the right operand (because OR returns TRUE if either of its operands is true):

```
IF (sal < 1500) OR (comm IS NULL) THEN
    . . .
END IF;
```

Now, consider the following AND expression:

```
IF credit_ok(cust_id) AND (loan < 5000) THEN
    . . .
END IF;
```

The Boolean function `credit_ok` is always called. However, if you switch the operands of AND as follows

```
IF (loan < 5000) AND credit_ok(cust_id) THEN
    . . .
END IF;
```

the function is called only when the expression `loan < 5000` is true (because AND returns TRUE only if both its operands are true).

The same idea applies to EXIT-WHEN statements.

Implicit Datatype Conversions

At run time, PL/SQL converts between structurally different datatypes implicitly. For instance, assigning a `PLS_INTEGER` variable to a `NUMBER` variable results in a conversion because their internal representations are different.

Avoiding implicit conversions can improve performance. Look at the example below. The integer literal 15 is represented internally as a signed 4-byte quantity, so PL/SQL must convert it to an Oracle number before the addition. However, the floating-point literal 15.0 is represented as a 22-byte Oracle number, so no conversion is necessary.

```
DECLARE
```

```
n NUMBER;  
c CHAR(5);  
BEGIN  
  n := n + 15;    -- converted  
  n := n + 15.0; -- not converted  
  ...  
END;
```

Here is another example:

```
DECLARE  
  c CHAR(5);  
BEGIN  
  c := 25;    -- converted  
  c := '25'; -- not converted  
  ...  
END;
```

Inappropriate Declarations for Numeric Datatypes

The datatype `NUMBER` and its subtypes are 22-byte, database-format numbers, designed for portability and arbitrary scale/precision, not performance. When you need to declare an integer variable, use the datatype `PLS_INTEGER`, which is the most efficient numeric type. That is because `PLS_INTEGER` values require less storage than `INTEGER` or `NUMBER` values. Also, `PLS_INTEGER` operations use machine arithmetic, so they are faster than `BINARY_INTEGER`, `INTEGER`, or `NUMBER` operations, which use library arithmetic.

Furthermore, `INTEGER`, `NATURAL`, `NATURALN`, `POSITIVE`, `POSITIVEN`, and `SIGNTYPE` are constrained subtypes. So, their variables require precision checking at run time, which can affect performance.

Unnecessary NOT NULL Constraints

In PL/SQL, using the `NOT NULL` constraint incurs a performance cost. Consider the following example:

```
PROCEDURE calc_m IS  
  m NUMBER NOT NULL := 0;  
  a NUMBER;  
  b NUMBER;  
BEGIN  
  ...  
  m := a + b;  
  ...  
END;
```

Because `m` is constrained by `NOT NULL`, the value of the expression `a + b` is assigned to a temporary variable, which is then tested for nullity. If the variable is not null, its value is assigned to `m`. Otherwise, an exception is raised. However, if `m` were not constrained, the value would be assigned to `m` directly.

A more efficient way to write the last example follows:

```
PROCEDURE calc_m IS
    m NUMBER; -- no constraint
    a NUMBER;
    b NUMBER;
BEGIN
    ...
    m := a + b;
    IF m IS NULL THEN -- enforce constraint programmatically
        ...
    END IF;
END;
```

Note that the subtypes `NATURALN` and `POSTIVEN` are defined as `NOT NULL`. So, using them incurs the same performance cost.

Size Declarations for VARCHAR2 Variables

The `VARCHAR2` datatype involves a trade-off between memory use and efficiency. For a `VARCHAR2 (>= 2000)` variable, PL/SQL dynamically allocates only enough memory to hold the actual value. However, for a `VARCHAR2 (< 2000)` variable, PL/SQL preallocates enough memory to hold a maximum-size value. So, for example, if you assign the same 500-byte value to a `VARCHAR2 (2000)` variable and to a `VARCHAR2 (1999)` variable, the latter uses 1499 bytes more memory.

Misuse of Shared Memory in a PL/SQL Program

When you call a packaged subprogram for the first time, the whole package is loaded into the shared memory pool. So, subsequent calls to related subprograms in the package require no disk I/O, and your code executes faster. However, 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.

Pinned Packages

Another way to improve performance is to pin frequently used packages in the shared memory 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.

You can pin packages with the help of the supplied package `DBMS_SHARED_POOL`. For more information, see *Oracle9i Supplied PL/SQL Packages and Types Reference*.

Serially Reusable Packages

To help you manage the use of memory, PL/SQL provides the pragma `SERIALLY_REUSABLE`, which lets you mark some packages as *serially reusable*. You can so mark a package 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 RPC).

The global memory for such 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`.

The maximum number of work areas needed for a package is the number of concurrent users of that package, which is usually much smaller than the number of logged-on users. The increased use of SGA memory is more than offset by the decreased use of UGA memory. Also, Oracle ages-out work areas not in use if it needs to reclaim SGA memory.

For bodiless packages, you code the pragma in the package spec using the following syntax:

```
PRAGMA SERIALLY_REUSABLE;
```

For packages with a body, you must code the pragma in the spec and body. You cannot code the pragma only in the body. The following example shows how a public variable in a serially reusable package behaves across call boundaries:

```
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;
/
BEGIN
    /* Initialize package state. */
    pkg1.init_pkg_state(4);
    /* On same server call, print package state. */
    pkg1.print_pkg_state; -- prints 4
END;
/
-- subsequent server call
BEGIN
    -- the package's public variable is initialized
    -- to the default value automatically
    pkg1.print_pkg_state; -- prints 0
END;
```

For more information, see *Oracle9i Application Developer's Guide - Fundamentals*.

Identifying PL/SQL Performance Problems

As you develop larger and larger PL/SQL applications, it becomes more difficult to isolate performance problems. So, 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.

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. In a typical session, you take the following steps:

4. Start by calling the procedure `start_profiler` in package `DBMS_PROFILER` and associating a comment with the Profiler session.
5. Run the application to be profiled.
6. Call the procedure `flush_data` repeatedly to save incremental data and free memory allocated for data structures.
7. Stop by calling the procedure `stop_profiler`.

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 more information about package `DBMS_PROFILER`, see *Oracle9i Supplied PL/SQL Packages and Types Reference*.

Analyzing the Collected Performance Data

The next step is to 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.

Using 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.

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. In a typical session, you take the following steps:

1. Optionally, select specific subprograms for trace data collection.
2. Start by calling the procedure `set_plsql_trace` in package DBMS_TRACE.
3. Run the application to be traced.
4. Stop by calling the procedure `clear_plsql_trace`.

For more information about package DBMS_TRACE, see *Oracle9i Supplied 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.

PL/SQL Features for Performance Tuning

After correcting the flaws that slow down an application, you can use the following PL/SQL features and techniques:

- [Improving PL/SQL Performance with Native Dynamic SQL](#)
- [Improving PL/SQL Performance with Bulk Binds](#)
- [Improving PL/SQL Performance with the NOCOPY Compiler Hint](#)
- [Improving PL/SQL Performance with the RETURNING Clause](#)
- [Improving PL/SQL Performance with External Routines](#)
- [Improving PL/SQL Performance with Object Types and Collections](#)
- [Compiling PL/SQL Code for Native Execution](#)

These easy-to-use features can speed up an application considerably.

Improving PL/SQL Performance with Native Dynamic SQL

Some programs (a general-purpose report writer for example) must build and process a variety of SQL statements at run time. So, their full text is unknown until then. Such statements can, and probably will, change from execution to execution. So, 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*.

Native dynamic SQL is easier to use and much faster than the DBMS_SQL package. In the following example, you declare a cursor variable, then associate it with a dynamic SELECT statement that returns rows from database table emp:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR;
    emp_cv    EmpCurTyp;
    my_ename VARCHAR2(15);
    my_sal    NUMBER := 1000;
BEGIN
    OPEN emp_cv FOR
        'SELECT ename, sal FROM emp
         WHERE sal > :s' USING my_sal;
    ...
END;
```


For more information, see [Chapter 11](#).

Improving PL/SQL Performance with Bulk Binds

When SQL statements execute inside a loop using collection elements as bind variables, context switching between the PL/SQL and SQL engines can slow down execution. For example, the following UPDATE statement is sent to the SQL engine with each iteration of the FOR loop:

```
DECLARE
    TYPE NumList IS VARRAY(20) OF NUMBER;
    depts NumList := NumList(10, 30, 70, ...); -- department numbers
BEGIN
    ...
    FOR i IN depts.FIRST..depts.LAST LOOP
        ...
        UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(i);
    END LOOP;
END;
```

In such cases, if the SQL statement affects four or more database rows, the use of bulk binds can improve performance considerably. For example, the following UPDATE statement is sent to the SQL engine just once, with the entire nested table:

```
FORALL i IN depts.FIRST..depts.LAST
    UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(i);
```

To maximize performance, rewrite your programs as follows:

- If an INSERT, UPDATE, or DELETE statement executes inside a loop and references collection elements, move it into a FORALL statement.
- If a SELECT INTO, FETCH INTO, or RETURNING INTO clause references a collection, incorporate the BULK COLLECT clause.
- If possible, use host arrays to pass collections back and forth between your programs and the database server.
- If the failure of a DML operation on a particular row is not a serious problem, include the keywords SAVE EXCEPTIONS in the FORALL statement and report or clean up the errors in a subsequent loop using the %BULK_EXCEPTIONS attribute.

These are not a trivial tasks. They require careful analysis of program control-flows and dependencies.

For more information about bulk binding, see ["Reducing Loop Overhead for Collections with Bulk Binds"](#) on page 5-32.

Improving PL/SQL Performance with the NOCOPY Compiler Hint

By default, OUT and IN OUT parameters are passed by value. That is, the value of an IN OUT actual parameter is copied into the corresponding formal parameter. Then, if the subprogram exits normally, the values assigned to OUT and IN OUT formal parameters are copied into the corresponding actual parameters.

When the parameters hold large data structures such as collections, records, and instances of object types, all this copying slows down execution and uses up memory. To prevent that, you can specify the NOCOPY hint, which allows the PL/SQL compiler to pass OUT and IN OUT parameters by reference. In the following example, you ask the compiler to pass IN OUT parameter `my_unit` by reference instead of by value:

```
DECLARE
    TYPE Platoon IS VARRAY(200) OF Soldier;
    PROCEDURE reorganize (my_unit IN OUT NOCOPY Platoon) IS ...
BEGIN
    ...
END;
```

For more information, see ["Passing Large Data Structures with the NOCOPY Compiler Hint"](#) on page 8-17.

Improving PL/SQL Performance with the RETURNING Clause

Often, applications need information about the row affected by a SQL operation, for example, to generate a report or take a subsequent action. The INSERT, UPDATE, and DELETE statements can include a RETURNING clause, which returns column values from the affected row into PL/SQL variables or host variables. This eliminates the need to SELECT the row after an insert or update, or before a delete. As a result, fewer network round trips, less server CPU time, fewer cursors, and less server memory are required.

In the following example, you update the salary of an employee and at the same time retrieve the employee's name and new salary into PL/SQL variables.

```
PROCEDURE update_salary (emp_id NUMBER) IS
    name    VARCHAR2(15);
    new_sal NUMBER;
BEGIN
```

```
...
UPDATE emp SET sal = sal * 1.1
      WHERE empno = emp_id
      RETURNING ename, sal INTO name, new_sal;
-- Now do computations involving name and new_sal
...
END;
```

Improving PL/SQL Performance with External Routines

PL/SQL is specialized for SQL transaction processing. So, some tasks are more quickly done in a lower-level language such as C, which is very efficient at machine-precision calculations.

PL/SQL extends the functionality of the Oracle server by providing an interface for calling routines written in other languages. Standard libraries already written and available in other languages can be called from PL/SQL programs. This promotes reusability, efficiency, and modularity.

To speed up execution, you can rewrite computation-bound programs in C. In addition, you can move such programs from client to server, where they will execute faster thanks to more computing power and less across-network communication.

For example, you can write methods for an image object type in C, store them in a dynamic link library (DLL), register the library with PL/SQL, then call it from your applications. At run time, the library loads dynamically and, for safety, runs in a separate address space (implemented as a separate process).

For more information, see *Oracle9i Application Developer's Guide - Fundamentals*.

Improving PL/SQL Performance with Object Types and Collections

Collection types (see [Chapter 5](#)) and object types (see [Chapter 10](#)) increase your productivity by allowing for realistic data modeling. Complex real-world entities and relationships map directly into object types. And, a well-constructed object model can improve application performance by eliminating table joins, reducing round trips, and the like.

Client programs, including PL/SQL programs, can declare objects and collections, pass them as parameters, store them in the database, retrieve them, and so on. Also, by encapsulating operations with data, object types let you move data-maintenance code out of SQL scripts and PL/SQL blocks into methods.

Objects and collections are more efficient to store and retrieve because they can be manipulated as a whole. Also, object support is integrated with the database architecture, so it can take advantage of the many scalability and performance improvements built into each Oracle release.

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 this technique with both the supplied Oracle packages, and procedures you write yourself. 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.

To speed up one or more procedures using this technique:

1. Update the supplied makefile and enter the appropriate paths and other values for your system. The path of this makefile is `$ORACLE_HOME/plsql/spnc_makefile.mk`.
2. Use the `ALTER SYSTEM` or `ALTER SESSION` command, or update your initialization file, to set the parameter `PLSQL_COMPILER_FLAGS` to include the value `NATIVE`. The default setting includes the value `INTERPRETED`, and you must remove this keyword from the parameter value.
3. Compile one or more procedures, using one of these methods:
 - Use the `ALTER PROCEDURE` or `ALTER PACKAGE` command to recompile the procedure or the entire package.
 - Drop the procedure and create it again.
 - Use `CREATE OR REPLACE` to recompile the procedure.
 - Run one of the SQL*Plus scripts that sets up a set of Oracle-supplied packages.
 - Create a database using a preconfigured initialization file with `PLSQL_COMPILER_FLAGS=NATIVE`. During database creation, the `UTLIRP` script is run to compile all the Oracle-supplied packages.
4. 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 data dictionary views `USER_STORED_SETTINGS`, `DBA_STORED_SETTINGS`, and

ALL_STORED_SETTINGS. For example, to check the status of the procedure MY_PROC, you could enter:

```
SELECT param_value FROM user_stored_settings WHERE
       param_name = 'PLSQL_COMPILER_FLAGS'
       and object_name = 'MY_PROC';
```

The PARAM_VALUE column has a value of NATIVE for procedures that are compiled for native execution, and INTERPRETED otherwise.

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 compiled in the default way (interpreted), all compiled for native execution, or a mixture of both.

Because the PLSQL_COMPILER_FLAGS setting is stored inside the library unit for each procedure, procedures compiled for native execution are compiled the same way when the procedure is recompiled automatically after being invalidated, such as when a table that it depends on is recreated.

You can control the behavior of PL/SQL native compilation through the ALTER SYSTEM or ALTER SESSION commands or by setting or changing these parameters in the initialization file:

- PLSQL_COMPILER_FLAGS
- PLSQL_NATIVE_LIBRARY_DIR (cannot be set by ALTER SESSION for security reasons)
- PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT
- PLSQL_NATIVE_MAKE_UTILITY
- PLSQL_NATIVE_MAKE_FILE_NAME

See Also: *Oracle9i Database Reference* for complete details about the initialization parameters and data dictionary views.

Example of Compiling a PL/SQL Procedure for Native Execution

```
connect scott/tiger;
set serveroutput on;
alter session set plsql_native_library_dir='/home/orauser/lib';
alter session set plsql_native_make_utility='gmake';
alter session set plsql_native_make_file_name='/home/orauser/spnc_makefile.mk';
alter session set plsql_compiler_flags='NATIVE';
```

```
create or replace procedure hello_native_compilation
as
begin
  dbms_output.put_line('Hello world');
  select sysdate from dual;
end;
```

As the procedure is compiled, you see the various compilation and link commands being executed. The procedure is immediately available to call, and runs as a shared library directly within the Oracle process.

Limitations of Native Compilation

- If a package specification is compiled for native execution, the corresponding body should be compiled using the same setting.
- Debugging tools for PL/SQL do not handle procedures compiled for native execution.
- When many procedures and packages (typically, over 5000) are compiled for native execution, the large number of shared objects in a single directory might affect system performance. In this case, you can set the initialization parameter `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` in the initialization file before creating the database or compiling the PL/SQL packages or procedures. Set this parameter to a value (typically around 1000). Then create subdirectories underneath the directory specified in the `PLSQL_NATIVE_LIBRARY_DIR` parameter. Name the subdirectories `d0`, `d1`, `d2` . . . `d999`, up to the value specified for the subdirectory count. When the procedures are compiled for native execution, the DLLs are automatically distributed among these subdirectories by the PL/SQL compiler.

PL/SQL Language Elements

Grammar, which knows how to control even kings. —Molière

This chapter is a quick reference guide to PL/SQL syntax and semantics. It shows you how commands, parameters, and other language elements are sequenced to form PL/SQL statements. Also, to save you time and trouble, it provides usage notes and short examples.

This chapter discusses the following topics:

- Assignment Statement
- AUTONOMOUS_TRANSACTION Pragma
- Blocks
- CASE Statement
- CLOSE Statement
- Collection Methods
- Collections
- Comments
- COMMIT Statement
- Constants and Variables
- Cursor Attributes
- Cursor Variables
- Cursors
- DELETE Statement
- EXCEPTION_INIT Pragma
- Exceptions
- EXECUTE IMMEDIATE Statement
- EXIT Statement
- Expressions

FETCH Statement
FORALL Statement
Functions
GOTO Statement
IF Statement
INSERT Statement
Literals
LOCK TABLE Statement
LOOP Statements
MERGE Statement
NULL Statement
Object Types
OPEN Statement
OPEN-FOR Statement
OPEN-FOR-USING Statement
Packages
Procedures
RAISE Statement
Records
RESTRICT_REFERENCES Pragma
RETURN Statement
ROLLBACK Statement
%ROWTYPE Attribute
SAVEPOINT Statement
SELECT INTO Statement
SERIALLY_REUSABLE Pragma
SET TRANSACTION Statement
SQL Cursor
SQLCODE Function
SQLERRM Function
%TYPE Attribute
UPDATE Statement

Reading the Syntax Diagrams

When you are unsure of the syntax to use in a PL/SQL statement, trace through its syntax diagram, reading from left to right and top to bottom. You can verify or construct any PL/SQL statement that way.

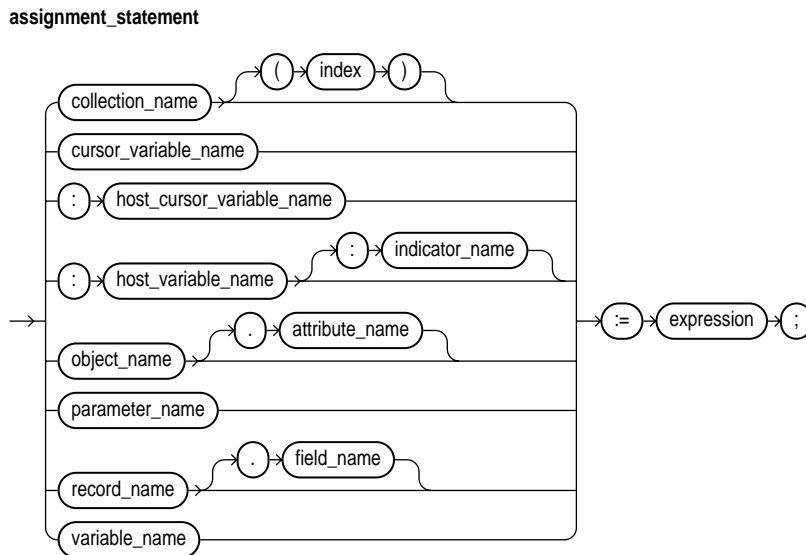
The diagrams are graphic representations of Bachus-Naur Form (BNF) productions. Within the diagrams, keywords are enclosed in boxes, delimiters in circles, and identifiers in ovals.

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.

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 ["Assignments"](#) on page 2-22.

Syntax



Keyword and Parameter Description

attribute_name

This identifies 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

This identifies a nested table, index-by table, or varray previously declared within the current scope.

cursor_variable_name

This identifies 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

This is an arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. For the syntax of `expression`, see ["Expressions"](#) on page 13-72. 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

This identifies a field in a user-defined or `%ROWTYPE` record.

host_cursor_variable_name

This identifies 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

This identifies 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

This is a numeric expression that must yield a value of type `BINARY_INTEGER` or a value implicitly convertible to that datatype.

indicator_name

This identifies 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

This identifies an object (instance of an object type) previously declared within the current scope.

parameter_name

This identifies a formal OUT or IN OUT parameter of the subprogram in which the assignment statement appears.

record_name

This identifies a user-defined or %ROWTYPE record previously declared within the current scope.

variable_name

This identifies 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. So, never reference a variable before you assign it a value.

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. When applied to an expression, the relational operators return a Boolean value. So, the following assignment is legal:

```
DECLARE
    out_of_range BOOLEAN;
    ...
BEGIN
    ...
    out_of_range := (salary < minimum) OR (salary > maximum);
```

As the next example shows, you can assign the value of an expression to a specific field in a record:

```
DECLARE
    emp_rec emp%ROWTYPE;
BEGIN
    ...
    emp_rec.sal := current_salary + increase;
```

Moreover, 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. For example, the following assignment is legal:

```
DECLARE
    emp_rec1 emp%ROWTYPE;
    emp_rec2 emp%ROWTYPE;
    dept_rec dept%ROWTYPE;
BEGIN
    ...
    emp_rec1 := emp_rec2;
```

Using the following syntax, you can assign the value of an expression to a specific element in a collection:

```
collection_name(index) := expression;
```

In the following example, you assign the uppercase value of `last_name` to the third row in nested table `ename_tab`:

```
ename_tab(3) := UPPER(last_name);
```

Examples

Several examples of assignment statements follow:

```
wages := hours_worked * hourly_salary;
country := 'France';
costs := labor + supplies;
done := (count > 100);
dept_rec.loc := 'BOSTON';
comm_tab(5) := sales * 0.15;
```

Related Topics

Constants and Variables, Expressions, SELECT INTO Statement

AUTONOMOUS_TRANSACTION Pragma

The `AUTONOMOUS_TRANSACTION` pragma instructs the PL/SQL compiler to mark a routine as *autonomous* (independent). An autonomous transaction is an independent transaction started by another transaction, 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 6-53.

Syntax

`autonomous_transaction_pragma`

→ PRAGMA AUTONOMOUS_TRANSACTION → :

Keyword and Parameter Description

PRAGMA

This keyword signifies that the statement is a pragma (compiler directive). Pragas 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

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 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. 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.

Once started, an autonomous transaction is fully independent. It shares no locks, resources, or commit-dependencies with the main transaction. So, 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`. Also, unlike regular triggers, autonomous triggers can execute DDL statements (such as `CREATE` and `DROP`) using native dynamic SQL.

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`, as follows, changes made by its autonomous transactions are *not* visible to the main transaction when it resumes:

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.

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. In that case, 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, the transaction is rolled back.

Examples

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

```
CREATE PACKAGE banking AS
...
    FUNCTION balance (acct_id INTEGER) RETURN REAL;
END banking;

CREATE PACKAGE BODY banking AS
...
    FUNCTION balance (acct_id INTEGER) RETURN REAL IS
        PRAGMA AUTONOMOUS_TRANSACTION;
        my_bal REAL;
    BEGIN
```

```
    ...  
    END;  
END banking;
```

In the example below, you mark a database trigger as autonomous. Unlike regular triggers, autonomous triggers can contain transaction control statements.

```
CREATE TRIGGER parts_trigger  
BEFORE INSERT ON parts FOR EACH ROW  
DECLARE  
    PRAGMA AUTONOMOUS_TRANSACTION;  
BEGIN  
    INSERT INTO parts_log VALUES(:new.pnum, :new.pname);  
    COMMIT; -- allowed only in autonomous triggers  
END;
```

Related Topics

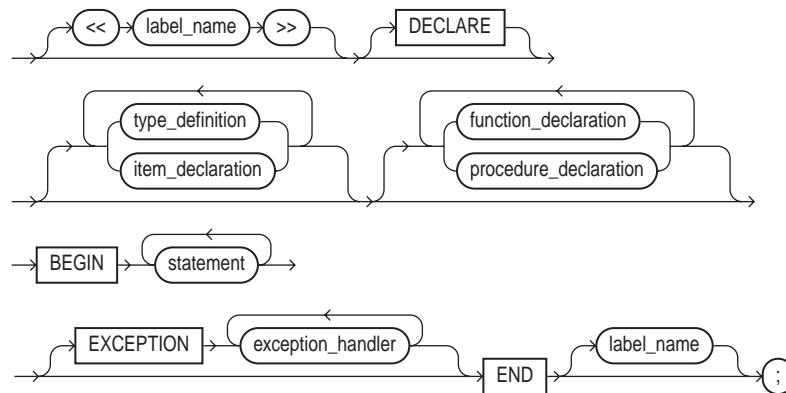
**EXCEPTION_INIT Pragma, RESTRICT_REFERENCES Pragma,
SERIALLY_RESUABLE Pragma**

Blocks

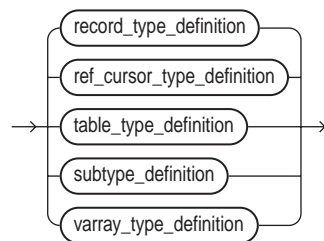
The basic program unit in PL/SQL is the block. A PL/SQL block is defined by the keywords `DECLARE`, `BEGIN`, `EXCEPTION`, and `END`. These keywords partition the block into a declarative part, an executable part, and an exception-handling part. Only the executable part is required. You can nest a block within another block wherever you can place an executable statement. For more information, see ["Block Structure"](#) on page 1-2 and ["Scope and Visibility"](#) on page 2-19.

Syntax

plsql_block



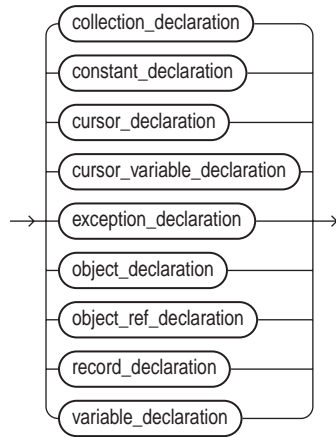
type_definition



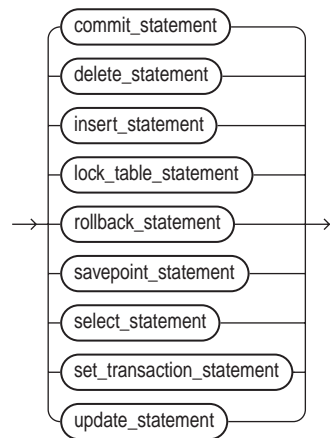
subtype_definition

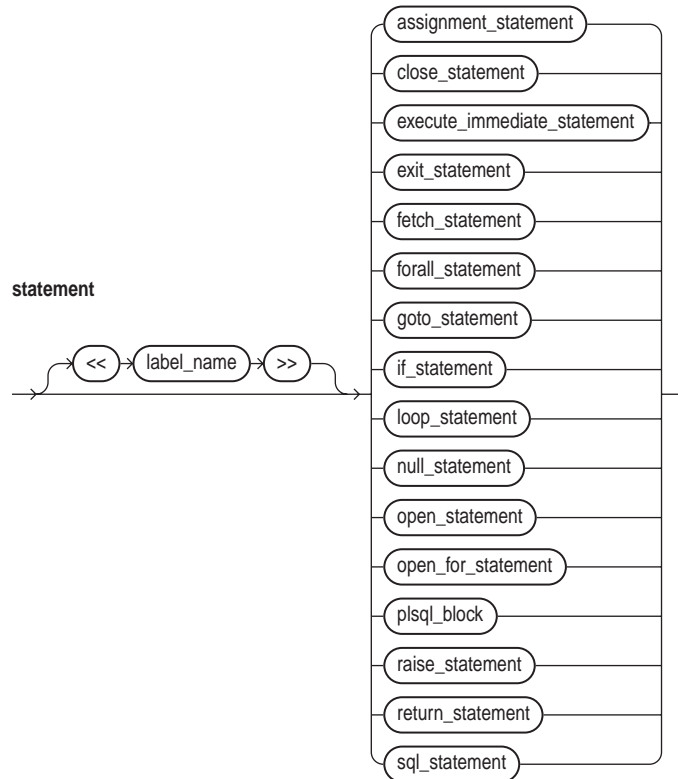


item_declaration



sql_statement





Keyword and Parameter Description

base_type

This is any scalar or user-defined PL/SQL datatype specifier such as CHAR, DATE, or RECORD.

BEGIN

This keyword signals the start of the executable part of a PL/SQL block, which contains executable statements. The executable part of a block is required. That is, a PL/SQL block must contain at least one executable statement. The NULL statement meets this requirement.

collection_declaration

This declares a collection (index-by table, nested table, or varray). For the syntax of `collection_declaration`, see ["Collections"](#) on page 13-28.

constant_declaration

This declares a constant. For the syntax of `constant_declaration`, see ["Constants and Variables"](#) on page 13-38.

constraint

This 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

This declares an explicit cursor. For the syntax of `cursor_declaration`, see ["Cursors"](#) on page 13-53.

cursor_variable_declaration

This declares a cursor variable. For the syntax of `cursor_variable_declaration`, see ["Cursor Variables"](#) on page 13-47.

DECLARE

This keyword 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.

PL/SQL does not allow forward references. So, you must declare an item before referencing it in other statements, including other declarative statements. Also, you must declare subprograms at the end of a declarative section after all other program items.

END

This keyword signals the end of a PL/SQL block. It must be the last keyword in a block. Neither the `END IF` in an `IF` statement nor the `END LOOP` in a `LOOP` statement can substitute for the keyword `END`. Remember, `END` does *not* signal the end of a transaction. Just as a block can span multiple transactions, a transaction can span multiple blocks.

EXCEPTION

This keyword 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.

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, see [Chapter 7](#).

exception_declaration

This declares an exception. For the syntax of `exception_declaration`, see "[Exceptions](#)" on page 13-63.

exception_handler

This associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see "[Exceptions](#)" on page 13-63.

function_declaration

This declares a function. For the syntax of `function_declaration`, see "[Functions](#)" on page 13-90.

label_name

This is an undeclared identifier that optionally labels a PL/SQL block. If used, `label_name` must be enclosed by double angle brackets and must appear at the beginning of the block. Optionally, `label_name` (*not* enclosed by angle brackets) can also appear at the end of the block.

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, as the following example shows:

```
<<outer>>
DECLARE
    x INTEGER;
BEGIN
    . . .
```

```
DECLARE
  x INTEGER;
BEGIN
  ...
  IF x = outer.x THEN -- refers to global x
    ...
  END IF;
END;
END outer;
```

object_declaration

This declares an object (instance of an object type). For the syntax of `object_declaration`, see ["Object Types"](#) on page 13-120.

procedure_declaration

This declares a procedure. For the syntax of `procedure_declaration`, see ["Procedures"](#) on page 13-143.

record_declaration

This declares a user-defined record. For the syntax of `record_declaration`, see ["Records"](#) on page 13-150.

statement

This is an executable (not declarative) statement that you use to create algorithms. A sequence of statements can include procedural statements such as `RAISE`, `SQL` statements such as `UPDATE`, and PL/SQL blocks (sometimes called "block statements").

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

This identifies 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

This declares a variable. For the syntax of `variable_declaration`, see ["Constants and Variables"](#) on page 13-38.

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.

Example

The following PL/SQL block declares several variables and constants, then calculates a ratio using values selected from a database table:

```
-- available online in file 'examp11'
DECLARE
    numerator    NUMBER;
    denominator  NUMBER;
    the_ratio    NUMBER;
    lower_limit  CONSTANT NUMBER := 0.72;
    samp_num     CONSTANT NUMBER := 132;
BEGIN
    SELECT x, y INTO numerator, denominator FROM result_table
        WHERE sample_id = samp_num;
    the_ratio := numerator/denominator;
    IF the_ratio > lower_limit THEN
        INSERT INTO ratio VALUES (samp_num, the_ratio);
    ELSE
        INSERT INTO ratio VALUES (samp_num, -1);
    END IF;
    COMMIT;
EXCEPTION
    WHEN ZERO_DIVIDE THEN
        INSERT INTO ratio VALUES (samp_num, 0);
        COMMIT;
    WHEN OTHERS THEN
        ROLLBACK;
END;
```

Related Topics

Constants and Variables, Exceptions, Functions, Procedures

CASE Statement

The CASE statement selects a sequence of statements to execute. To select the sequence, the CASE statement uses a selector (an expression whose value is used to select one of several alternatives) or, in the searched CASE statement, multiple search conditions.

See also: .

Syntax

searched_case_statement ::=

```
[ <<label_name>> ]
CASE { WHEN boolean_expression THEN {statement;} ... }...
[ ELSE {statement;}... ]
END CASE [ label_name ];
```

simple_case_statement ::=

```
[ <<label_name>> ]
CASE case_operand
{ WHEN when_operand THEN {statement;} ... }...
[ ELSE {statement;}... ]
END CASE [ label_name ];
```

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

Each `WHEN` clause is executed only once.

The `WHEN` clauses are executed in order.

After a matching `WHEN` clause is found, subsequent `WHEN` clauses are not executed.

Because the execution order of the `WHEN` clauses is defined by the preceding rules, the statements in a `WHEN` clause are allowed to modify the database and call non-deterministic functions.

There is no "fall-through" 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.

Examples

The following example shows a simple `CASE` statement. Notice that you can use multiple statements after a `WHEN` clause.

```
DECLARE
  n number;
BEGIN
  CASE n
    WHEN 1 THEN dbms_output.put_line('n = 1');
    WHEN 2 THEN
      dbms_output.put_line('n = 2');
      dbms_output.put_line('That implies n > 1');
    ELSE dbms_output.put_line('n is some other value. ');
  END CASE;
END;
```

The following example shows a searched CASE statement. Notice that the WHEN clauses can use different conditions rather than all testing the same variable or using the same operator. Because this example does not use an ELSE clause, an exception is raised if none of the WHEN conditions are met.

```
DECLARE
    quantity NUMBER;
    projected NUMBER;
    needed NUMBER;
BEGIN
    <<here>>
    CASE
        WHEN quantity is null THEN
            dbms_output.put_line('Quantity not available');
        WHEN quantity + projected >= needed THEN
            dbms_output.put_line('Quantity ' || quantity ||
                ' should be enough if projections are met.');
```

WHEN quantity >= 0 THEN
 dbms_output.put_line('Quantity ' || quantity || ' is probably
not enough.');

```
    END CASE here;
    EXCEPTION
        WHEN CASE_NOT_FOUND THEN
            dbms_output.put_line('Somehow quantity must be less than 0.')
```

END;

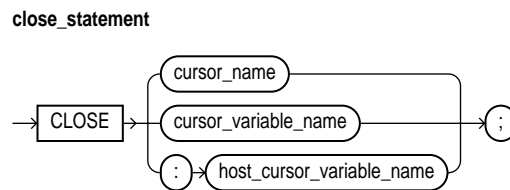
Related Topics

["Conditional Control: IF and CASE Statements"](#) on page 4-2, ["CASE Expressions"](#) on page 2-31, NULLIF and COALESCE expressions in *Oracle9i SQL Reference*

CLOSE Statement

The `CLOSE` statement allows resources held by an open cursor or cursor variable to be reused. No more rows can be fetched from a closed cursor or cursor variable. For more information, see ["Managing Cursors"](#) on page 6-6.

Syntax



Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope and currently open.

cursor_variable_name

This identifies a PL/SQL cursor variable (or parameter) previously declared within the current scope and currently open.

host_cursor_variable_name

This identifies 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. If you reopen a cursor without closing it first, PL/SQL raises the predefined exception `CURSOR_ALREADY_OPEN`. However, you need not close a cursor variable before reopening it.

If you try to close an already-closed or never-opened cursor or cursor variable, PL/SQL raises the predefined exception `INVALID_CURSOR`.

Example

In the following example, after the last row is fetched and processed, you close the cursor variable `emp_cv`:

```
LOOP
    FETCH emp_cv INTO emp_rec;
    EXIT WHEN emp_cv%NOTFOUND;
    ... -- process data record
END LOOP;
/* Close cursor variable. */
CLOSE emp_cv;
```

Related Topics

[FETCH Statement](#), [OPEN Statement](#), [OPEN-FOR Statement](#)

Collection Methods

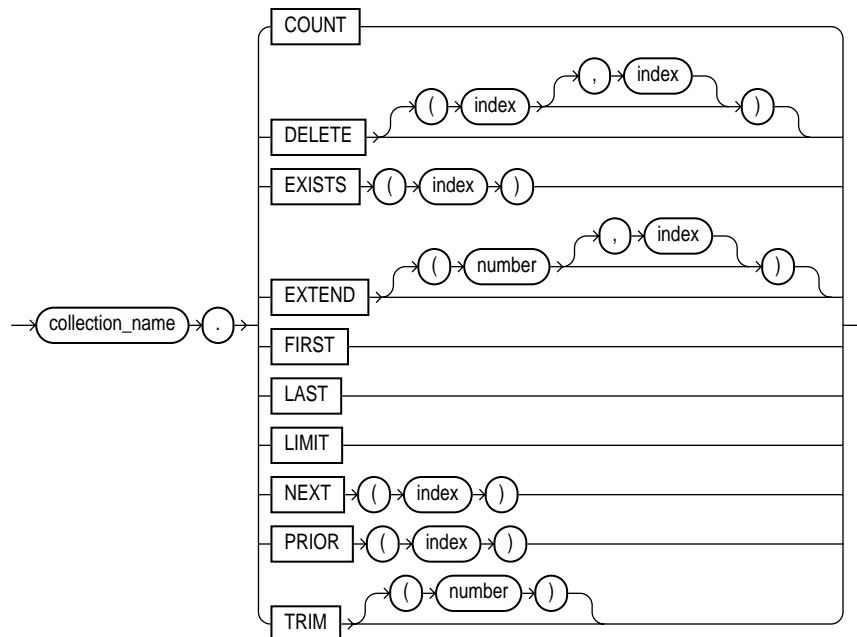
A collection method is a built-in function or procedure that operates on collections and is called using dot notation. The methods `EXISTS`, `COUNT`, `LIMIT`, `FIRST`, `LAST`, `PRIOR`, `NEXT`, `EXTEND`, `TRIM`, and `DELETE` help generalize code, make collections easier to use, and make your applications easier to maintain.

`EXISTS`, `COUNT`, `LIMIT`, `FIRST`, `LAST`, `PRIOR`, and `NEXT` are functions, which appear as part of an expression. `EXTEND`, `TRIM`, and `DELETE` are procedures, which appear as a statement. `EXISTS`, `PRIOR`, `NEXT`, `TRIM`, `EXTEND`, and `DELETE` take integer parameters. `EXTEND` and `TRIM` cannot be used with index-by tables.

For more information, see ["Using Collection Methods"](#) on page 5-23.

Syntax

collection_method_call



Keyword and Parameter Description

collection_name

This identifies an index-by table, nested table, or varray previously declared within the current scope.

COUNT

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 index-by table or nested table. If *n* is null, DELETE(*n*) does nothing. DELETE(*m*, *n*) removes all elements in the range *m* . . *n* from an index-by table 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. So, if EXTEND encounters deleted elements, it includes them in its tally. You cannot use EXTEND with index-by tables.

FIRST, LAST

`FIRST` and `LAST` return the first and last (smallest and largest) index numbers in a collection. If the collection is empty, `FIRST` and `LAST` return `NULL`. If the collection contains only one element, `FIRST` and `LAST` return the same index number.

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

This is an expression that must yield (or convert implicitly to) an integer.

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 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`. 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. So, 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`.

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.

`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.

`PL/SQL` keeps placeholders for deleted elements. So, you can replace a deleted element simply 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. So, 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

In the following example, you use `NEXT` to traverse a nested table from which some elements have been deleted:

```
i := courses.FIRST; -- get subscript of first element
WHILE i IS NOT NULL LOOP
    -- do something with courses(i)
    i := courses.NEXT(i); -- get subscript of next element
END LOOP;
```

In the following example, `PL/SQL` executes the assignment statement only if element `i` exists:

```
IF courses.EXISTS(i) THEN
    courses(i) := new_course;
END IF;
```

The next example shows that you can use `FIRST` and `LAST` to specify the lower and upper bounds of a loop range provided each element in that range exists:

```
FOR i IN courses.FIRST..courses.LAST LOOP ...
```


In the following example, you delete elements 2 through 5 from a nested table:

```
courses.DELETE(2, 5);
```

In the final example, you use `LIMIT` to determine if you can add 20 more elements to varray `projects`:

```
IF (projects.COUNT + 20) < projects.LIMIT THEN  
    -- add 20 more elements
```

Related Topics

Collections, Functions, Procedures

Collections

A collection is an ordered group of elements, all of the same type (for example, the grades for a class of students). Each element has a unique subscript that determines its position in the collection. PL/SQL offers three kinds of collections: index-by tables, nested tables, and varrays (short for variable-size arrays). Nested tables extend the functionality of index-by tables (formerly called "PL/SQL tables").

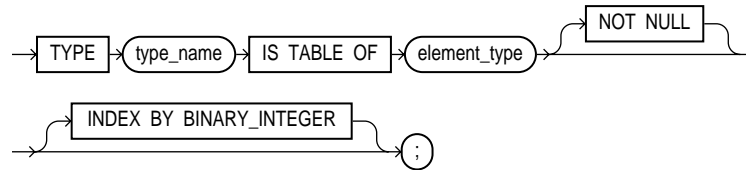
Collections work like the arrays found in most third-generation programming languages. Collections can have only one dimension and must be indexed by integers. In some languages, such as Ada and Pascal, arrays can have multiple dimensions and can be indexed by enumeration types. To model multi-dimensional 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. Also, collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms.

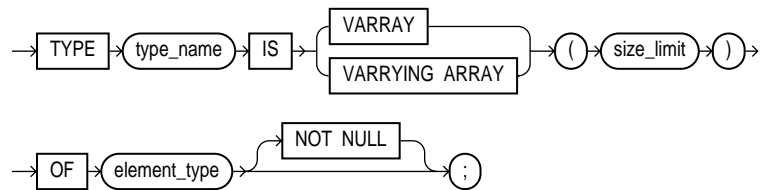
For more information, see ["Defining and Declaring Collections"](#) on page 5-5.

Syntax

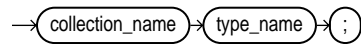
table_type_definition

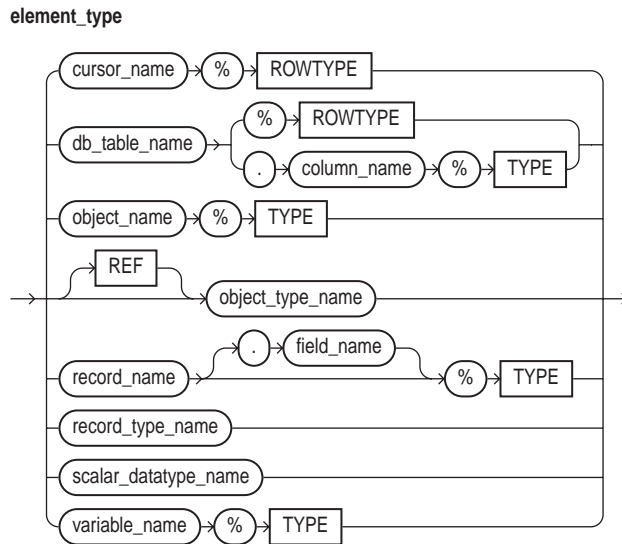


varray_type_definition



collection_declaration





Keyword and Parameter Description

element_type

This is any PL/SQL datatype except `BINARY_INTEGER`, `BOOLEAN`, `LONG`, `LONG RAW`, `NATURAL`, `NATURALN`, `NCHAR`, `NCLOB`, `NVARCHAR2`, `PLS_INTEGER`, `POSITIVE`, `POSITIVEN`, `REF CURSOR`, `SIGNTYPE`, or `STRING`. Also, with varrays, `element_type` cannot be `BLOB`, `CLOB`, or an object type with `BLOB` or `CLOB` attributes.

INDEX BY BINARY_INTEGER

This optional clause lets you define Version 2 PL/SQL tables, which are now called index-by tables.

size_limit

This is a positive integer literal that specifies the maximum size of a varray, which is the maximum number of elements the varray can contain.

type_name

This identifies a user-defined collection type that was defined using the datatype specifier `TABLE` or `VARRAY`.

Usage Notes

Nested tables extend the functionality of index-by tables, so they differ in several ways. See "[Nested Tables Versus Index-By Tables](#)" on page 5-3.

Every element reference includes the collection name and a subscript enclosed in parentheses; the subscript determines which element is processed. Except for index-by tables, which can have negative subscripts, collection subscripts have a fixed lower bound of 1.

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.

Index-by tables 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, index-by tables are sparse. That enables you, for example, to store reference data in a temporary index-by table using a numeric 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" a collection from the elements passed to it.

Because nested tables and varrays can be atomically null, they can be tested for nullity. However, they cannot be compared for equality or inequality. This restriction also applies to implicit comparisons. For example, collections cannot appear in a `DISTINCT`, `GROUP BY`, or `ORDER BY` list.

Collections can store instances of an object type and, conversely, can be attributes of an object type. Also, collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms.

When calling a function that returns a collection, you use the following syntax to reference elements in the collection:

```
collection_name(parameter_list)(subscript)
```

With the Oracle Call Interface (OCI) or the Oracle Precompilers, you can bind host arrays to index-by tables declared as the formal parameters of a subprogram. That lets you pass host arrays to stored functions and procedures.

Examples

To specify the element type of a collection, you can use %TYPE or %ROWTYPE, as the following example shows:

```
DECLARE
    TYPE JobList IS VARRAY(10) OF emp.job%TYPE; -- based on column
    CURSOR c1 IS SELECT * FROM dept;
    TYPE DeptFile IS TABLE OF c1%ROWTYPE; -- based on cursor
    TYPE EmpFile IS VARRAY(150) OF emp%ROWTYPE; -- based on database
table
```

In the next example, you use a RECORD type to specify the element type:

```
DECLARE
    TYPE Entry IS RECORD (
        term    VARCHAR2(20),
        meaning VARCHAR2(200));
    TYPE Glossary IS VARRAY(250) OF Entry;
```

In the example below, you declare an index-by table of records. Each element of the table stores a row from the emp database table.

```
DECLARE
    TYPE EmpTabTyp IS TABLE OF emp%ROWTYPE
        INDEX BY BINARY_INTEGER;
    emp_tab EmpTabTyp;
BEGIN
    /* Retrieve employee record. */
    SELECT * INTO emp_tab(7468) FROM emp WHERE empno = 7468;
```

When defining a `VARRAY` type, you must specify its maximum size. In the following example, you define a type that stores up to 366 dates:

```
DECLARE
    TYPE Calendar IS VARRAY(366) OF DATE;
```

Once you define a collection type, you can declare collections of that type, as the following SQL*Plus script shows:

```
CREATE TYPE Project AS OBJECT(
    project_no NUMBER(2),
    title      VARCHAR2(35),
    cost      NUMBER(7,2))
/
CREATE TYPE ProjectList AS VARRAY(50) OF Project -- VARRAY type
/
CREATE TABLE department (
    idnum      NUMBER(2),
    name      VARCHAR2(15),
    budget    NUMBER(11,2),
    projects ProjectList) -- declare varray
/
```

The identifier `projects` represents an entire varray. Each element of `projects` will store a `Project` object.

In the following example, you declare a nested table as the formal parameter of a packaged procedure:

```
CREATE PACKAGE personnel AS
    TYPE Staff IS TABLE OF Employee;
    ...
    PROCEDURE award_bonuses (members IN Staff);
```

You can specify a collection type in the `RETURN` clause of a function spec, as the following example shows:

```
DECLARE
    TYPE SalesForce IS VARRAY(20) OF Salesperson;
    FUNCTION top_performers (n INTEGER) RETURN SalesForce IS ...
```

In the following example, you update the list of projects assigned to the Security Department:

```
DECLARE
    new_projects ProjectList :=
        ProjectList(Project(1, 'Issue New Employee Badges', 13500),
                    Project(2, 'Inspect Emergency Exits', 1900),
                    Project(3, 'Upgrade Alarm System', 3350),
                    Project(4, 'Analyze Local Crime Stats', 825));
BEGIN
    UPDATE department
        SET projects = new_projects WHERE name = 'Security';
```

In the next example, you retrieve all the projects for the Accounting Department into a local varray:

```
DECLARE
    my_projects ProjectList;
BEGIN
    SELECT projects INTO my_projects FROM department
        WHERE name = 'Accounting';
```

Related Topics

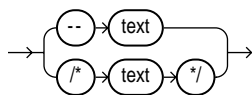
Collection Methods, Object Types, Records

Comments

Comments describe the purpose and use of code segments and so promote readability. PL/SQL supports two comment styles: single-line and multi-line. Single-line comments begin with a double hyphen (--) anywhere on a line and extend to the end of the line. Multi-line comments begin with a slash-asterisk (/ *), end with an asterisk-slash (* /), and can span multiple lines. For more information, see "Comments" on page 2-10.

Syntax

comment



Usage Notes

Comments can appear within a statement at the end of a line. However, you cannot nest comments.

You cannot use single-line comments in a PL/SQL block that will be processed dynamically 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. Instead, use multi-line comments.

While testing or debugging a program, you might want to disable a line of code. The following example shows how you can "comment-out" the line:

```
-- UPDATE dept SET loc = my_loc WHERE deptno = my_deptno;
```

You can use multi-line comment delimiters to comment-out whole sections of code.

Examples

The following examples show various comment styles:

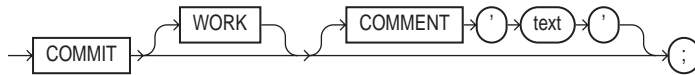
```
-- compute the area of a circle
area := pi * radius**2; -- pi equals 3.14159
/* Compute the area
   of a circle. */
area := pi * radius**2; /* pi equals 3.14159 */
```

COMMIT Statement

The `COMMIT` statement explicitly makes permanent any changes made to the database during the current transaction. Changes made to the database are not considered permanent until they are committed. A commit also makes the changes visible to other users. For more information, see "[Overview of Transaction Processing in PL/SQL](#)" on page 6-43.

Syntax

commit_statement



Keyword and Parameter Description

COMMENT

This keyword specifies a comment to be associated with the current transaction and is typically used with distributed transactions. The text must be a quoted literal no more than 50 characters long.

WORK

This keyword is optional and has no effect except to improve readability.

Usage Notes

The `COMMIT` statement releases all row and table locks. It also erases any savepoints you marked since the last commit or rollback. Until your changes are committed, the following conditions hold:

- 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, however, so you should close it. For more information, see ["Using FOR UPDATE"](#) on page 6-50.

When a distributed transaction fails, the text specified by `COMMENT` helps you diagnose the problem. If a distributed transaction is ever in doubt, Oracle stores the text in the data dictionary along with the transaction ID. For more information about distributed transactions, see *Oracle9i Database Concepts*.

In SQL, the `FORCE` clause manually commits an in-doubt distributed transaction. However, PL/SQL does not support this clause. For example, the following statement is illegal:

```
COMMIT WORK FORCE '23.51.54'; -- illegal
```

In embedded SQL, the `RELEASE` option frees all Oracle resources (locks and cursors) held by a program and disconnects from the database. However, PL/SQL does not support this option. For example, the following statement is illegal:

```
COMMIT WORK RELEASE; -- illegal
```

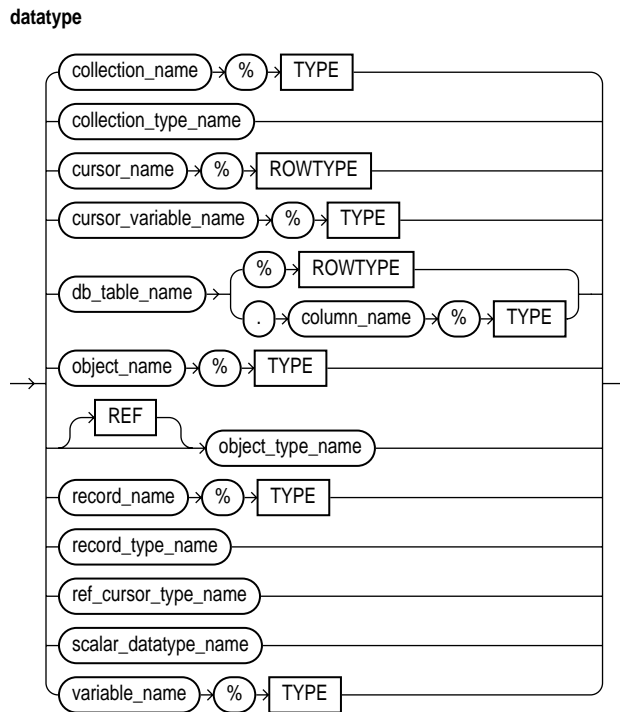
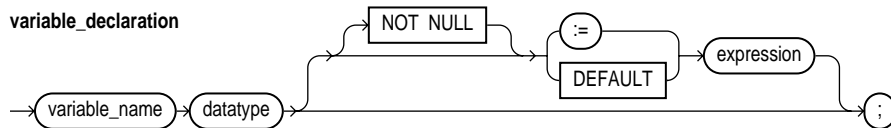
Related Topics

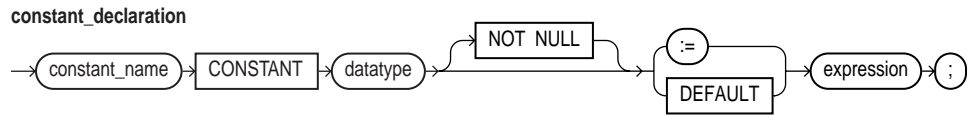
ROLLBACK Statement, SAVEPOINT Statement

Constants and Variables

You can declare constants and variables 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. Declarations can also assign an initial value and impose the NOT NULL constraint. For more information, see "[Declarations](#)" on page 2-11.

Syntax





Keyword and Parameter Description

collection_name

Identifies a collection (index-by table, nested table, or varray) previously declared within the current scope.

collection_type_name

Identifies a user-defined collection type that was 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

Identifies a program constant. For naming conventions, see ["Identifiers"](#) on page 2-4.

cursor_name

Identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

Identifies 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

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 constant or variable. The value and the constant or variable must have compatible datatypes.

NOT NULL

This constraint prevents the assigning of nulls to a variable or constant. At run time, trying to assign 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

Identifies an instance of an object type previously declared within the current scope.

record_name

Identifies a user-defined or `%ROWTYPE` record previously declared within the current scope.

record_name.field_name

Identifies a field in a user-defined or `%ROWTYPE` record previously declared within the current scope.

record_type_name

Identifies a user-defined record type that is defined using the datatype specifier `RECORD`.

ref_cursor_type_name

Identifies a user-defined cursor variable type is was defined using the datatype specifier `REF CURSOR`.

%ROWTYPE

This attribute provides a record type that represents a row in a database table or a row fetched from a previously declared cursor. Fields in the record and corresponding columns in the row have the same names and datatypes.

scalar_datatype_name

Identifies a predefined scalar datatype such as `BOOLEAN`, `NUMBER`, or `VARCHAR2`. Includes any qualifiers for size, precision, or character versus byte semantics.

%TYPE

This attribute provides the datatype of a previously declared collection, cursor variable, field, object, record, database column, or variable.

variable_name

Identifies 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`. So, unless you expressly initialize a variable, its value is undefined.

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.

Examples

Several examples of variable and constant declarations follow:

```
credit_limit CONSTANT NUMBER := 5000;
invalid      BOOLEAN := FALSE;
acct_id     INTEGER(4) NOT NULL DEFAULT 9999;
pi          CONSTANT REAL := 3.14159;
postal_code VARCHAR2(20);
last_name   VARCHAR2(20 CHAR);
my_ename    emp.ename%TYPE;
```

Related Topics

["Declarations"](#) on page 2-11, ["Predefined Datatypes"](#) on page 3-2, [Assignment Statement](#), [Expressions](#), [%ROWTYPE Attribute](#), [%TYPE Attribute](#)

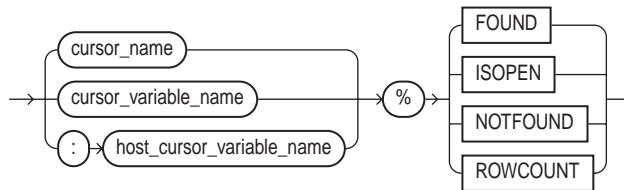
Cursor Attributes

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 Attributes"](#) on page 6-34.

The implicit cursor `SQL` has additional attributes, `%BULK_ROWCOUNT` and `%BULK_EXCEPTIONS`. For more information, see ["SQL Cursor"](#) on page 13-173.

Syntax

cursor_attribute



Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

This identifies a PL/SQL cursor variable (or parameter) previously declared within the current scope.

%FOUND Attribute

This is 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` yields `NULL`. Thereafter, it yields `TRUE` if the last fetch returned a row, or `FALSE` if the last fetch failed to return a row.

host_cursor_variable_name

This identifies 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

This is a cursor attribute that can be appended to the name of a cursor or cursor variable. If a cursor is open, `cursor_name%ISOPEN` yields `TRUE`; otherwise, it yields `FALSE`.

%NOTFOUND Attribute

This is 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` yields `NULL`. Thereafter, it yields `FALSE` if the last fetch returned a row, or `TRUE` if the last fetch failed to return a row.

%ROWCOUNT Attribute

This is 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` yields `0`. Thereafter, it yields 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. So, 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`. So, if `FETCH` never executes successfully, the loop is never exited. That is 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;
```

You can use the cursor attributes in procedural statements but *not* in SQL statements.

Examples

The PL/SQL block below uses `%FOUND` to select an action. The `IF` statement either inserts a row or exits the loop unconditionally.

```
-- available online in file 'examp12'
DECLARE
  CURSOR num1_cur IS SELECT num FROM num1_tab
    ORDER BY sequence;
  CURSOR num2_cur IS SELECT num FROM num2_tab
    ORDER BY sequence;
  num1      num1_tab.num%TYPE;
  num2      num2_tab.num%TYPE;
  pair_num NUMBER := 0;
BEGIN
  OPEN num1_cur;
  OPEN num2_cur;
  LOOP -- loop through the two tables and get pairs of numbers
    FETCH num1_cur INTO num1;
    FETCH num2_cur INTO num2;
    IF (num1_cur%FOUND) AND (num2_cur%FOUND) THEN
      pair_num := pair_num + 1;
      INSERT INTO sum_tab VALUES (pair_num, num1 + num2);
    ELSE
      EXIT;
    END IF;
  END LOOP;
  CLOSE num1_cur;
  CLOSE num2_cur;
END;
```

The next example uses the same block. However, instead of using `%FOUND` in an `IF` statement, it uses `%NOTFOUND` in an `EXIT WHEN` statement.

```
-- available online in file 'examp13'
DECLARE
    CURSOR num1_cur IS SELECT num FROM num1_tab
        ORDER BY sequence;
    CURSOR num2_cur IS SELECT num FROM num2_tab
        ORDER BY sequence;
    num1      num1_tab.num%TYPE;
    num2      num2_tab.num%TYPE;
    pair_num  NUMBER := 0;
BEGIN
    OPEN num1_cur;
    OPEN num2_cur;
    LOOP -- loop through the two tables and get
        -- pairs of numbers
        FETCH num1_cur INTO num1;
        FETCH num2_cur INTO num2;
        EXIT WHEN (num1_cur%NOTFOUND) OR (num2_cur%NOTFOUND);
        pair_num := pair_num + 1;
        INSERT INTO sum_tab VALUES (pair_num, num1 + num2);
    END LOOP;
    CLOSE num1_cur;
    CLOSE num2_cur;
END;
```

In the following example, you use `%ISOPEN` to make a decision:

```
IF NOT (emp_cur%ISOPEN) THEN
    OPEN emp_cur;
END IF;
FETCH emp_cur INTO emp_rec;
```

The following PL/SQL block uses `%ROWCOUNT` to fetch the names and salaries of the five highest-paid employees:

```
-- available online in file 'examp14'
DECLARE
    CURSOR c1 is
    SELECT ename, empno, sal FROM emp
        ORDER BY sal DESC; -- start with highest-paid employee
    my_ename CHAR(10);
    my_empno NUMBER(4);
    my_sal   NUMBER(7,2);
```

```
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO my_ename, my_empno, my_sal;
    EXIT WHEN (c1%ROWCOUNT > 5) OR (c1%NOTFOUND);
    INSERT INTO temp VALUES (my_sal, my_empno, my_ename);
    COMMIT;
  END LOOP;
  CLOSE c1;
END;
```

In the final example, you use %ROWCOUNT to raise an exception if an unexpectedly high number of rows is deleted:

```
DELETE FROM accts WHERE status = 'BAD DEBT';
IF SQL%ROWCOUNT > 10 THEN
  RAISE out_of_bounds;
END IF;
```

Related Topics

[Cursors, Cursor Variables](#)

Cursor Variables

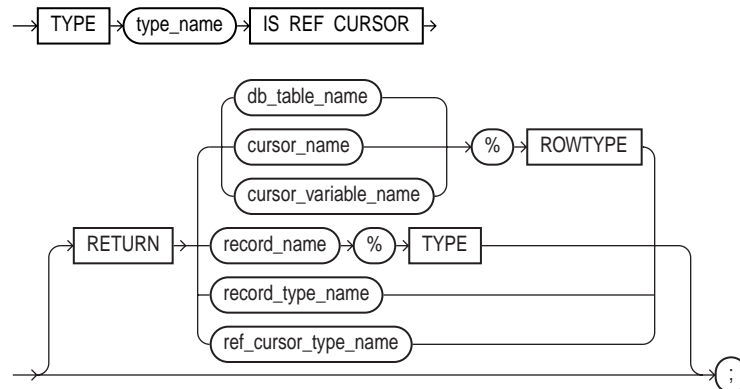
To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. To access the information, you can use an explicit cursor, which names the work area. Or, you can use a cursor variable, which points to the work area. Whereas a cursor always refers to the same query work area, a cursor variable can refer to different work areas. 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 memory location (address) of some item instead of the item itself. So, declaring a cursor variable creates a pointer, *not* an item.

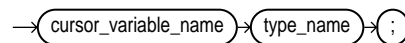
For more information, see ["Using Cursor Variables"](#) on page 6-16.

Syntax

ref_cursor_type_definition



cursor_variable_declaration



Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

This identifies a PL/SQL cursor variable previously declared within the current scope.

db_table_name

This identifies a database table (or view) that must be accessible when the declaration is elaborated.

record_name

This identifies a user-defined record previously declared within the current scope.

record_type_name

This identifies a user-defined record type that was defined using the datatype specifier `RECORD`.

REF CURSOR

In PL/SQL, pointers have datatype `REF X`, where `REF` is short for `REFERENCE` and `X` stands for a class of objects. Therefore, cursor variables have datatype `REF CURSOR`.

RETURN

This keyword introduces the `RETURN` clause, which 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 returned by a cursor or strongly typed cursor variable. Also, you can use the `%TYPE` attribute to provide the datatype of a previously declared record.

%ROWTYPE

This attribute provides 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

This attribute provides the datatype of a previously declared user-defined record.

type_name

This is a user-defined cursor variable type that was defined using the datatype specifier `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. Moreover, application development tools such as Oracle Forms and Oracle Reports, which have a PL/SQL engine, can use cursor variables entirely on the client side.

The Oracle database server also has a PL/SQL engine. So, you can pass cursor variables back and forth between an application and server through remote procedure calls (RPCs). And, 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.

Mainly, you use cursor variables to pass query result sets between PL/SQL stored subprograms and various clients. Neither PL/SQL nor any of its clients owns a result set; they simply 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 server can all refer to the same work area.

`REF CURSOR` types can be *strong* (restrictive) or *weak* (nonrestrictive). 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 the PL/SQL compiler lets you associate a strongly typed cursor variable only with type-compatible queries. However, weak `REF CURSOR` types are more flexible because the compiler lets you 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 6-33.

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

You can declare a cursor variable in a PL/SQL host environment such as an OCI or Pro*C program. To use the host cursor variable, you must pass it as a bind variable to PL/SQL. In the following Pro*C example, you pass a host cursor variable and a 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 emp;
  ELSIF :choice = 2 THEN
    OPEN :generic_cv FOR SELECT * FROM dept;
  ELSIF :choice = 3 THEN
    OPEN :generic_cv FOR SELECT * FROM salgrade;
  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.

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 three cursor variables in a single round-trip:

```
/* anonymous PL/SQL block in host environment */
BEGIN
  OPEN :emp_cv FOR SELECT * FROM emp;
  OPEN :dept_cv FOR SELECT * FROM dept;
  OPEN :grade_cv FOR SELECT * FROM salgrade;
END;
```

You can also pass a cursor variable to PL/SQL by calling a stored procedure that declares a cursor variable as one of its formal parameters. To centralize data retrieval, you can group type-compatible queries in a packaged procedure, as the following example shows:

```
CREATE PACKAGE emp_data AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp,
                          choice IN NUMBER);
END emp_data;

CREATE PACKAGE BODY emp_data AS
    PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp,
                          choice IN NUMBER) IS
    BEGIN
        IF choice = 1 THEN
            OPEN emp_cv FOR SELECT * FROM emp WHERE comm IS NOT NULL;
        ELSIF choice = 2 THEN
            OPEN emp_cv FOR SELECT * FROM emp WHERE sal > 2500;
        ELSIF choice = 3 THEN
            OPEN emp_cv FOR SELECT * FROM emp WHERE deptno = 20;
        END IF;
    END open_emp_cv;
END emp_data;
```

Alternatively, you can use a standalone procedure to open the cursor variable. Simply define the REF CURSOR type in a separate package, then reference that type in the standalone procedure. For instance, if you create the following (bodiless) package, you can create standalone procedures that reference the types it defines:

```
CREATE PACKAGE cv_types AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    TYPE DeptCurTyp IS REF CURSOR RETURN dept%ROWTYPE;
    TYPE BonusCurTyp IS REF CURSOR RETURN bonus%ROWTYPE;
    ...
END cv_types;
```

Related Topics

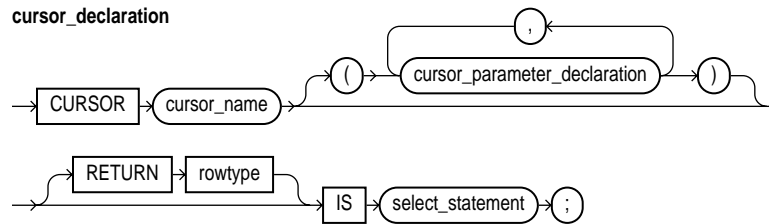
[CLOSE Statement](#), [Cursor Attributes](#), [Cursors](#), [FETCH Statement](#), [OPEN-FOR Statement](#)

Cursors

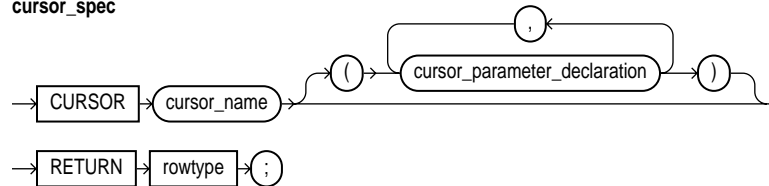
To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. An explicit cursor lets you name the work area, access the information, and process the rows individually. For more information, see ["Managing Cursors"](#) on page 6-6.

Syntax

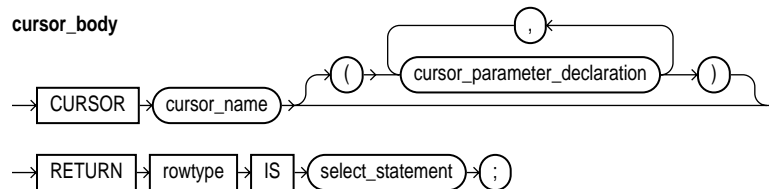
cursor_declaration



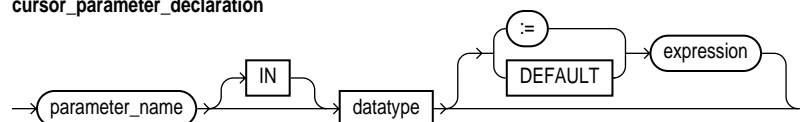
cursor_spec

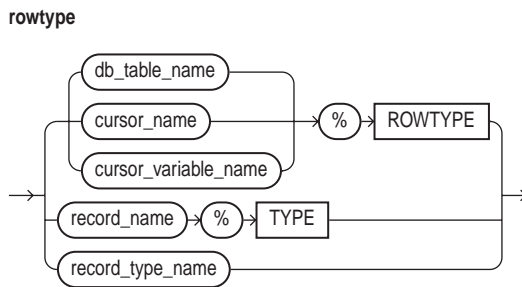


cursor_body



cursor_parameter_declaration





Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope.

datatype

This is a type specifier. For the syntax of `datatype`, see ["Constants and Variables"](#) on page 13-38.

db_table_name

This identifies a database table (or view) that must be accessible when the declaration is elaborated.

expression

This is 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.

parameter_name

This identifies a cursor parameter; that is, 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

This identifies a user-defined record previously declared within the current scope.

record_type_name

This identifies a user-defined record type that was defined using the datatype specifier `RECORD`.

RETURN

This keyword introduces the `RETURN` clause, which 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

This attribute provides 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

This is 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 13-164. If the cursor declaration declares parameters, each parameter must be used in the query.

%TYPE

This attribute 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. And, you must declare a variable before referencing it in a cursor declaration. The word `SQL` is reserved by PL/SQL for use 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"](#) on page 2-19.

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. For example, the following parameter declarations are illegal:

```
CURSOR c1 (emp_id NUMBER NOT NULL, dept_no NUMBER(2)) -- illegal
```

Examples

Some examples of cursor declarations follow:

```
CURSOR c1 IS SELECT empno, ename, job, sal FROM emp
    WHERE sal > 2000;
CURSOR c2 RETURN dept%ROWTYPE IS
    SELECT * FROM dept WHERE deptno = 10;
CURSOR c3 (start_date DATE) IS
    SELECT empno, sal FROM emp WHERE hiredate > start_date;
```

Related Topics

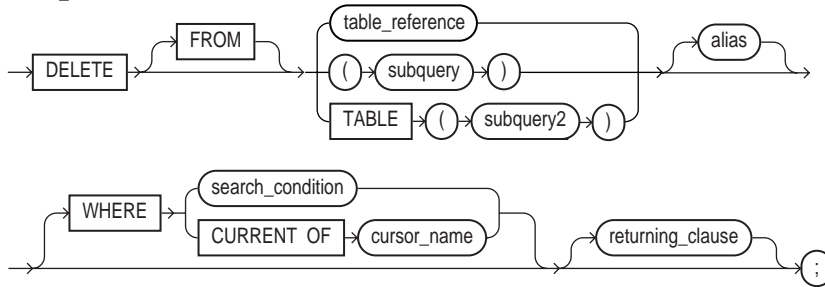
`CLOSE` Statement, `FETCH` Statement, `OPEN` Statement, `SELECT INTO` Statement

DELETE Statement

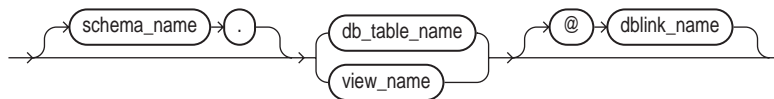
The `DELETE` statement removes entire rows of data from a specified table or view. For a full description of the `DELETE` statement, see *Oracle9i SQL Reference*.

Syntax

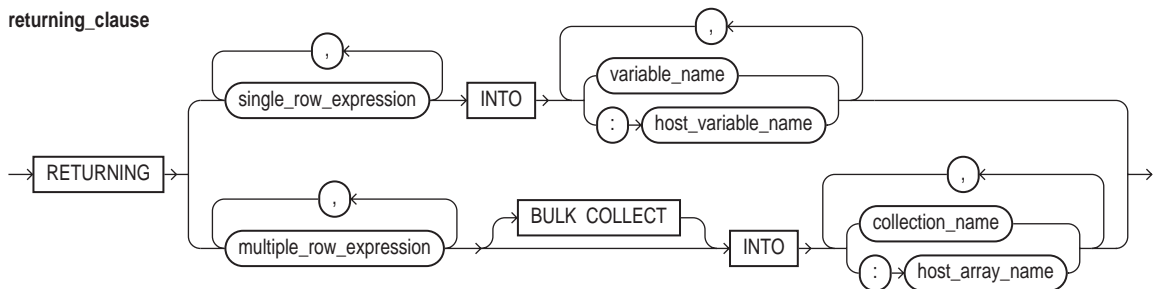
`delete_statement`



`table_reference`



`returning_clause`



Keyword and Parameter Description

alias

This is another (usually short) name for the referenced table or view and is typically used in the `WHERE` clause.

BULK COLLECT

This clause 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 `RETURNING INTO` list. The corresponding columns must store scalar (not composite) values. For more information, see ["Reducing Loop Overhead for Collections with Bulk Binds"](#) on page 5-32.

returning_clause

This clause lets you return values from the deleted rows, thereby eliminating the need to `SELECT` the rows beforehand. You can retrieve the column values into variables and/or host variables, or into collections and/or host arrays. However, you cannot use the `RETURNING` clause for remote or parallel deletes.

subquery

This is 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 13-164.

table_reference

This specifies 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

This clause 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

This clause 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

The following statement deletes from the `bonus` table all employees whose sales were below quota:

```
DELETE FROM bonus WHERE sales_amt < quota;
```

The following statement returns two column values from a deleted row into local variables:

```
DECLARE
    my_empno emp.empno%TYPE;
    my_ename emp.ename%TYPE;
    my_job    emp.job%TYPE;
BEGIN
    . . .
    DELETE FROM emp WHERE empno = my_empno
        RETURNING ename, job INTO my_ename, my_job;
END;
```

You can combine the `BULK COLLECT` clause with a `FORALL` statement, in which case, the SQL engine bulk-binds column values incrementally. In the following example, if collection `depts` has 3 elements, each of which causes 5 rows to be deleted, then collection `enums` has 15 elements when the statement completes:

```
FORALL j IN depts.FIRST..depts.LAST
  DELETE FROM emp WHERE deptno = depts(j)
  RETURNING empno BULK COLLECT INTO enums;
```

The column values returned by each execution are added to the values returned previously.

Related Topics

[FETCH Statement](#), [SELECT Statement](#)

EXCEPTION_INIT Pragma

The pragma `EXCEPTION_INIT` associates 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 instead of using the `OTHERS` handler. For more information, see ["Associating a PL/SQL Exception with a Number: Pragma EXCEPTION_INIT"](#) on page 7-8.

Syntax

`exception_init_pragma`

```
→ PRAGMA EXCEPTION_INIT → ( → exception_name → , → error_number → ) → ;
```

Keyword and Parameter Description

error_number

This is any valid Oracle error number. These are the same error numbers returned by the function `SQLCODE`.

exception_name

This identifies a user-defined exception previously declared within the current scope.

PRAGMA

This keyword signifies that the statement is a pragma (compiler directive). Pragas 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

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.

Example

The following pragma associates the exception `deadlock_detected` with Oracle error 60:

```
DECLARE
    deadlock_detected EXCEPTION;
    PRAGMA EXCEPTION_INIT(deadlock_detected, -60);
BEGIN
    ...
EXCEPTION
    WHEN deadlock_detected THEN
        -- handle the error
    ...
END;
```

Related Topics

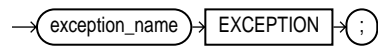
[AUTONOMOUS_TRANSACTION Pragma, Exceptions, SQLCODE Function](#)

Exceptions

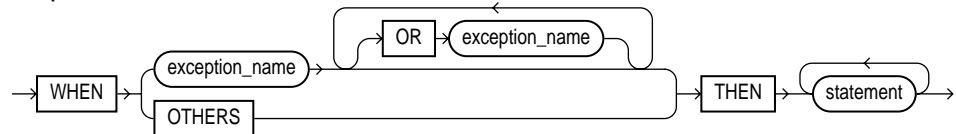
An exception is a runtime error or warning condition, which can be predefined or user-defined. Predefined exceptions are raised implicitly (automatically) by the runtime system. User-defined exceptions must be raised explicitly by `RAISE` statements. To handle raised exceptions, you write separate routines called exception handlers. For more information, see [Chapter 7](#).

Syntax

exception_declaration



exception_handler



Keyword and Parameter Description

exception_name

This identifies a predefined exception such as `ZERO_DIVIDE`, or a user-defined exception previously declared within the current scope.

OTHERS

This keyword 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

This is an executable statement. For the syntax of `statement`, see ["Blocks"](#) on page 13-11.

WHEN

This keyword 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 ["Predefined PL/SQL Exceptions"](#) on page 7-4. 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

The following PL/SQL block has two exception handlers:

```
DECLARE
    bad_emp_id EXCEPTION;
    bad_acct_no EXCEPTION;
    ...
BEGIN
    ...
EXCEPTION
    WHEN bad_emp_id OR bad_acct_no THEN -- user-defined
        ROLLBACK;
    WHEN ZERO_DIVIDE THEN -- predefined
        INSERT INTO inventory VALUES (part_number, quantity);
        COMMIT;
END;
```

Related Topics

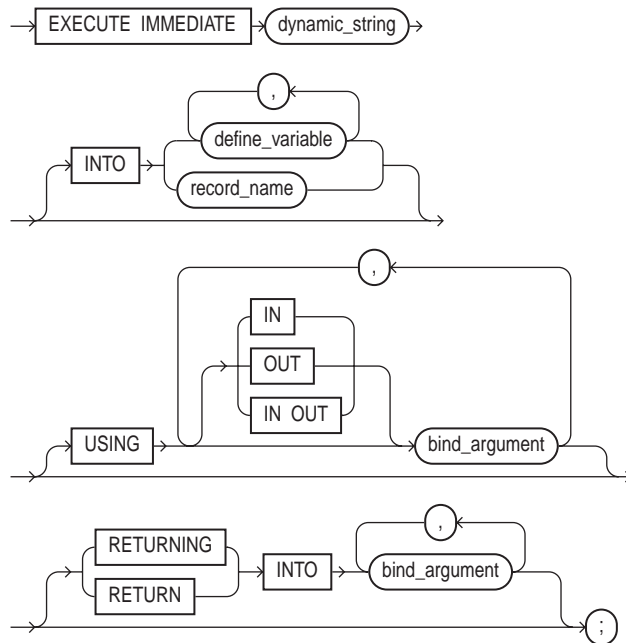
Blocks, EXCEPTION_INIT Pragma, RAISE Statement

EXECUTE IMMEDIATE Statement

The `EXECUTE IMMEDIATE` statement prepares (parses) and immediately executes a dynamic SQL statement or anonymous PL/SQL block. For more information, see [Chapter 11](#).

Syntax

`execute_immediate_statement`



Keyword and Parameter Description

bind_argument

This can be an expression whose value is passed to the dynamic SQL statement or PL/SQL block, or it can be a variable that stores a value returned by the dynamic SQL statement or PL/SQL block.

define_variable_name

This identifies a variable that stores a selected column value.

dynamic_string

This is a string literal, variable, or expression that represents a SQL statement or PL/SQL block.

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

This identifies a user-defined or `%ROWTYPE` record that stores a selected row.

RETURNING INTO ...

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.

USING ...

This clause specifies a list of input and/or output bind arguments. If you do not specify a parameter mode, it defaults to `IN`.

Usage Notes

Except for multi-row queries, the dynamic string can contain any SQL statement (*without* the terminator) or any PL/SQL block (with 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.

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. So, 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"](#) on page 11-17.

Dynamic SQL supports all the SQL datatypes. So, for example, define variables and bind arguments can be collections, LOBs, instances of an object type, and refs. As a rule, dynamic SQL does not support PL/SQL-specific types. So, 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. However, you incur some overhead because `EXECUTE IMMEDIATE` re-prepares the dynamic string before every execution.

Examples

The following PL/SQL block contains several examples of dynamic SQL:

```
DECLARE
    sql_stmt      VARCHAR2(200);
    plsql_block   VARCHAR2(500);
    emp_id        NUMBER(4) := 7566;
    salary        NUMBER(7,2);
    dept_id       NUMBER(2) := 50;
    dept_name     VARCHAR2(14) := 'PERSONNEL';
    location      VARCHAR2(13) := 'DALLAS';
    emp_rec       emp%ROWTYPE;
BEGIN
    EXECUTE IMMEDIATE 'CREATE TABLE bonus (id NUMBER, amt NUMBER)';

    sql_stmt := 'INSERT INTO dept VALUES (:1, :2, :3)';
    EXECUTE IMMEDIATE sql_stmt USING dept_id, dept_name, location;

    sql_stmt := 'SELECT * FROM emp WHERE empno = :id';
    EXECUTE IMMEDIATE sql_stmt INTO emp_rec USING emp_id;

    plsql_block := 'BEGIN emp_pkg.raise_salary(:id, :amt); END;';
    EXECUTE IMMEDIATE plsql_block USING 7788, 500;

    sql_stmt := 'UPDATE emp SET sal = 2000 WHERE empno = :1
                RETURNING sal INTO :2';
    EXECUTE IMMEDIATE sql_stmt USING emp_id RETURNING INTO salary;
```

```
EXECUTE IMMEDIATE 'DELETE FROM dept WHERE deptno = :num'  
    USING dept_id;  
  
EXECUTE IMMEDIATE 'ALTER SESSION SET SQL_TRACE TRUE';  
END;
```

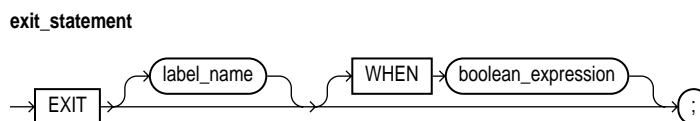
Related Topics

[OPEN-FOR-USING Statement](#)

EXIT Statement

You use the `EXIT` statement to exit 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 ["Iterative Control: LOOP and EXIT Statements"](#) on page 4-9.

Syntax



Keyword and Parameter Description

boolean_expression

This is an expression that yields the Boolean value `TRUE`, `FALSE`, or `NULL`. It is evaluated with each iteration of the loop in which the `EXIT WHEN` statement appears. If the expression yields `TRUE`, the current loop (or the loop labeled by `label_name`) is exited immediately. For the syntax of `boolean_expression`, see ["Expressions"](#) on page 13-72.

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

This identifies the loop to be exited. You can exit not only the current loop but any enclosing labeled loop.

Usage Notes

The `EXIT` statement can be used only inside a loop. PL/SQL lets you code an infinite loop. For example, the following loop will never terminate normally:

```
WHILE TRUE LOOP ... END LOOP;
```

In such cases, you must use an `EXIT` statement to exit the 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

The `EXIT` statement in the following example is illegal because you cannot exit from a block directly; you can exit only from a loop:

```
DECLARE
    amount    NUMBER;
    maximum   NUMBER;
BEGIN
    ...
    BEGIN
        ...
        IF amount >= maximum THEN
            EXIT; -- illegal; use RETURN instead
        END IF;
    END;
END;
```

The following loop normally executes ten times, but it will exit prematurely if there are less than ten rows to fetch:

```
FOR i IN 1..10 LOOP
    FETCH c1 INTO emp_rec;
    EXIT WHEN c1%NOTFOUND;
    total_comm := total_comm + emp_rec.comm;
END LOOP;
```

The following example illustrates the use of loop labels:

```
<<outer>>
FOR i IN 1..10 LOOP
    ...
    <<inner>>
    FOR j IN 1..100 LOOP
        ...
        EXIT outer WHEN ... -- exits both loops
    END LOOP inner;
END LOOP outer;
```

Related Topics

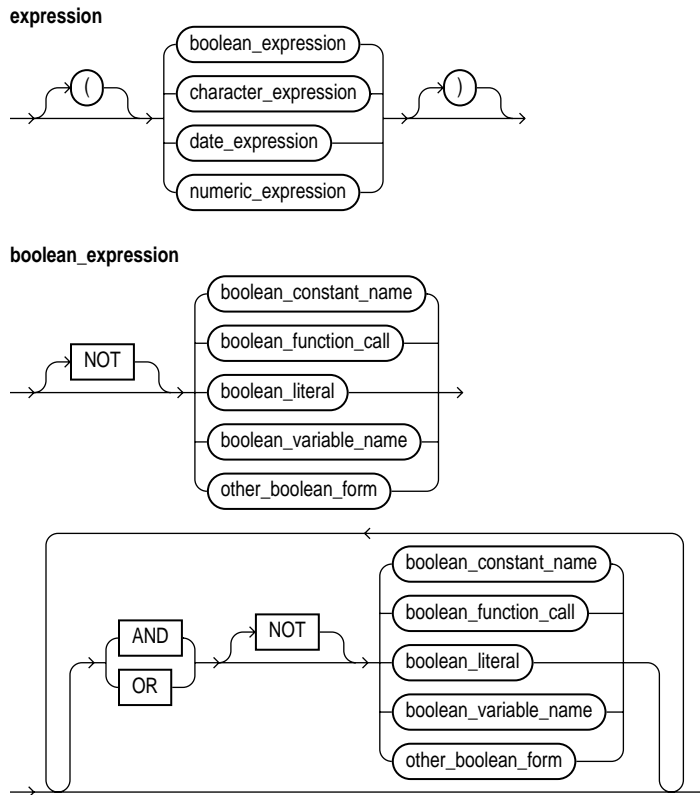
Expressions, LOOP Statements

Expressions

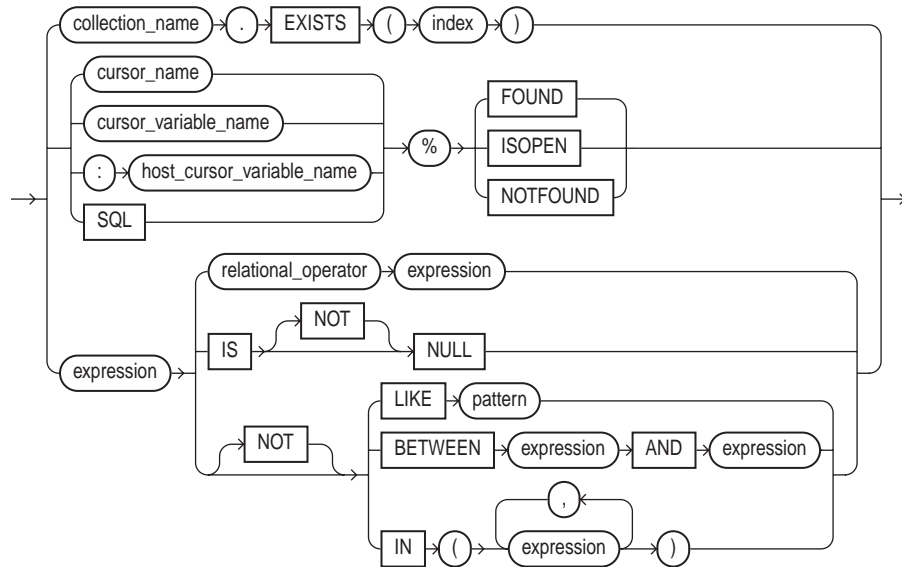
An expression is an arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression is a single variable.

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 ["Expressions and Comparisons"](#) on page 2-23.

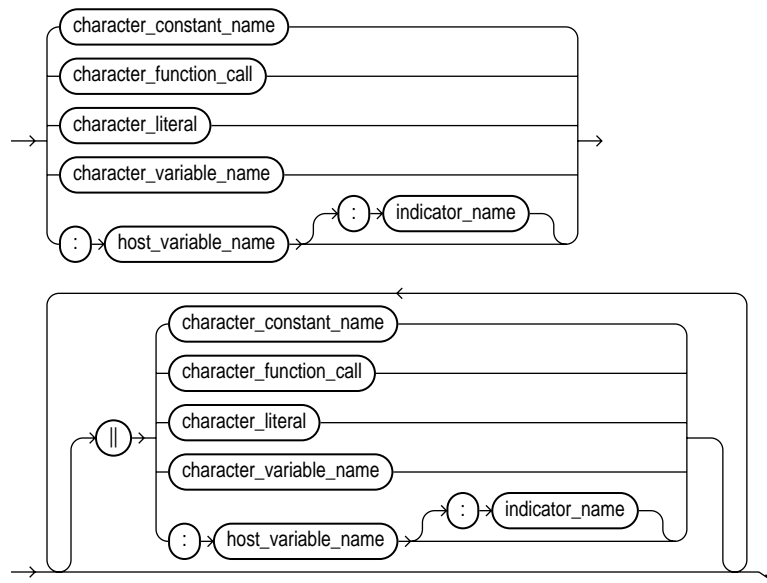
Syntax



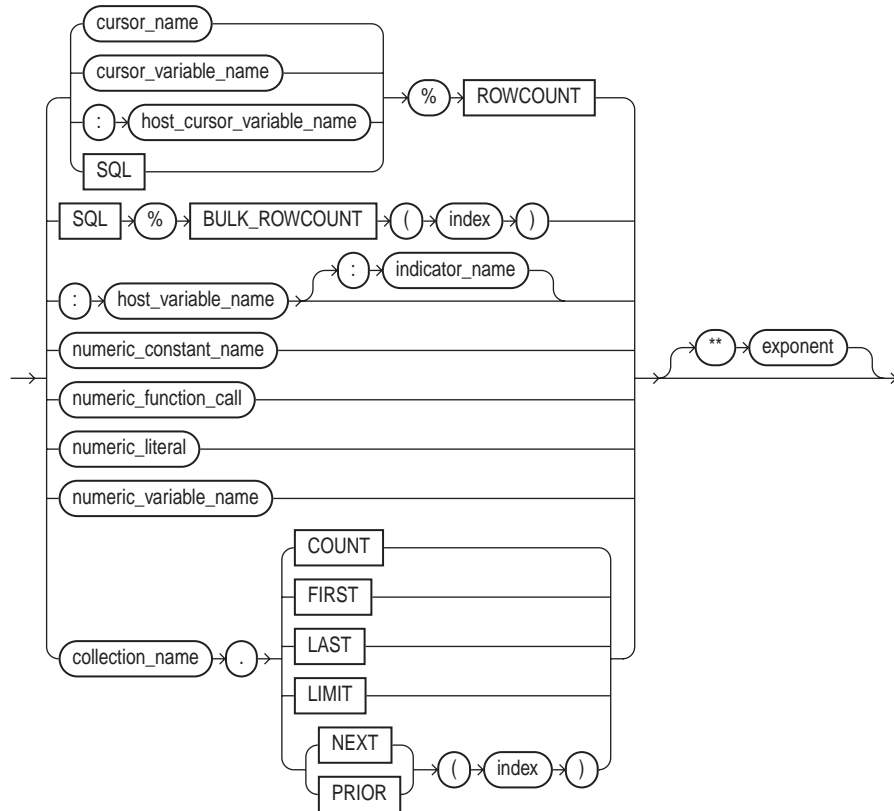
other_boolean_form

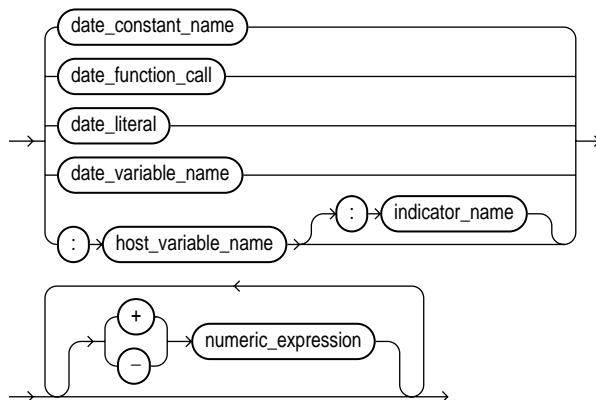
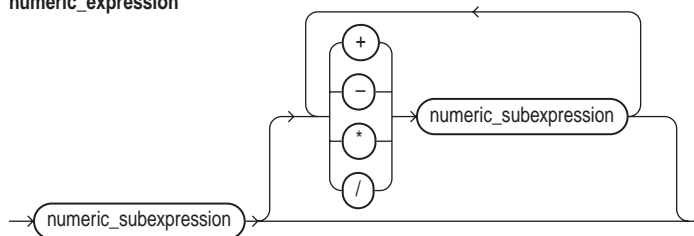


character_expression



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

This identifies a constant of type `BOOLEAN`, which must be initialized to the value `TRUE`, `FALSE`, or `NULL`. Arithmetic operations on Boolean constants are illegal.

boolean_expression

This is an expression that yields the Boolean value `TRUE`, `FALSE`, or `NULL`.

boolean_function_call

This is any function call that returns a Boolean value.

boolean_literal

This is the predefined value `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

This identifies 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 illegal.

%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 13-173.

character_constant_name

This identifies 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

This is an expression that yields a character or character string.

character_function_call

This is a function call that returns a character value or a value implicitly convertible to a character value.

character_literal

This is a literal that represents a character value or a value implicitly convertible to a character value.

character_variable_name

This identifies a previously declared variable that stores a character value.

collection_name

This identifies a collection (nested table, index-by table, or varray) previously declared within the current scope.

cursor_name

This identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

This identifies a PL/SQL cursor variable previously declared within the current scope.

date_constant_name

This identifies 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

This is an expression that yields a date/time value.

date_function_call

This is a function call that returns a date value or a value implicitly convertible to a date value.

date_literal

This is a literal that represents a date value or a value implicitly convertible to a date value.

date_variable_name

This identifies a previously declared variable that stores a date value.

EXISTS, COUNT, FIRST, LAST, LIMIT, NEXT, PRIOR

These are 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 13-23.

exponent

This is an expression that must yield a numeric value.

%FOUND, %ISOPEN, %NOTFOUND, %ROWCOUNT

These are 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

This identifies 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

This identifies 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

This comparison operator 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
```

yield `FALSE` if the set contains a null.

index

This is a numeric expression that must yield a value of type `BINARY_INTEGER` or a value implicitly convertible to that datatype.

indicator_name

This identifies 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

This comparison operator returns the Boolean value `TRUE` if its operand is null, or `FALSE` if its operand is not null.

LIKE

This comparison operator 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

These are logical operators, which follow the tri-state logic of [Table 2-2](#) on page 2-25. `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 2-25.

NULL

This keyword 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

This identifies 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

This is an expression that yields an integer or real value.

numeric_function_call

This is a function call that returns a numeric value or a value implicitly convertible to a numeric value.

numeric_literal

This is a literal that represents a number or a value implicitly convertible to a number.

numeric_variable_name

This identifies a previously declared variable that stores a numeric value.

pattern

This is 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.

relational_operator

This operator lets you compare expressions. For the meaning of each operator, see "[Comparison Operators](#)" on page 2-26.

SQL

This identifies 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.

+, -, /, *, **

These symbols are the addition, subtraction, division, multiplication, and exponentiation operators, respectively.

||

This is 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 "[Datatype Conversion](#)" on page 3-24.

In conditional control statements, if a Boolean expression yields `TRUE`, its associated sequence of statements is executed. But, if the expression yields `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 yield 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-95'          -- date expression
MONTHS_BETWEEN(d1, d2) -- date expression
pi * r**2            -- numeric expression
emp_cv%ROWCOUNT     -- numeric expression
```

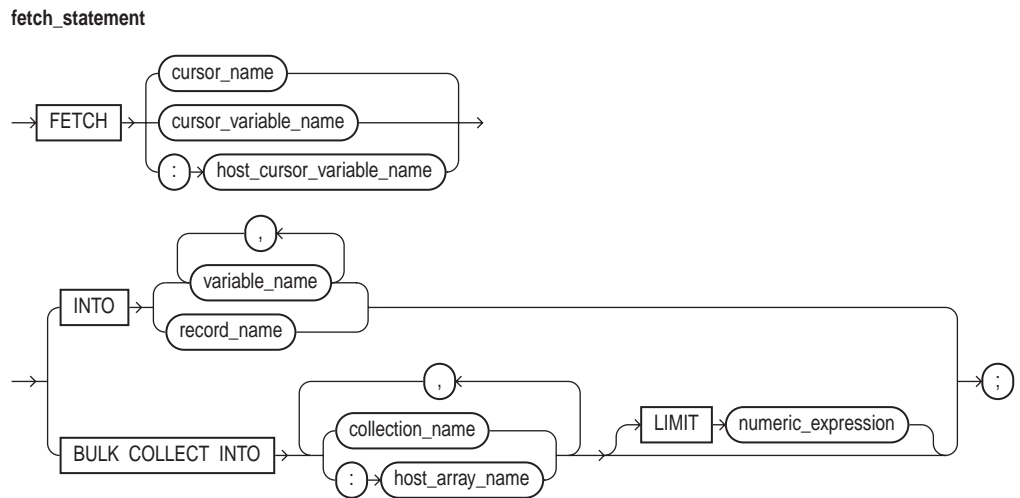
Related Topics

Assignment Statement, Constants and Variables, EXIT Statement, IF Statement, LOOP Statements

FETCH Statement

The `FETCH` statement retrieves rows of data one at a time from the result set of a multi-row query. The data is stored in variables or fields that correspond to the columns selected by the query. For more information, see ["Managing Cursors"](#) on page 6-6.

Syntax



Keyword and Parameter Description

BULK COLLECT

This clause 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

This identifies 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

This identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

This identifies a PL/SQL cursor variable (or parameter) previously declared within the current scope.

host_array_name

This identifies 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

This identifies 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 limit the number of rows fetched from the database.

record_name

This identifies 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

This identifies a previously declared 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 yields `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.

Eventually, the `FETCH` statement must fail to return a row, so when that happens, no exception is raised. To detect the failure, 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.

Examples

The following example shows that any variables in the query associated with a cursor are evaluated only when the cursor is opened:

```
DECLARE
  my_sal NUMBER(7,2);
  n      INTEGER(2) := 2;
  CURSOR emp_cur IS SELECT  n*sal FROM emp;
```

```

BEGIN
  OPEN emp_cur;  -- n equals 2 here
  LOOP
    FETCH emp_cur INTO my_sal;
    EXIT WHEN emp_cur%NOTFOUND;
    -- process the data
    n := n + 1;  -- does not affect next FETCH; sal will be
multiplied by 2
  END LOOP;

```

In the following example, you fetch rows one at a time from the cursor variable emp_cv into the user-defined record emp_rec:

```

DECLARE
  TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
  emp_cv EmpCurTyp;
  emp_rec emp%ROWTYPE;
BEGIN
  LOOP
    FETCH emp_cv INTO emp_rec;
    EXIT WHEN emp_cv%NOTFOUND;
    ...
  END LOOP;
END;

```

The BULK COLLECT clause lets you bulk-bind entire columns of Oracle data. That way, you can fetch all rows from the result set at once. In the following example, you bulk-fetch from a cursor into a collection:

```

DECLARE
  TYPE NameList IS TABLE OF emp.ename%TYPE;
  names NameList;
  CURSOR c1 IS SELECT ename FROM emp WHERE job = 'CLERK';
BEGIN
  OPEN c1;
  FETCH c1 BULK COLLECT INTO names;
  ...
  CLOSE c1;
END;

```

In the example below, you use the `LIMIT` clause. With each iteration of the loop, the `FETCH` statement fetches 100 rows (or less) into index-by table `acct_ids`. The previous values are overwritten.

```
DECLARE
    TYPE NumList IS TABLE OF NUMBER INDEX BY BINARY_INTEGER;
    CURSOR c1 IS SELECT acct_id FROM accounts;
    acct_ids NumList;
    rows NATURAL := 100; -- set limit
BEGIN
    OPEN c1;
    LOOP
        /* The following statement fetches 100 rows (or less). */
        FETCH c1 BULK COLLECT INTO acct_ids LIMIT rows;
        EXIT WHEN c1%NOTFOUND;
        ...
    END LOOP;
    CLOSE c1;
END;
```

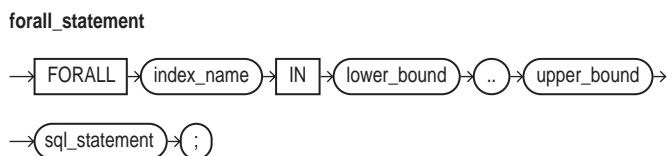
Related Topics

[CLOSE Statement, Cursors, Cursor Variables, LOOP Statements, OPEN Statement, OPEN-FOR Statement](#)

FORALL Statement

The `FORALL` statement instructs the PL/SQL engine to bulk-bind input collections before sending them to the SQL engine. Although the `FORALL` statement contains an iteration scheme, it is *not* a `FOR` loop. For more information, see ["Reducing Loop Overhead for Collections with Bulk Binds"](#) on page 5-32.

Syntax



Keyword and Parameter Description

index_name

This is 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. So, another variable with the same name cannot be referenced inside the statement. Inside a `FORALL` statement, `index_name` cannot appear in expressions and cannot be assigned a value.

lower_bound .. upper_bound

These are expressions that must yield number, which, if necessary, PL/SQL rounds to the nearest integer. The integers must specify a valid range of consecutive index numbers. The SQL engine executes the SQL statement once for each index number in the range. The expressions are evaluated only when the `FORALL` statement is first entered.

SAVE EXCEPTIONS

These optional keywords cause the `FORALL` loop to continue even if some DML operations fail. 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.

sql_statement

This must be an INSERT, UPDATE, or DELETE statement that references collection elements.

Usage Notes

The SQL statement can reference more than one collection. However, the PL/SQL engine bulk-binds only subscripted collections.

All collection elements in the specified range must exist. If an element is missing or was deleted, you get an error.

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 executions are *not* rolled back.

Example

The following example shows that you can use the lower and upper bounds to bulk-bind arbitrary slices of a collection:

```
DECLARE
    TYPE NumList IS VARRAY(15) OF NUMBER;
    depts NumList := NumList();
BEGIN
    -- fill varray here
    ...
    FORALL j IN 6..10 -- bulk-bind middle third of varray
        UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(j);
END;
```

Remember, the PL/SQL engine bulk-binds only subscripted collections. So, in the following example, it does not bulk-bind the collection `sals`, which is passed to the function `median`:

```
FORALL i IN 1..20
    INSERT INTO emp2 VALUES (enums(i), names(i), median(sals), ...);
```

Related Topics

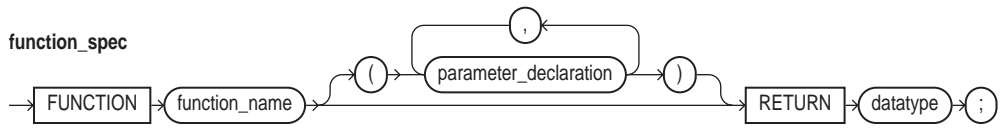
BULK COLLECT Clause

Functions

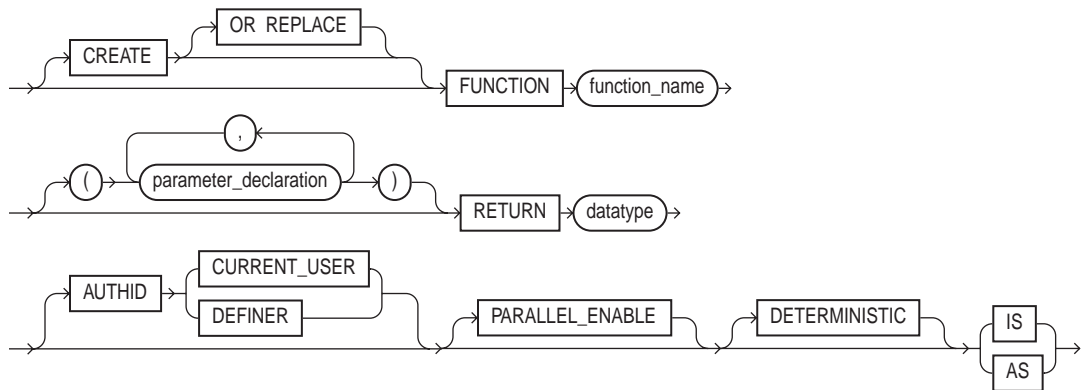
A function is a subprogram that can take parameters and be invoked. Generally, you use a function to compute a value. A function has two parts: the specification and the body. The specification (spec for short) begins with the keyword `FUNCTION` and ends with the `RETURN` clause, which specifies the 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.

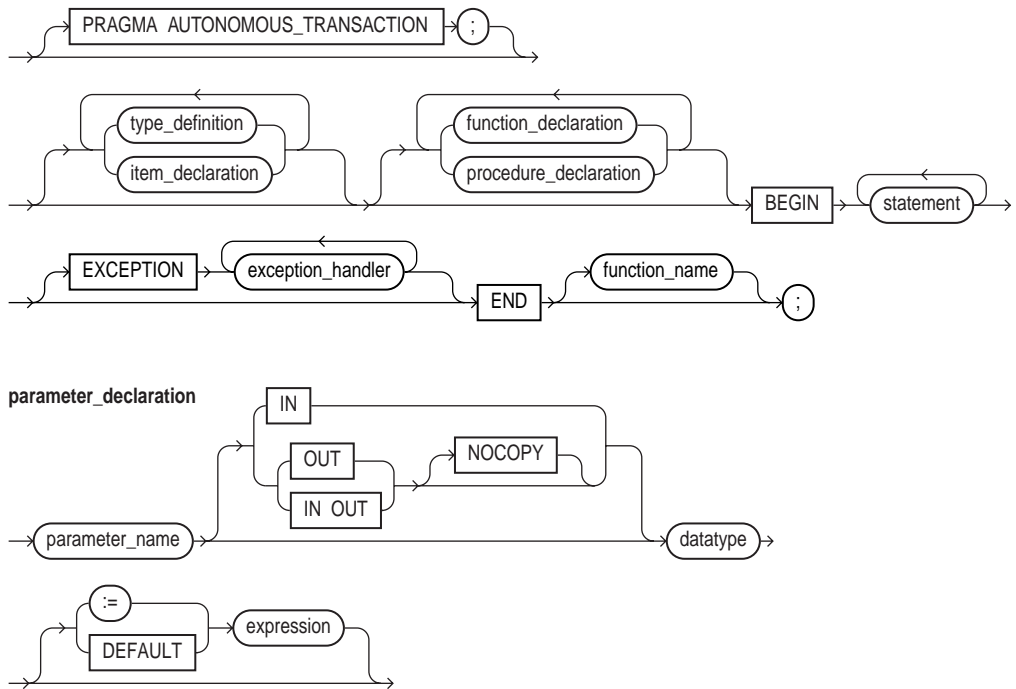
The function body has three parts: an optional declarative part, an executable part, and an optional exception-handling part. The declarative part contains declarations of types, cursors, constants, variables, exceptions, and subprograms. These items are local and cease to exist when you exit the function. The executable part contains statements that assign values, control execution, and manipulate Oracle data. The exception-handling part contains handlers that deal with exceptions raised during execution. For more information, see ["Understanding PL/SQL Functions"](#) on page 8-6.

Syntax



function_declaration | function body





Keyword and Parameter Description

AUTHID

This 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`. For more information, see "[Invoker Rights Versus Definer Rights](#)" on page 8-47.

CREATE

The optional `CREATE` clause lets you create standalone functions, which are stored in the Oracle database. You can execute the `CREATE` statement interactively from `SQL*Plus` or from a program using native dynamic SQL.

datatype

This is a type specifier. For the syntax of `datatype`, see ["Constants and Variables"](#) on page 13-38.

DETERMINISTIC

This hint 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, see the statements `CREATE INDEX` and `CREATE MATERIALIZED VIEW` in *Oracle9i SQL Reference*.

exception_handler

This associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see ["Exceptions"](#) on page 13-63.

expression

This is 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

This identifies a user-defined function.

IN, OUT, IN OUT

These parameter modes define the behavior of formal parameters. An `IN` parameter lets you pass values to the subprogram being called. An `OUT` parameter lets you return values to the caller of the subprogram. An `IN OUT` parameter lets you pass initial values to the subprogram being called and return updated values to the caller.

item_declaration

This declares a program object. For the syntax of `item_declaration`, see ["Blocks"](#) on page 13-11.

NOCOPY

This is a compiler hint (not directive), which allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference instead of by value (the default). For more information, see ["Passing Large Data Structures with the NOCOPY Compiler Hint"](#) on page 8-17.

PARALLEL_ENABLE

This 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.

parameter_name

This identifies a formal parameter, which is a variable declared in a function spec and referenced in the function body.

PRAGMA AUTONOMOUS_TRANSACTION

This pragma instructs the PL/SQL compiler to mark a function as *autonomous* (independent). An autonomous transaction is an independent transaction started by another transaction, 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 6-53.

procedure_declaration

This declares a procedure. For the syntax of `procedure_declaration`, see ["Procedures"](#) on page 13-143.

RETURN

This keyword introduces the `RETURN` clause, which specifies the datatype of the return value.

type_definition

This specifies a user-defined datatype. For the syntax of `type_definition`, see ["Blocks"](#) on page 13-11.

:= | DEFAULT

This operator or keyword lets you initialize IN parameters to default values.

Usage Notes

As the following example shows, 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 meant to control side effects. See ["Controlling Side Effects of PL/SQL Subprograms"](#) on page 8-9.

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. Also, 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. So, you cannot assign it a value. An OUT parameter acts like a local variable. So, you can change its value and reference the value in any way. An IN OUT parameter acts like an initialized variable. So, 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 8-16.

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. Also, functions should be free from side effects, which change the values of variables not local to the subprogram.

Example

The following function returns the balance of a specified bank account:

```
FUNCTION balance (acct_id INTEGER) RETURN REAL IS
    acct_bal REAL;
BEGIN
    SELECT bal INTO acct_bal FROM accts WHERE acctno = acct_id;
    RETURN acct_bal;
```

```
END balance;
```

Related Topics

Collection Methods, Packages, Procedures

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 "[GOTO Statement](#)" on page 4-17.

Syntax

label_declaration

```
→ (<<) → (label_name) → (>>) →
```

goto_statement

```
→ (GOTO) → (label_name) → (;)
```

Keyword and Parameter Description

label_name

This is an undeclared identifier that labels an executable statement or a PL/SQL block. You use a `GOTO` statement to transfer control to the statement or block following `<<label_name>>`.

Usage Notes

Some possible destinations of a `GOTO` statement are illegal. In particular, a `GOTO` statement cannot branch into an `IF` statement, `LOOP` statement, or sub-block. For example, the following `GOTO` statement is illegal:

```
BEGIN
  ...
  GOTO update_row;  -- illegal branch into IF statement
  ...
  IF valid THEN
    ...
    <<update_row>>
    UPDATE emp SET ...
  END IF;
```

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

A `GOTO` label cannot precede just any keyword. It must precede an executable statement or a `PL/SQL` block. For example, the following `GOTO` statement is illegal:

```
FOR ctr IN 1..50 LOOP
    DELETE FROM emp WHERE ...
    IF SQL%FOUND THEN
        GOTO end_loop; -- illegal
    END IF;
    ...
<<end_loop>>
END LOOP; -- not an executable statement
```

To debug the last example, simply add the `NULL` statement, as follows:

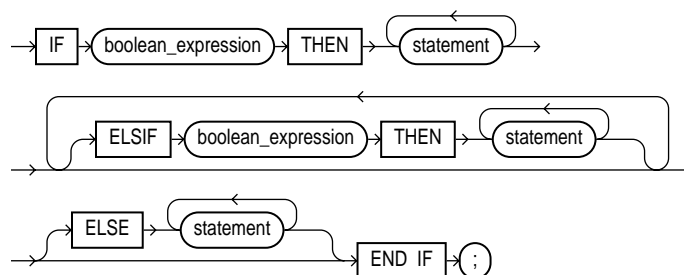
```
FOR ctr IN 1..50 LOOP
    DELETE FROM emp WHERE ...
    IF SQL%FOUND THEN
        GOTO end_loop;
    END IF;
    ...
<<end_loop>>
NULL; -- an executable statement that specifies inaction
END LOOP;
```


IF Statement

The `IF` statement lets you execute a sequence of statements conditionally. Whether the sequence is executed or not depends on the value of a Boolean expression. For more information, see ["Conditional Control: IF and CASE Statements"](#) on page 4-2.

Syntax

`if_statement`



Keyword and Parameter Description

boolean_expression

This is an expression that yields the Boolean value `TRUE`, `FALSE`, or `NULL`. It is associated with a sequence of statements, which is executed only if the expression yields `TRUE`.

ELSE

If control reaches this keyword, the sequence of statements that follows it is executed.

ELSIF

This keyword introduces a Boolean expression to be evaluated if the expression following `IF` and all the expressions following any preceding `ELSIF`s yield `FALSE` or `NULL`.

THEN

This keyword associates the Boolean expression that precedes it with the sequence of statements that follows it. If the expression yields `TRUE`, the associated sequence of statements is 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 yields `TRUE`. If the expression yields `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 yields `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 yields `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 yields `TRUE`, its associated sequence of statements is executed and control passes to the next statement. If all expressions yield `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

In the example below, if `shoe_count` has a value of 10, both the first and second Boolean expressions yield `TRUE`. Nevertheless, `order_quantity` is assigned the proper value of 50 because processing of an `IF` statement stops after an expression yields `TRUE` and its associated sequence of statements is executed. The expression associated with `ELSIF` is never evaluated and control passes to the `INSERT` statement.

```
IF shoe_count < 20 THEN
    order_quantity := 50;
ELSIF shoe_count < 30 THEN
    order_quantity := 20;
ELSE
    order_quantity := 10;
END IF;
```

```
INSERT INTO purchase_order VALUES (shoe_type, order_quantity);
```

In the following example, depending on the value of `score`, one of two status messages is inserted into the `grades` table:

```
IF score < 70 THEN
    fail := fail + 1;
    INSERT INTO grades VALUES (student_id, 'Failed');
ELSE
    pass := pass + 1;
    INSERT INTO grades VALUES (student_id, 'Passed');
END IF;
```

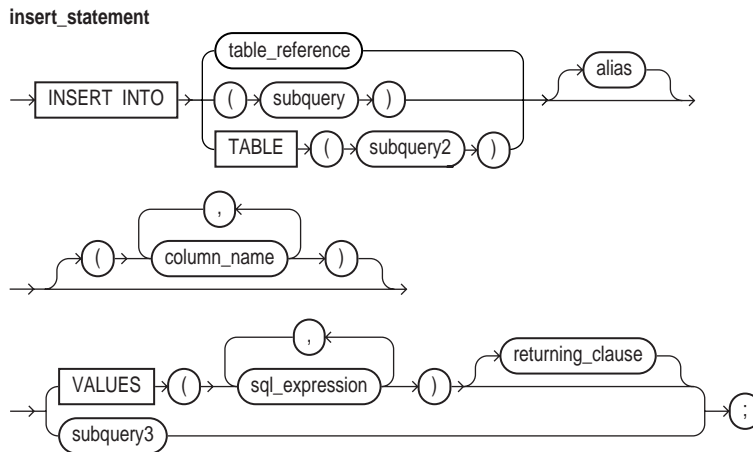
Related Topics

Expressions

INSERT Statement

The `INSERT` statement adds new rows of data to a specified database table. For a full description of the `INSERT` statement, see *Oracle9i SQL Reference*.

Syntax



Keyword and Parameter Description

alias

This is another (usually short) name for the referenced table or view.

column_name[, column_name]...

This identifies a list of columns in a database table or view. Column names need not appear in the order in which they were defined by the `CREATE TABLE` or `CREATE VIEW` statement. However, no column name can appear more than once in the list. If the list does not include all the columns in a table, the missing columns are set to `NULL` or to a default value specified in the `CREATE TABLE` statement.

returning_clause

This clause lets you return values from inserted rows, thereby eliminating the need to `SELECT` the rows afterward. You can retrieve the column values into variables and/or host variables, or into collections and/or host arrays. However, you cannot use the `RETURNING` clause for remote or parallel inserts. For the syntax of `returning_clause`, see "[DELETE Statement](#)" on page 13-57.

sql_expression

This is any expression valid in SQL. For more information, see *Oracle9i SQL Reference*.

subquery

This is 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 13-164.

subquery3

This is a `SELECT` statement that returns a value or set of values. As many rows are added to the table as are returned by the subquery. It 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

This identifies 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 13-57.

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.

VALUES (...)

This clause 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 only one value for each column in the column list. Also, 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

The following examples show various forms of `INSERT` statement:

```
INSERT INTO bonus SELECT ename, job, sal, comm FROM emp
  WHERE comm > sal * 0.25;
...
INSERT INTO emp (empno, ename, job, sal, comm, deptno)
  VALUES (4160, 'STURDEVIN', 'SECURITY GUARD', 2045, NULL, 30);
...
INSERT INTO dept
  VALUES (my_deptno, UPPER(my_dname), 'CHICAGO');
```

Related Topics

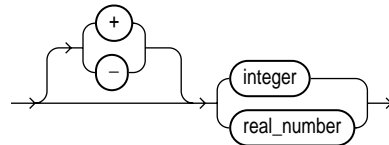
[SELECT Statement](#)

Literals

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 2-7.

Syntax

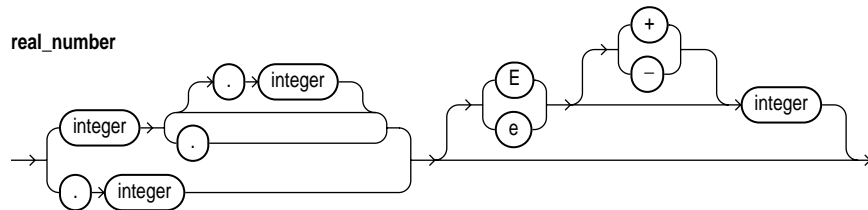
numeric_literal



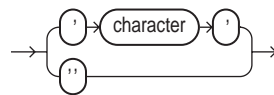
integer



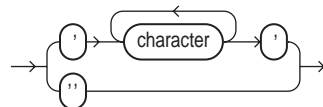
real_number

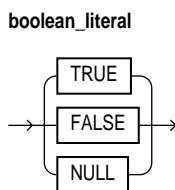


character_literal



string_literal





Keyword and Parameter Description

character

This is a member of the PL/SQL character set. For more information, see "[Character Set](#)" on page 2-2.

digit

This is one of the numerals 0 .. 9.

TRUE, FALSE, NULL

This is a predefined Boolean value.

Usage Notes

Two kinds of numeric literals can be used in arithmetic expressions: integers and reals. Numeric literals must be separated by punctuation. Spaces can be used in addition to the punctuation.

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. So, for example, PL/SQL considers the literals 'Q' and 'q' to be different.

A string literal is a sequence of zero or more characters enclosed by single quotes. The null string (' ') contains zero characters. To represent an apostrophe within a string, write two single quotes. PL/SQL is case sensitive within string literals. So, for example, PL/SQL considers the literals 'white' and 'White' to be different.

Also, trailing blanks are significant within string literals, so 'abc' and 'abc ' are different. Trailing blanks in a literal are never trimmed.

The Boolean values `TRUE` and `FALSE` cannot be inserted into a database column.

Examples

Several examples of numeric literals follow:

```
25  6.34  7E2  25e-03  .1  1.  +17  -4.4
```

Several examples of character literals follow:

```
'H'  '&'  ' '  '9'  ']'  'g'
```

A few examples of string literals follow:

```
'$5,000'  
'02-AUG-87'  
'Don''t leave without saving your work.'
```

Related Topics

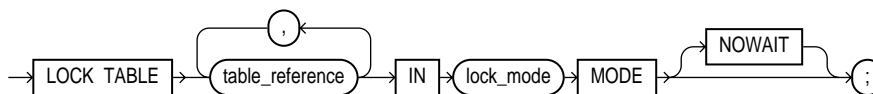
Constants and Variables, Expressions

LOCK TABLE Statement

The `LOCK TABLE` statement lets you lock 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 6-51.

Syntax

`lock_table_statement`



Keyword and Parameter Description

table_reference

This identifies 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 13-57.

lock_mode

This parameter specifies the lock mode. 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`.

Example

The following statement locks the `accts` table in shared mode:

```
LOCK TABLE accts IN SHARE MODE;
```

Related Topics

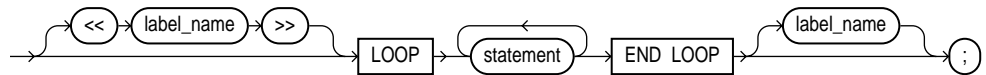
[COMMIT Statement](#), [ROLLBACK Statement](#)

LOOP Statements

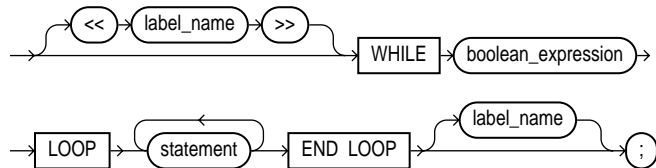
LOOP statements execute a sequence of statements multiple times. The loop encloses the sequence of statements that is to be repeated. PL/SQL provides four kinds of loop statements: basic loop, WHILE loop, FOR loop, and cursor FOR loop. For more information, see "[Iterative Control: LOOP and EXIT Statements](#)" on page 4-9.

Syntax

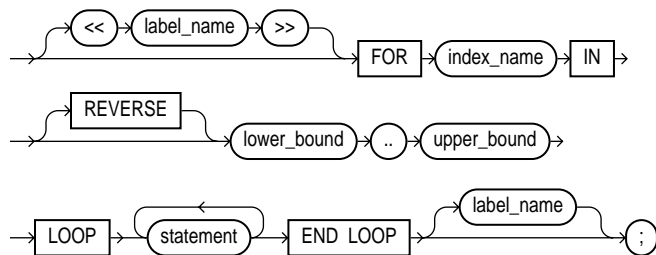
basic_loop_statement

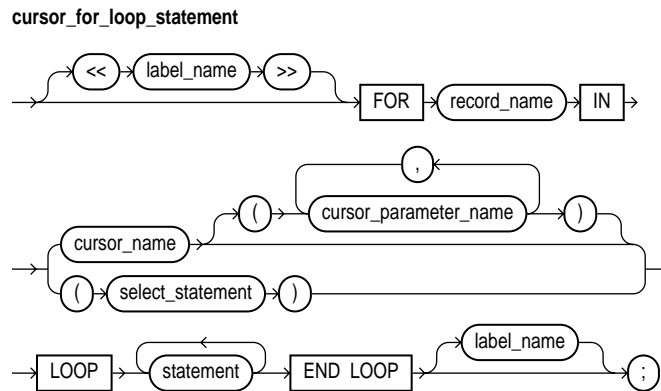


while_loop_statement



for_loop_statement





Keyword and Parameter Description

basic_loop_statement

The simplest form of LOOP statement is the basic (or infinite) loop, which encloses a sequence of statements between the keywords LOOP and END LOOP. With each iteration of the loop, the sequence of statements is executed, then control resumes at the top of the loop. If further processing is undesirable or impossible, you can use the EXIT, GOTO, or RAISE statement to complete the loop. A raised exception will also complete the loop.

boolean_expression

This is an expression that yields the Boolean value TRUE, FALSE, or NULL. It is associated with a sequence of statements, which is executed only if the expression yields TRUE. For the syntax of boolean_expression, see ["Expressions"](#) on page 13-72.

cursor_for_loop_statement

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

This identifies 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

This identifies a cursor parameter; that is, a variable declared as the formal parameter of a cursor. (For the syntax of `cursor_parameter_declaration`, see "Cursors" on page 13-53.) 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

Whereas the number of iterations through a WHILE loop is unknown until the loop completes, the number of iterations through a FOR loop is known before the loop is entered. Numeric FOR 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 sequence of statements in the loop 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

This is an undeclared identifier that names the loop index (sometimes called a loop counter). Its scope is the loop itself. Therefore, you cannot reference the index outside the loop.

The implicit declaration of `index_name` overrides any other declaration outside the loop. So, another variable with the same name cannot be referenced inside the loop unless a label is used, as follows:

```
<<main>>
DECLARE
    num NUMBER;
BEGIN
    ...
    FOR num IN 1..10 LOOP
        IF main.num > 5 THEN -- refers to the variable num,
            ...           -- not to the loop index
        END IF;
    END LOOP;
END main;
```

Inside a loop, its index is treated like a constant. The index can appear in expressions, but cannot be assigned a value.

label_name

This is an undeclared identifier that optionally labels a loop. If used, `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, as follows:

```
label_name.index_name
```

In the following example, you compare two loop indexes that have the same name, one used by an enclosing loop, the other by a nested loop:

```
<<outer>>
FOR ctr IN 1..20 LOOP
  ...
  <<inner>>
  FOR ctr IN 1..10 LOOP
    IF outer.ctr > ctr THEN ...
  END LOOP inner;
END LOOP outer;
```

lower_bound .. upper_bound

These are expressions that must yield 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, as the example below shows. However, the loop counter increment (or decrement) must be 1.

```
FOR i IN -5..10 LOOP
  ...
END LOOP;
```

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 $\pm 2^{31}$. So, if a bound evaluates to a number outside that range, you get a *numeric overflow* error when PL/SQL attempts the assignment.

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

This identifies 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. So, another record with the same name cannot be referenced inside the loop unless a label is used.

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 `sal+NVL(comm,0)`:

```
CURSOR c1 IS SELECT empno, sal+comm wages, job ...
```

REVERSE

By default, iteration proceeds upward from the lower bound to the upper bound. However, if you use the keyword `REVERSE`, iteration proceeds downward from the upper bound to the lower bound.

An example follows:

```
FOR i IN REVERSE 1..10 LOOP -- i starts at 10, ends at 1
    -- statements here execute 10 times
END LOOP;
```


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

This is 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 13-164. 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 yields `TRUE`, the sequence of statements is executed, then control resumes at the top of the loop. If the expression yields `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 yields `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.

Example

The following cursor FOR loop calculates a bonus, then inserts the result into a database table:

```
DECLARE
    bonus REAL;
    CURSOR c1 IS SELECT empno, sal, comm FROM emp;
BEGIN
    FOR clrec IN c1 LOOP
        bonus := (clrec.sal * 0.05) + (clrec.comm * 0.25);
        INSERT INTO bonuses VALUES (clrec.empno, bonus);
    END LOOP;
    COMMIT;
END;
```

Related Topics

Cursors, EXIT Statement, FETCH Statement, OPEN Statement, %ROWTYPE Attribute

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 the syntax and full details of this statement, see the *Oracle9i SQL Reference*.

Usage Notes

This statement is primarily useful in data warehousing situations where large amounts of data are commonly inserted and updated.

Examples

The following example creates a bonuses table in the sample schema `oe` with a default bonus of 100. It then inserts into the bonuses table all employees who made sales (based on the `sales_rep_id` column of the `oe.orders` table). Finally, the Human Resources manager decides that all employees should receive a bonus:

- Those who have not made sales get a bonus of 1% of their salary.
- Those who already made sales get an increase in their bonus equal to 1% of their salary.

The `MERGE` statement implements these changes in one step:

```
CREATE TABLE bonuses (employee_id NUMBER, bonus NUMBER DEFAULT 100);
INSERT INTO bonuses(employee_id)
(SELECT e.employee_id FROM employees e, orders o
WHERE e.employee_id = o.sales_rep_id
GROUP BY e.employee_id);
SELECT * FROM bonuses;
EMPLOYEE_ID BONUS
-----
153 100
154 100
155 100
156 100
158 100
159 100
160 100
161 100
```

```
163 100
MERGE INTO bonuses D
  USING (SELECT employee_id, salary, department_id FROM employees
        WHERE department_id = 80) S
  ON (D.employee_id = S.employee_id)
  WHEN MATCHED THEN UPDATE SET D.bonus = D.bonus + S.salary*.01
  WHEN NOT MATCHED THEN INSERT (D.employee_id, D.bonus)
  VALUES (S.employee_id, S.salary*0.1);
```

```
EMPLOYEE_ID BONUS
-----
153          180
154          175
155          170
156          200
158          190
159          180
160          175
161          170
163          195
157          950
145         1400
170          960
179          620
152          900
169         1000
...
```

NULL Statement

The `NULL` statement explicitly specifies inaction; it does nothing other than pass control to the next statement. In a construct allowing alternative actions, the `NULL` statement serves as a placeholder. For more information, see ["NULL Statement"](#) on page 4-21.

Syntax

`null_statement`

→ NULL → ;

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, but that indeed no action is necessary.

Each clause in an `IF` statement must contain at least one executable statement. The `NULL` statement meets this requirement. So, you can use the `NULL` statement in clauses that correspond to circumstances in which no action is taken. The `NULL` statement and Boolean value `NULL` are unrelated.

Examples

In the following example, the `NULL` statement emphasizes that only salespeople receive commissions:

```
IF job_title = 'SALESPERSON' THEN
    compute_commission(emp_id);
ELSE
    NULL;
END IF;
```

In the next example, the `NULL` statement shows that no action is taken for unnamed exceptions:

```
EXCEPTION
    . . .
    WHEN OTHERS THEN
        NULL;
```

Object Types

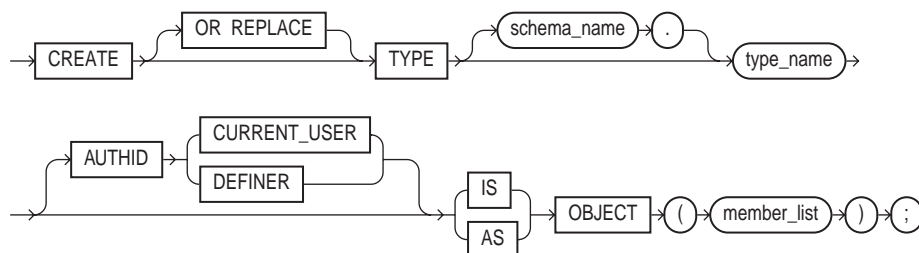
An object type is a user-defined composite datatype that encapsulates a data structure along with the functions and procedures needed to manipulate the data. The variables that form the data structure are called *attributes*. The functions and procedures that characterize the behavior of the object type are called *methods*.

Currently, you cannot define object types within PL/SQL. They must be `CREATED` and stored in an Oracle database, where they can be shared by many programs. When you define an object type (in SQL*Plus for example) using the `CREATE TYPE` statement, you create an abstract template for some real-world object. The template specifies only those attributes and behaviors the object will need in the application environment.

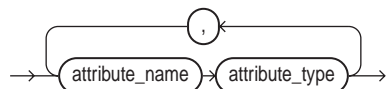
The data structure formed by the set of attributes is public (visible to client programs). However, well-behaved programs do not manipulate it directly. Instead, they use the set of methods provided. That way, the data is kept in a proper state. At run time, when the data structure is filled with values, you have created an *instance* of an object type. You can create as many instances (usually called *objects*) as you need. For more information, see [Chapter 10](#).

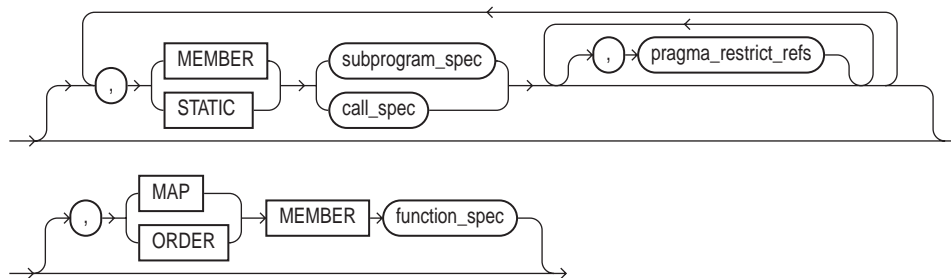
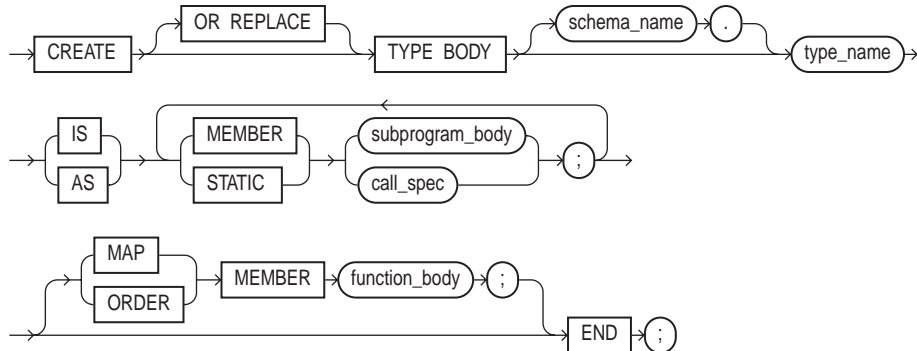
Syntax

`object_type_declaration` | `object_type_spec`



`member_list`



**object_type_body****Keyword and Parameter Description****attribute_datatype**

This is any Oracle datatype except LONG, LONG RAW, NCHAR, NCLOB, NVARCHAR2, ROWID, UROWID, the PL/SQL-specific types BINARY_INTEGER (and its subtypes), BOOLEAN, PLS_INTEGER, RECORD, REF CURSOR, %TYPE, and %ROWTYPE, and types defined inside a PL/SQL package.

attribute_name

This identifies an object attribute. 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.

AUTHID Clause

This determines whether all member methods 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 "[Invoker Rights Versus Definer Rights](#)" on page 8-47.

call_spec

This 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. To learn how to write Java call specs, see *Oracle9i Java Stored Procedures Developer's Guide*. To learn how to write C call specs *Oracle9i Application Developer's Guide - Fundamentals*.

function_body

This defines the underlying implementation of a MEMBER function. For the syntax of `function_body`, see "[Functions](#)" on page 13-90.

MAP

This keyword indicates that a method orders objects by mapping them to values of a scalar datatype such as CHAR or REAL, which have a predefined order. PL/SQL uses the ordering to evaluate Boolean expressions such as $x > y$, and to do comparisons implied by the DISTINCT, GROUP BY, and ORDER BY clauses. A map method returns the relative position of an object in the ordering of all such objects.

An object type can contain only one map method, which must be a parameterless function having the return type DATE, NUMBER, VARCHAR2, or an ANSI SQL type such as CHARACTER, INTEGER, or REAL.

MEMBER | STATIC

This keyword lets you declare a subprogram or call spec as a method in an object type spec. The method cannot have the same name as the object type or any of its attributes. MEMBER methods are invoked on instances, as in

```
instance_expression.method()
```

However, STATIC methods are invoked on the object type, not its instances, as in

```
object_type_name.method()
```


For each subprogram spec in an object type spec, there must be a corresponding subprogram body in the object type body. To match specs and bodies, the compiler does a token-by-token comparison of their headers. So, the headers must match word for word.

MEMBER methods accept a built-in parameter named SELF, which is an instance of the object type. Whether declared implicitly or explicitly, it is always the first parameter passed to a MEMBER method. However, STATIC methods cannot accept or reference SELF.

In the method body, SELF denotes the object whose method was invoked. For example, method `transform` declares SELF as an IN OUT parameter:

```
CREATE TYPE Complex AS OBJECT (  
    MEMBER FUNCTION transform (SELF IN OUT Complex) ...
```

You cannot specify a different datatype for SELF. In MEMBER functions, if SELF is not declared, its parameter mode defaults to IN. However, in MEMBER procedures, if SELF is not declared, its parameter mode defaults to IN OUT. You cannot specify the OUT parameter mode for SELF.

ORDER

This keyword indicates that a method compares two objects. An object type can contain only one order method, which must be a function that returns a numeric result.

Every order method takes just two parameters: the built-in parameter SELF and another object of the same type. If `c1` and `c2` are `Customer` objects, a comparison such as `c1 > c2` calls method `match` automatically. The method returns a negative number, zero, or a positive number signifying that SELF is respectively less than, equal to, or greater than the other parameter. If either parameter passed to an order method is null, the method returns a null.

pragma_restrict_refs

This is pragma `RESTRICT_REFERENCES`, which lets you check for violations of "purity" rules. To be callable from SQL statements, a member function must obey those rules, which are meant to 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 13-154 (in this context, omit the pragma terminator).

The pragma asserts that a member 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 *Oracle9i Application Developer's Guide - Fundamentals*.

schema_name

This qualifier identifies the schema containing the object type. If you omit `schema_name`, Oracle assumes the object type is in your schema.

subprogram_body

This defines the underlying implementation of a `MEMBER` or `STATIC` function or procedure. Its syntax is like that of `function_body` or `procedure_body` without the terminator. See "[Functions](#)" on page 13-90 and/or "[Procedures](#)" on page 13-143.

subprogram_spec

This declares the interface to a `MEMBER` or `STATIC` function or procedure. Its syntax is like that of `function_spec` or `procedure_spec` without the terminator. See "[Functions](#)" on page 13-90 and/or "[Procedures](#)" on page 13-143.

type_name

This identifies a user-defined object type that was defined using the datatype specifier `OBJECT`.

Usage Notes

Once 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.

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. So, 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. So, 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 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. PL/SQL never calls a constructor implicitly, so you must call it explicitly. Constructor calls are allowed wherever function calls are allowed.

Examples

In the SQL*Plus script below, an object type for a stack is defined. The last item added to a stack is the first item removed. The operations *push* and *pop* update the stack while preserving last in, first out (LIFO) behavior. The simplest implementation of a stack uses an integer array. Integers are stored in array elements, with one end of the array representing the top of the stack.

```
CREATE TYPE IntArray AS VARRAY(25) OF INTEGER;

CREATE TYPE Stack AS OBJECT (
    max_size INTEGER,
    top      INTEGER,
    position IntArray,
    MEMBER PROCEDURE initialize,
    MEMBER FUNCTION full RETURN BOOLEAN,
    MEMBER FUNCTION empty RETURN BOOLEAN,
    MEMBER PROCEDURE push (n IN INTEGER),
    MEMBER PROCEDURE pop (n OUT INTEGER)
);

CREATE TYPE BODY Stack AS
    MEMBER PROCEDURE initialize IS
        -- fill stack with nulls
    BEGIN
        top := 0;
        -- call constructor for varray and set element 1 to NULL
        position := IntArray(NULL);
        max_size := position.LIMIT; -- use size constraint (25)
        position.EXTEND(max_size - 1, 1); -- copy element 1
    END initialize;

    MEMBER FUNCTION full RETURN BOOLEAN IS
        -- return TRUE if stack is full
    BEGIN
        RETURN (top = max_size);
    END full;

    MEMBER FUNCTION empty RETURN BOOLEAN IS
        -- return TRUE if stack is empty
    BEGIN
        RETURN (top = 0);
    END empty;
```

```

MEMBER PROCEDURE push (n IN INTEGER) IS
-- push integer onto stack
BEGIN
    IF NOT full THEN
        top := top + 1;
        position(top) := n;
    ELSE -- stack is full
        RAISE_APPLICATION_ERROR(-20101, 'stack overflow');
    END IF;
END push;

MEMBER PROCEDURE pop (n OUT INTEGER) IS
-- pop integer off stack and return its value
BEGIN
    IF NOT empty THEN
        n := position(top);
        top := top - 1;
    ELSE -- stack is empty
        RAISE_APPLICATION_ERROR(-20102, 'stack underflow');
    END IF;
END pop;
END;

```

In methods `push` and `pop`, the built-in procedure `raise_application_error` issues user-defined error messages. That way, you can report errors to the client program and avoid returning unhandled exceptions to the host environment. In an object type, methods can reference attributes and other methods without a qualifier, as the following example shows:

```

CREATE TYPE Stack AS OBJECT (
    top INTEGER,
    MEMBER FUNCTION full RETURN BOOLEAN,
    MEMBER PROCEDURE push (n IN INTEGER),
    ...
);

CREATE TYPE BODY Stack AS
    ...
    MEMBER PROCEDURE push (n IN INTEGER) IS
    BEGIN
        IF NOT full THEN
            top := top + 1;
            ...
        END push;
    END;

```

The following example shows that you can nest object types:

```
CREATE TYPE Address AS OBJECT (  
    street_address VARCHAR2(35),  
    city            VARCHAR2(15),  
    state           CHAR(2),  
    zip_code       INTEGER  
);  
  
CREATE TYPE Person AS OBJECT (  
    first_name     VARCHAR2(15),  
    last_name      VARCHAR2(15),  
    birthday       DATE,  
    home_address   Address, -- nested object type  
    phone_number   VARCHAR2(15),  
    ss_number      INTEGER,  
);
```

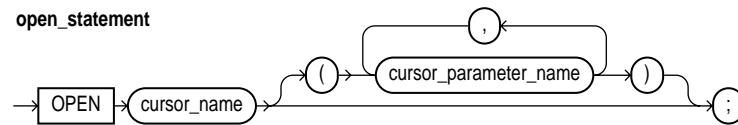
Related Topics

Functions, Packages, Procedures

OPEN Statement

The `OPEN` statement executes the multi-row query associated with an explicit cursor. It also allocates resources used by Oracle to process the query and identifies the result set, which consists of all rows that meet the query search criteria. The cursor is positioned before the first row in the result set. For more information, see ["Managing Cursors"](#) on page 6-6.

Syntax



Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope and not currently open.

cursor_parameter_name

This identifies a cursor parameter; that is, a variable declared as the formal parameter of a cursor. (For the syntax of `cursor_parameter_declaration`, see ["Cursors"](#) on page 13-53.) 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 (thereby creating an implicit cursor) only the first time the statement is executed. All the parsed SQL statements are cached. A SQL statement must be reparsed only if it is aged out of the cache by a new SQL statement.

So, 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. Rather, 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. Therefore, 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 need not have a corresponding actual parameter. They can simply 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

Given the cursor declaration

```
CURSOR parts_cur IS SELECT part_num, part_price FROM parts;
```

the following statement opens the cursor:

```
OPEN parts_cur;
```

Given the cursor declaration

```
CURSOR emp_cur(my_ename VARCHAR2, my_comm NUMBER DEFAULT 0)
  IS SELECT * FROM emp WHERE ...
```

any of the following statements opens the cursor:

```
OPEN emp_cur('LEE');
OPEN emp_cur('BLAKE', 300);
OPEN emp_cur(employee_name, 150);
```

Related Topics

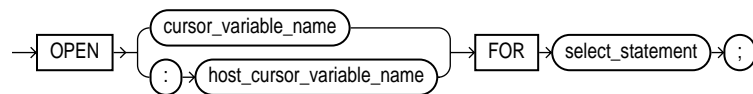
[CLOSE Statement](#), [Cursors](#), [FETCH Statement](#), [LOOP Statements](#)

OPEN-FOR Statement

The `OPEN-FOR` statement executes the multi-row query associated with a cursor variable. It also allocates resources used by Oracle to process the query and identifies the result set, which consists of all rows that meet the query search criteria. The cursor variable is positioned before the first row in the result set. For more information, see ["Using Cursor Variables"](#) on page 6-16.

Syntax

`open_for_statement`



Keyword and Parameter Description

cursor_variable_name

This identifies a cursor variable (or parameter) previously declared within the current scope.

host_cursor_variable_name

This identifies 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

This is 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 13-164, except that `select_statement` cannot have an `INTO` clause.

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 emp;
    OPEN :dept_cv FOR SELECT * FROM dept;
    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 need not 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. No flexibility is lost, however, because you can pass whole queries (not just parameters) to a cursor variable.

You can pass a cursor variable to PL/SQL by calling a stored procedure that declares a cursor variable as one of its formal parameters. However, remote subprograms on another server cannot accept the values of cursor variables. Therefore, you cannot use a remote procedure call (RPC) to open a cursor variable.

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.

Examples

To centralize data retrieval, you can group type-compatible queries in a stored procedure. When called, the following packaged procedure opens the cursor variable emp_cv for the chosen query:

```
CREATE PACKAGE emp_data AS
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp, choice IN INT);
END emp_data;
```

```
CREATE PACKAGE BODY emp_data AS
  PROCEDURE open_emp_cv (emp_cv IN OUT EmpCurTyp, choice IN INT) IS
  BEGIN
    IF choice = 1 THEN
      OPEN emp_cv FOR SELECT * FROM emp WHERE comm IS NOT NULL;
    ELSIF choice = 2 THEN
      OPEN emp_cv FOR SELECT * FROM emp WHERE sal > 2500;
    ELSIF choice = 3 THEN
      OPEN emp_cv FOR SELECT * FROM emp WHERE deptno = 20;
    END IF;
  END;
END emp_data;
```

For more flexibility, you can pass a cursor variable and a selector to a stored procedure that executes queries with different return types. Here is an example:

```
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 emp;
    ELSIF choice = 2 THEN
      OPEN generic_cv FOR SELECT * FROM dept;
    ELSIF choice = 3 THEN
      OPEN generic_cv FOR SELECT * FROM salgrade;
    END IF;
  END;
END admin_data;
```

Related Topics

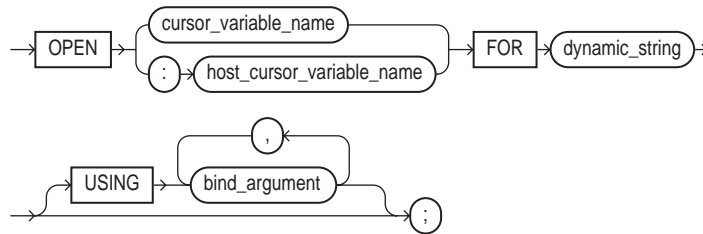
[CLOSE Statement](#), [Cursor Variables](#), [FETCH Statement](#), [LOOP Statements](#)

OPEN-FOR-USING Statement

The `OPEN-FOR-USING` statement associates a cursor variable with a multi-row 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 ["Using the OPEN-FOR, FETCH, and CLOSE Statements"](#) on page 11-8.

Syntax

`open_for_using_statement`



Keyword and Parameter Description

cursor_variable_name

This identifies a weakly typed cursor variable (one without a return type) previously declared within the current scope.

bind_argument

This is an expression whose value is passed to the dynamic `SELECT` statement.

dynamic_string

This is a string literal, variable, or expression that represents a multi-row `SELECT` statement.

host_cursor_variable_name

This identifies 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.

USING ...

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 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"](#) on page 11-17.

Any bind arguments in the query are evaluated only when the cursor variable is opened. So, 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, `LOBs`, 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 Booleans or index-by tables.

Example

In the following example, we declare a cursor variable, then associate it with a dynamic SELECT statement that returns rows from the emp table:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR; -- define weak REF CURSOR type
    emp_cv   EmpCurTyp; -- declare cursor variable
    my_ename VARCHAR2(15);
    my_sal   NUMBER := 1000;
BEGIN
    OPEN emp_cv FOR -- open cursor variable
        'SELECT ename, sal FROM emp WHERE sal > :s' USING my_sal;
    ...
END;
```

Related Topics

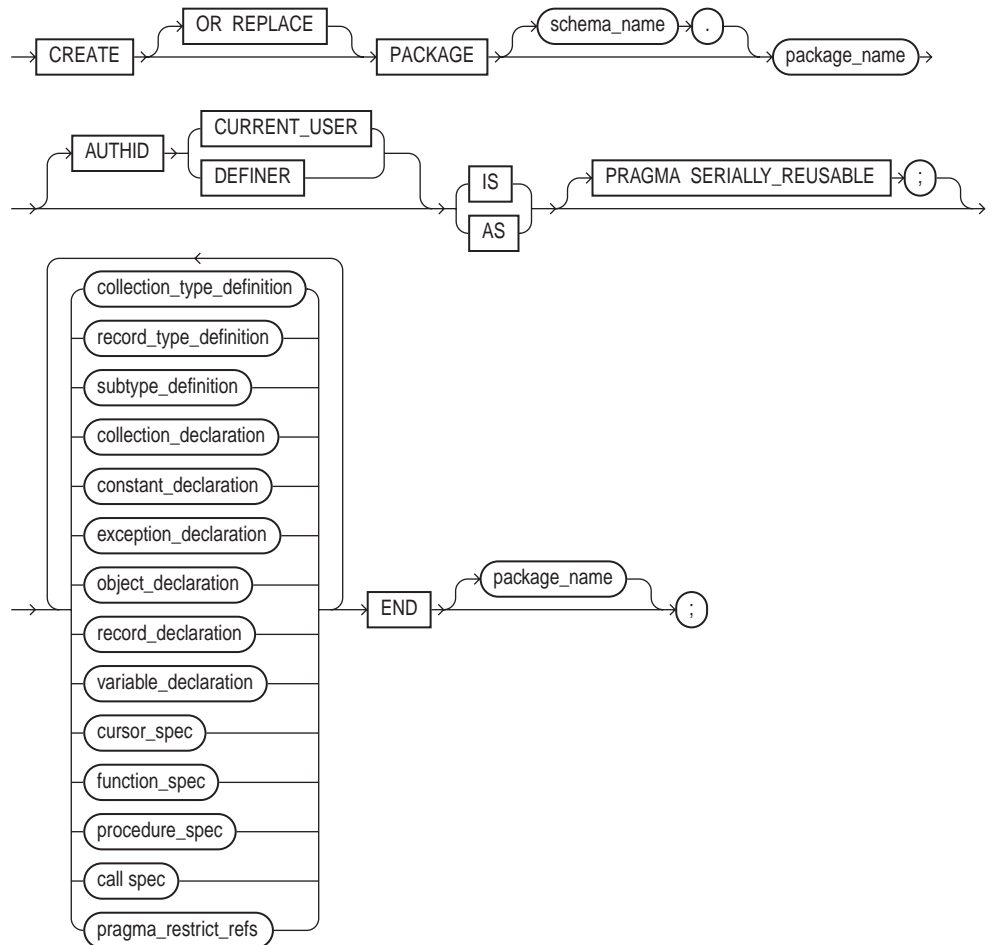
[EXECUTE IMMEDIATE Statement](#)

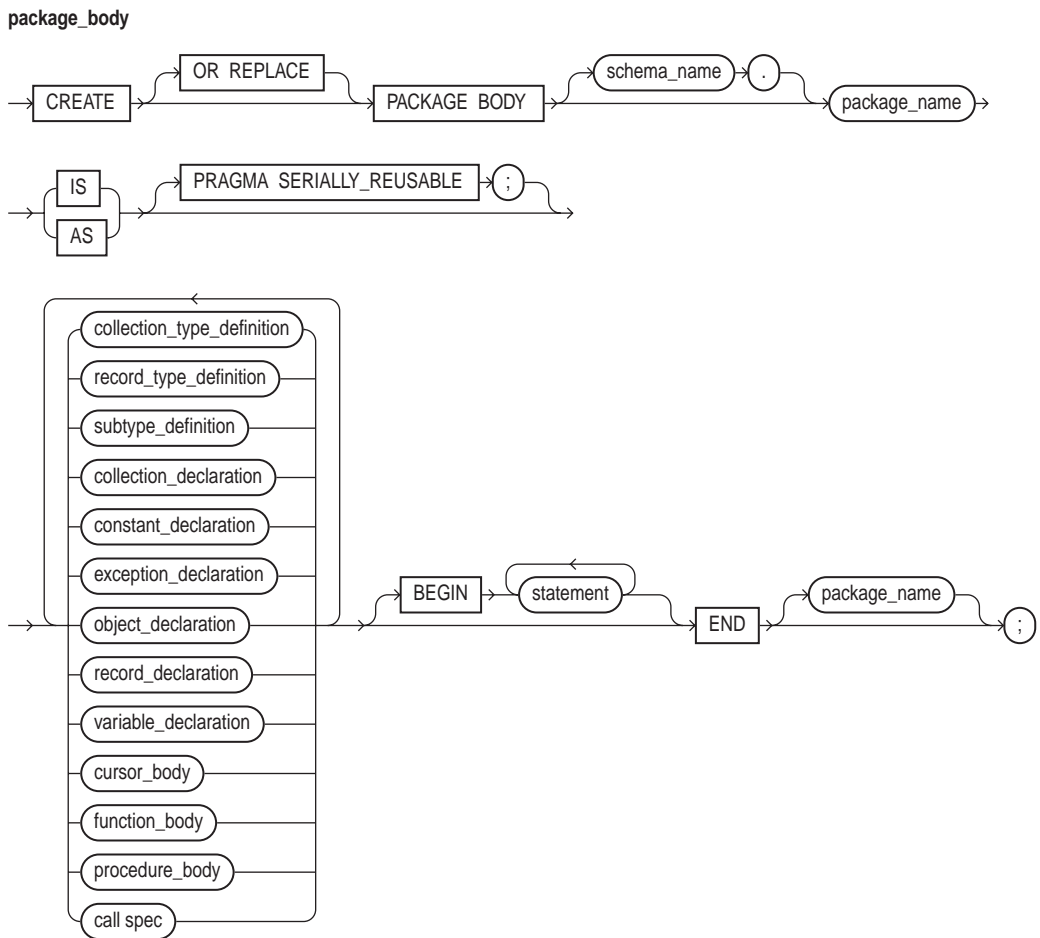
Packages

A package is a schema object that groups logically related PL/SQL types, items, and subprograms. Packages have two parts: a specification (spec for short) and a body. For more information, see [Chapter 9](#).

Syntax

package_declaration | package_spec





Keyword and Parameter Description

AUTHID

This 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 ["Invoker Rights Versus Definer Rights"](#) on page 8-47.

call_spec

This 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 *Oracle9i Java Stored Procedures Developer's Guide* and/or *Oracle9i Application Developer's Guide - Fundamentals*.

collection_declaration

This declares a collection (nested table, index-by table, or varray). For the syntax of `collection_declaration`, see "[Collections](#)" on page 13-28.

collection_type_definition

This defines a collection type using the datatype specifier `TABLE` or `VARRAY`.

constant_declaration

This declares a constant. For the syntax of `constant_declaration`, see "[Constants and Variables](#)" on page 13-38.

cursor_body

This defines the underlying implementation of an explicit cursor. For the syntax of `cursor_body`, see "[Cursors](#)" on page 13-53.

cursor_spec

This declares the interface to an explicit cursor. For the syntax of `cursor_spec`, see "[Cursors](#)" on page 13-53.

exception_declaration

This declares an exception. For the syntax of `exception_declaration`, see "[Exceptions](#)" on page 13-63.

function_body

This defines the underlying implementation of a function. For the syntax of `function_body`, see "[Functions](#)" on page 13-90.

function_spec

This declares the interface to a function. For the syntax of `function_spec`, see "[Functions](#)" on page 13-90.

object_declaration

This declares an object (instance of an object type). For the syntax of `object_declaration`, see ["Object Types"](#) on page 13-120.

package_name

This identifies a package stored in the database. For naming conventions, see ["Identifiers"](#) on page 2-4.

pragma_restrict_refs

This is pragma `RESTRICT_REFERENCES`, which lets you check for violations of "purity" rules. To be callable from SQL statements, a function must obey those rules, which are meant to 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 13-154.

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 *Oracle9i Application Developer's Guide - Fundamentals*.

PRAGMA SERIALLY_REUSABLE

This pragma lets you mark a package as *serially reusable*. You can so mark a package 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 RPC). For more information, see *Oracle9i Application Developer's Guide - Fundamentals*.

procedure_body

This defines the underlying implementation of a procedure. For the syntax of `procedure_body`, see ["Procedures"](#) on page 13-143.

procedure_spec

This declares the interface to a procedure. For the syntax of `procedure_spec`, see ["Procedures"](#) on page 13-143.

record_declaration

This declares a user-defined record. For the syntax of `record_declaration`, see ["Records"](#) on page 13-150.

record_type_definition

This defines a record type using the datatype specifier `RECORD` or the attribute `%ROWTYPE`.

schema_name

This qualifier identifies the schema containing the package. If you omit `schema_name`, Oracle assumes the package is in your schema.

variable_declaration

This declares a variable. For the syntax of `variable_declaration`, see ["Constants and Variables"](#) on page 13-38.

Usage Notes

You cannot define packages in a PL/SQL block or subprogram. However, 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 from an Oracle Precompiler or OCI host program, or interactively from SQL*Plus.

Most packages have a spec and a body. The spec 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 (definition). So, if a 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 spec, as the following example shows:

```
CREATE PACKAGE emp_actions AS
    ...
    number_hired INTEGER;
END emp_actions;

CREATE 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 need not define the package bodies fully until you are ready to complete the application. Furthermore, you can debug, enhance, or replace a package body without changing the interface (package spec) to the package body. So, you need not recompile calling programs.

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. So, except for white space, the headers must match word for word. Otherwise, PL/SQL raises an exception.

Related Topics

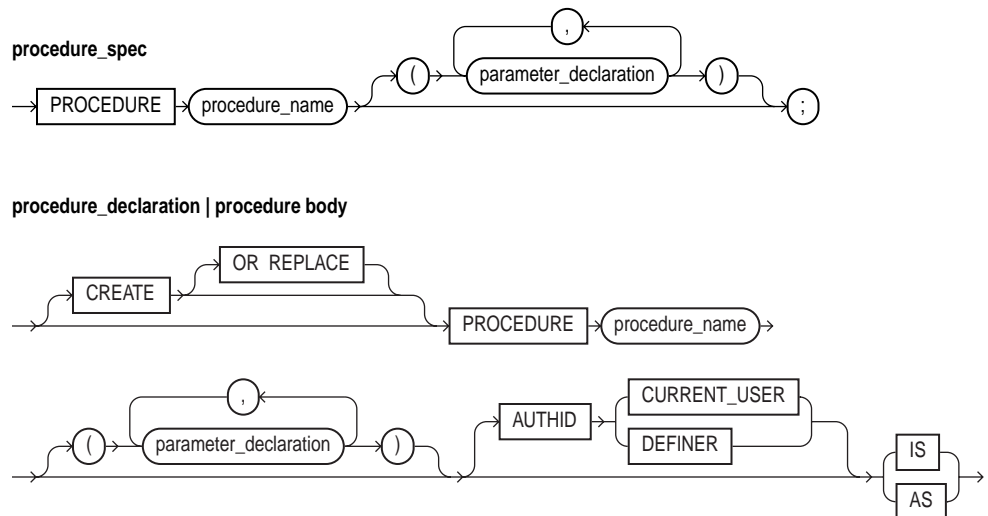
Collections, Cursors, Exceptions, Functions, Procedures, Records

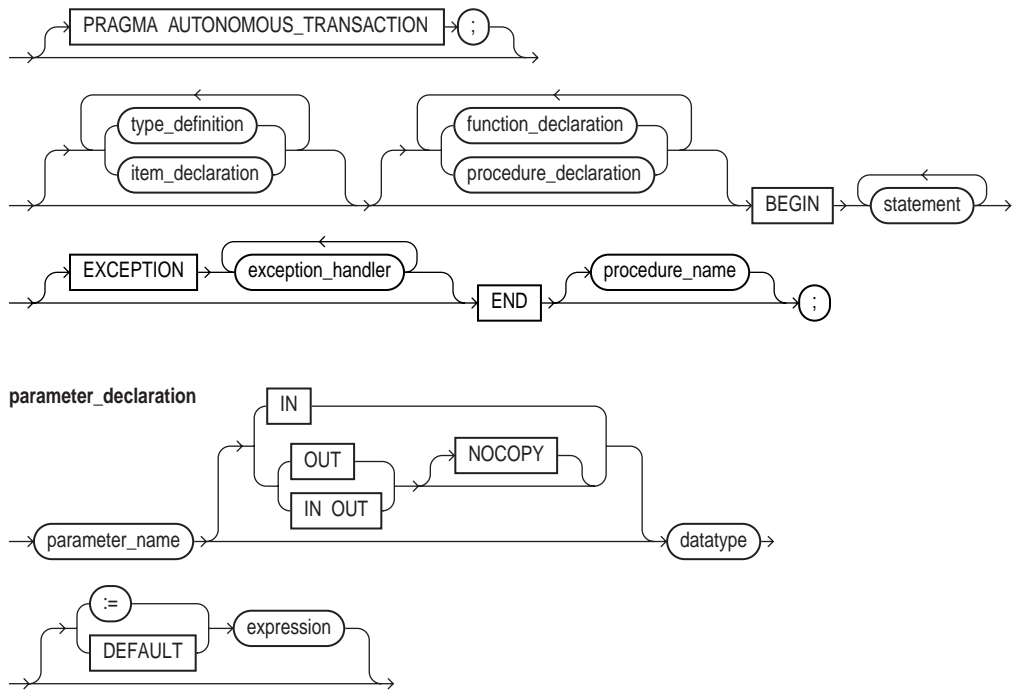
Procedures

A procedure is a subprogram that can take parameters and be invoked. 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.

Syntax





Keyword and Parameter Description

AUTHID

This clause determines whether a stored procedure 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`. For more information, see ["Invoker Rights Versus Definer Rights"](#) on page 8-47.

CREATE

The optional `CREATE` clause lets you create standalone procedures, which are stored in the Oracle database. You can execute the `CREATE` statement interactively from `SQL*Plus` or from a program using native dynamic `SQL`.

datatype

This is a type specifier. For the syntax of `datatype`, see ["Constants and Variables"](#) on page 13-38.

exception_handler

This associates an exception with a sequence of statements, which is executed when that exception is raised. For the syntax of `exception_handler`, see ["Exceptions"](#) on page 13-63.

expression

This is 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_declaration

This declares a function. For the syntax of `function_declaration`, see ["Functions"](#) on page 13-90.

IN, OUT, IN OUT

These parameter modes define the behavior of formal parameters. An `IN` parameter lets you pass values to the subprogram being called. An `OUT` parameter lets you return values to the caller of the subprogram. An `IN OUT` parameter lets you pass initial values to the subprogram being called and return updated values to the caller.

item_declaration

This declares a program object. For the syntax of `item_declaration`, see ["Blocks"](#) on page 13-11.

NOCOPY

This is a compiler hint (not directive), which allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference instead of by value (the default). For more information, see ["Passing Large Data Structures with the NOCOPY Compiler Hint"](#) on page 8-17.

parameter_name

This identifies a formal parameter, which is a variable declared in a procedure spec and referenced in the procedure body.

PRAGMA AUTONOMOUS_TRANSACTION

This pragma instructs the PL/SQL compiler to mark a function as *autonomous* (independent). An autonomous transaction is an independent transaction started by another transaction, 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 6-53.

procedure_name

This identifies a user-defined procedure.

type_definition

This specifies a user-defined datatype. For the syntax of `type_definition`, see ["Blocks"](#) on page 13-11.

:= | DEFAULT

This operator or keyword lets you initialize `IN` parameters to default values.

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. So, you cannot assign it a value. An `OUT` parameter acts like a local variable. So, you can change its value and reference the value in any way. An `IN OUT` parameter acts like an initialized variable. So, 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 8-16.

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 8-19.

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

The following procedure debits a bank account:

```
PROCEDURE debit_account (acct_id INTEGER, amount REAL) IS
  old_balance REAL;
  new_balance REAL;
  overdrawn EXCEPTION;
BEGIN
  SELECT bal INTO old_balance FROM accts WHERE acctno = acct_id;
  new_balance := old_balance - amount;
  IF new_balance < 0 THEN
    RAISE overdrawn;
  ELSE
    UPDATE accts SET bal = new_balance WHERE acctno = acct_id;
  END IF;
EXCEPTION
  WHEN overdrawn THEN
    ...
END debit_account;
```

In the following example, you call the procedure using named notation:

```
debit_account(amount => 500, acct_id => 10261);
```

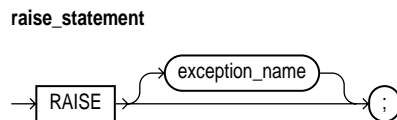
Related Topics

Collection Methods, Functions, Packages

RAISE Statement

The `RAISE` statement stops normal execution of a PL/SQL block or subprogram and transfers control to the appropriate exception handler. Normally, predefined exceptions are raised implicitly by the runtime system. However, `RAISE` statements can also raise predefined exceptions. User-defined exceptions must be raised explicitly by `RAISE` statements. For more information, see ["Defining Your Own PL/SQL Exceptions"](#) on page 7-7.

Syntax



Keyword and Parameter Description

exception_name

This identifies a predefined or user-defined exception. For a list of the predefined exceptions, see ["Predefined PL/SQL Exceptions"](#) on page 7-4.

Usage Notes

PL/SQL blocks and subprograms should `RAISE` an exception only when an error makes it undesirable or impossible 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. That is, the exception reproduces itself in successive enclosing blocks until a handler is found or there are no more blocks to search. In the latter case, PL/SQL returns an *unhandled exception* error to the host environment.

Omitting the exception name in a `RAISE` statement, which is allowed only in an exception handler, reraises the current exception. When a parameterless `RAISE` statement executes in an exception handler, the first block searched is the enclosing block, not the current block.

Example

In the following example, you raise an exception when an inventoried part is out of stock:

```
IF quantity_on_hand = 0 THEN
    RAISE out_of_stock;
END IF;
```

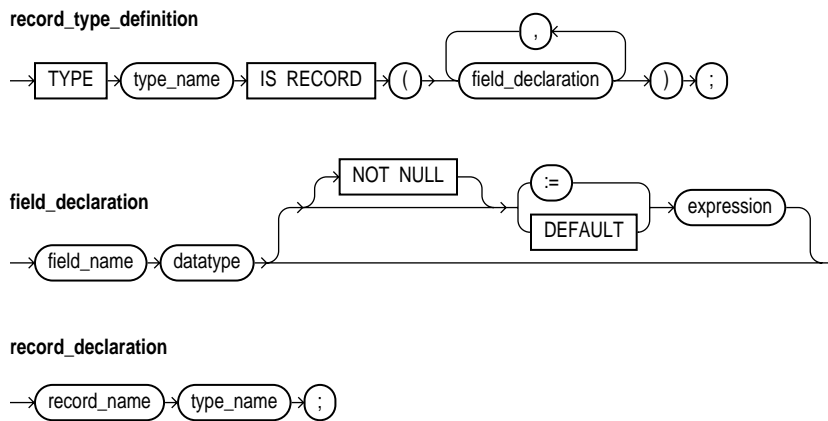
Related Topics

[Exceptions](#)

Records

Records are items of type `RECORD`. Records have uniquely named fields that can store data values of different types. Thus, a record lets you treat related but dissimilar data as a logical unit. For more information, see ["What Is a Record?"](#) on page 5-46.

Syntax



Keyword and Parameter Description

datatype

This is a datatype specifier. For the syntax of `datatype`, see ["Constants and Variables"](#) on page 13-38.

expression

This is an arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression consists of a single variable. For the syntax of `expression`, see ["Expressions"](#) on page 13-72. 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

This identifies a field in a user-defined record.

NOT NULL

This constraint prevents the assigning of nulls to a field. 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

This identifies a user-defined record.

type_name

This identifies a user-defined record type that was defined using the datatype specifier `RECORD`.

:= | DEFAULT

This operator or keyword lets you initialize 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. Also, a record can be initialized in its declaration, as the following example shows:

```
DECLARE
    TYPE TimeTyp IS RECORD(
        seconds SMALLINT := 0,
        minutes SMALLINT := 0,
        hours    SMALLINT := 0);
```

The next example shows that you can use the `%TYPE` attribute to specify the datatype of a field. It also shows that you can add the `NOT NULL` constraint to any field declaration and thereby prevent the assigning of nulls to that field. Fields declared as `NOT NULL` must be initialized.

```
DECLARE
    TYPE DeptRecTyp IS RECORD(
        deptno NUMBER(2) NOT NULL := 99,
        dname  dept.dname%TYPE,
        loc    dept.loc%TYPE);
    dept_rec DeptRecTyp;
```

To reference individual fields in a record, you use dot notation. For example, you might assign a value to the field `dname` in the record `dept_rec` as follows:

```
dept_rec.dname := 'PURCHASING';
```

Instead of assigning values separately to each field in a record, you can assign values to all fields at once. This can be done in two ways. First, 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.

Second, 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.

You can declare and reference nested records. That is, a record can be the component of another record, as the following example shows:

```
DECLARE
    TYPE TimeTyp IS RECORD(
        minutes SMALLINT,
        hours    SMALLINT);
    TYPE MeetingTyp IS RECORD(
        day      DATE,
        time_of TimeTyp,  -- nested record
        place   VARCHAR2(20),
        purpose VARCHAR2(50));
    TYPE PartyTyp IS RECORD(
        day      DATE,
        time_of TimeTyp,  -- nested record
        place   VARCHAR2(15));
    meeting MeetingTyp;
    seminar MeetingTyp;
    party   PartyTyp;
```

The next example shows that you can assign one nested record to another if they have the same datatype:

```
seminar.time_of := meeting.time_of;
```

Such assignments are allowed even if the containing records have different datatypes.

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
```

Example

In the following example, you define a `RECORD` type named `DeptRecTyp`, declare a record named `dept_rec`, then select a row of values into the record:

```
DECLARE
    TYPE DeptRecTyp IS RECORD(
        deptno NUMBER(2),
        dname  VARCHAR2(14),
        loc    VARCHAR2(13));
    dept_rec DeptRecTyp;
    ...
BEGIN
    SELECT deptno, dname, loc INTO dept_rec FROM dept
        WHERE deptno = 20;
```

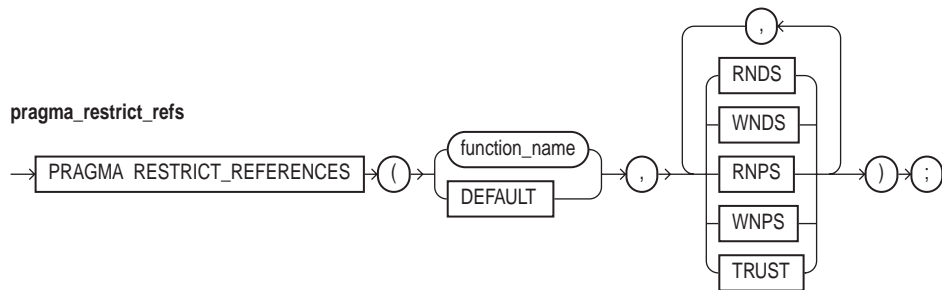
Related Topics

Collections, Functions, Procedures, Packages

RESTRICT_REFERENCES Pragma

To be callable from SQL statements, a stored function must obey certain "purity" rules, which are meant to control side effects. (See "[Controlling Side Effects of PL/SQL Subprograms](#)" on page 8-9.) 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 and/or write database tables and/or package variables. For more information, see *Oracle9i Application Developer's Guide - Fundamentals*.

Syntax



Keyword and Parameter Description

DEFAULT

This specifies that the pragma applies to all functions in the package spec or object type spec. You can still declare the pragma for individual functions. Such pragmas override the default pragma.

function_name

This identifies a user-defined function.

PRAGMA

This keyword 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.

RNDS

This asserts that the function reads no database state (does not query database tables).

RNPS

This asserts that the function reads no package state (does not reference the values of packaged variables)

TRUST

This asserts that the function can be trusted not to violate one or more rules.

WNDS

This asserts that the function writes no database state (does not modify database tables).

WNPS

This asserts that the function 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 the function from parallel queries, you must specify all four constraints. No constraint implies another. For example, `WNPS` does not imply `RNPS`.

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.

If you specify `DEFAULT` instead of a function name, the pragma applies to all functions in the package spec or object type spec (including, in the latter case, the system-defined constructor). You can still declare the pragma for individual functions. Such pragmas override the default pragma.

A `RESTRICT_REFERENCES` pragma can apply to only one function declaration. So, a pragma that references the name of overloaded functions always applies to the nearest foregoing function declaration.

Examples

The following pragma asserts that packaged function `balance` writes no database state (WNDS) and reads no package state (RNPS):

```
CREATE PACKAGE loans AS
    ...
    FUNCTION balance RETURN NUMBER;
    PRAGMA RESTRICT_REFERENCES (balance, WNDS, RNPS);
END loans;
```

A pragma that references the name of overloaded functions always applies to the nearest foregoing function declaration. So, in the following example, the pragma applies to the second declaration of `credit_ok`:

```
CREATE PACKAGE loans AS
    FUNCTION credit_ok (amount_limit NUMBER) RETURN BOOLEAN;
    FUNCTION credit_ok (time_limit DATE) RETURN BOOLEAN;
    PRAGMA RESTRICT_REFERENCES (credit_ok, WNDS);
    ...
END loans;
```

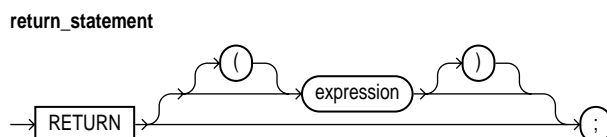
Related Topics

[AUTONOMOUS_TRANSACTION Pragma](#), [EXCEPTION_INIT Pragma](#),
[SERIALLY_REUSABLE Pragma](#)

RETURN Statement

The `RETURN` statement immediately completes the execution of a subprogram and returns control to the caller. Execution then resumes with the statement following the subprogram call. In a function, the `RETURN` statement also sets the function identifier to the return value. For more information, see ["Using the RETURN Statement"](#) on page 8-8.

Syntax



Keyword and Parameter Description

expression

This is an arbitrarily complex 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

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, none of which need be the last lexical statement. Executing any of them completes the subprogram immediately. However, to have multiple exit points in a subprogram is a poor programming practice.

In procedures, a `RETURN` statement cannot contain an expression. The statement simply returns control to the caller before the normal end of the procedure is reached.

However, 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. Therefore, 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.

The `RETURN` statement can also be used in an anonymous block to exit the block (and all enclosing blocks) immediately, but the `RETURN` statement cannot contain an expression.

Example

In the following example, the function `balance` returns the balance of a specified bank account:

```
FUNCTION balance (acct_id INTEGER) RETURN REAL IS
    acct_bal REAL;
BEGIN
    SELECT bal INTO acct_bal FROM accts WHERE acctno = acct_id;
    RETURN acct_bal;
END balance;
```

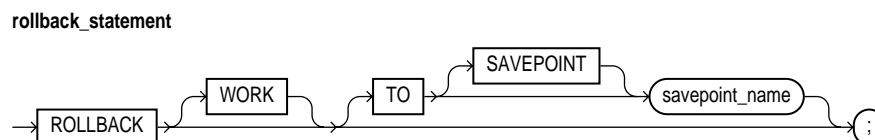
Related Topics

Functions, Procedures

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 6-43.

Syntax



Keyword and Parameter Description

ROLLBACK

When a parameterless `ROLLBACK` statement is executed, all database changes made during the current transaction are undone.

ROLLBACK TO

This statement undoes all database changes (and releases all locks acquired) since the savepoint identified by `savepoint_name` was marked.

SAVEPOINT

This keyword is optional and has no effect except to improve readability.

savepoint_name

This is an undeclared identifier, which marks the current point in the processing of a transaction. For naming conventions, see ["Identifiers"](#) on page 2-4.

WORK

This keyword is optional and has no effect except to improve readability.

Usage Notes

All savepoints marked after the savepoint to which you roll back are erased. However, 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 the implicit savepoint is done. Normally, just the failed SQL statement is rolled back, not the whole transaction. However, if the statement raises an unhandled exception, the host environment determines what is rolled back.

In SQL, the `FORCE` clause manually rolls back an in-doubt distributed transaction. However, PL/SQL does not support this clause. For example, the following statement is illegal:

```
ROLLBACK WORK FORCE '24.37.85'; -- illegal
```

In embedded SQL, the `RELEASE` option frees all Oracle resources (locks and cursors) held by a program and disconnects from the database. However, PL/SQL does not support this option. For example, the following statement is illegal:

```
ROLLBACK WORK RELEASE; -- illegal
```

Related Topics

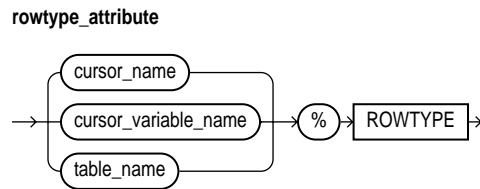
[COMMIT Statement](#), [SAVEPOINT Statement](#)

%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. Fields in a record and corresponding columns in a row have the same names and datatypes.

You can use the %ROWTYPE attribute in variable declarations as a datatype specifier. Variables declared using %ROWTYPE are treated like those declared using a datatype name. For more information, see ["Using %ROWTYPE"](#) on page 2-14.

Syntax



Keyword and Parameter Description

cursor_name

This identifies an explicit cursor previously declared within the current scope.

cursor_variable_name

This identifies a PL/SQL strongly (not weakly) typed cursor variable previously declared within the current scope.

table_name

This identifies a database table (or view) that must be accessible when the declaration is elaborated.

Usage Notes

The %ROWTYPE attribute lets you declare records structured like a row of data in a database table. To reference a field in the record, you use dot notation. For example, you might reference the deptno field as follows:

```
IF emp_rec.deptno = 20 THEN ...
```

You can assign the value of an expression to a specific field, as follows:

```
emp_rec.sal := average * 1.15;
```

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. Second, 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

In the example below, you use %ROWTYPE to declare two records. The first record stores a row selected from the emp table. The second record stores a row fetched from the c1 cursor.

```
DECLARE
    emp_rec    emp%ROWTYPE;
    CURSOR c1 IS SELECT deptno, dname, loc FROM dept;
    dept_rec   c1%ROWTYPE;
```

In the next example, you select a row from the emp table into a %ROWTYPE record:

```
DECLARE
    emp_rec    emp%ROWTYPE;
    ...
BEGIN
    SELECT * INTO emp_rec FROM emp WHERE empno = my_empno;
    IF (emp_rec.deptno = 20) AND (emp_rec.sal > 2000) THEN
        ...
    END IF;
END;
```

Related Topics

Constants and Variables, Cursors, Cursor Variables, FETCH Statement

SAVEPOINT Statement

The `SAVEPOINT` statement names and marks the current point in the processing of a transaction. With the `ROLLBACK TO` statement, savepoints let you undo parts of a transaction instead of the whole transaction. For more information, see "[Overview of Transaction Processing in PL/SQL](#)" on page 6-43.

Syntax

savepoint_statement

```
→ SAVEPOINT → savepoint_name → ;
```

Keyword and Parameter Description

savepoint_name

This is an undeclared identifier, which marks the current point in the processing of a transaction.

Usage Notes

When you roll back to a savepoint, any savepoints marked after that savepoint are erased. However, the savepoint to which you roll back is not erased. A simple rollback or commit erases all savepoints. Savepoint names can be reused within a transaction. This moves the savepoint 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. However, 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. However, if the statement raises an unhandled exception, the host environment determines what is rolled back.

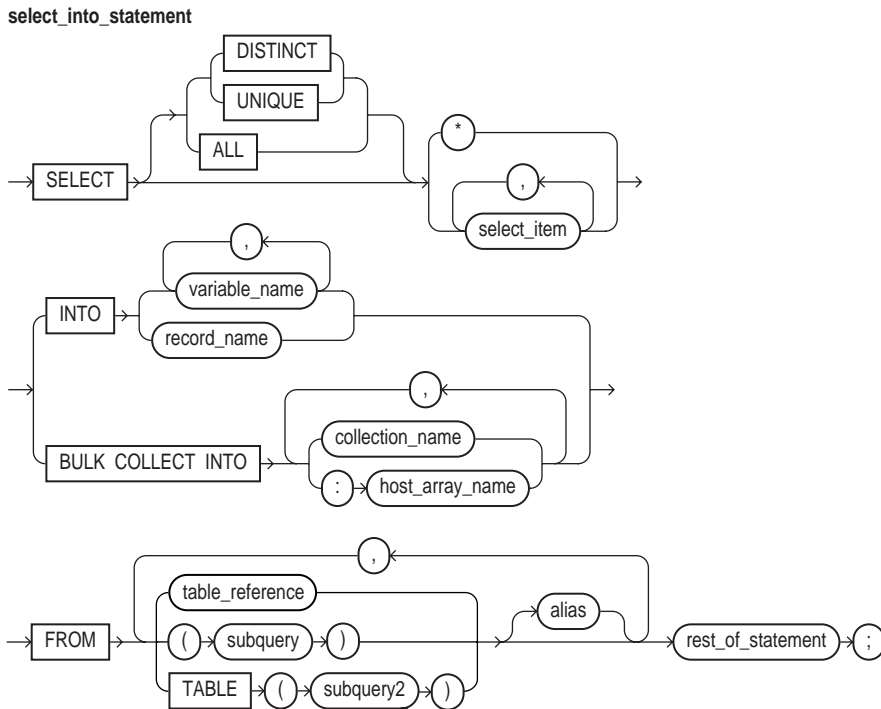
Related Topics

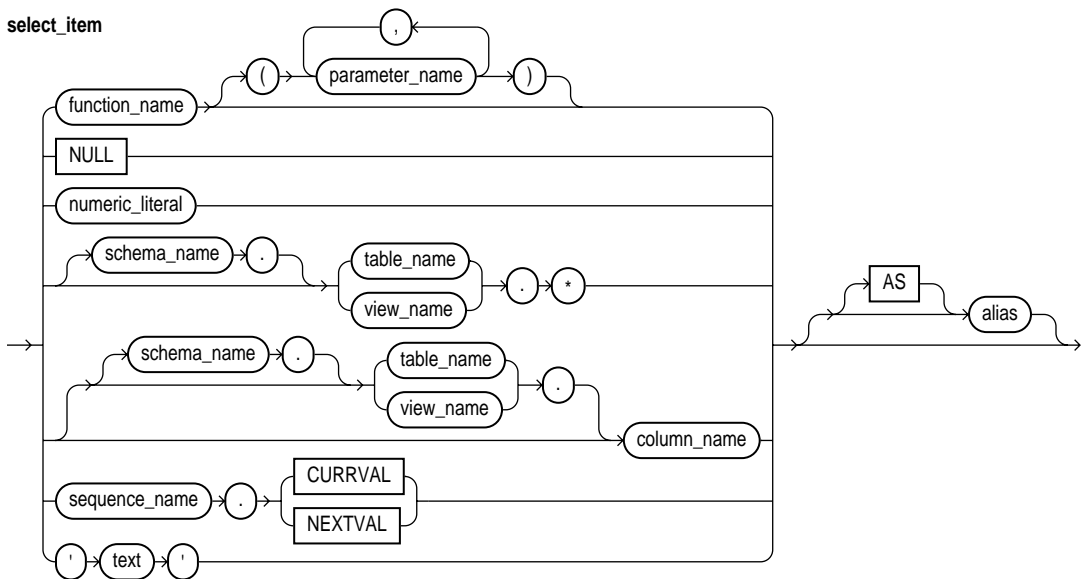
`COMMIT` Statement, `ROLLBACK` Statement

SELECT INTO Statement

The `SELECT INTO` statement retrieves data from one or more database tables, then assigns the selected values to variables or fields. For a full description of the `SELECT` statement, see *Oracle9i SQL Reference*.

Syntax





Keyword and Parameter Description

alias

This is another (usually short) name for the referenced column, table, or view.

BULK COLLECT

This clause 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. For more information, see ["Reducing Loop Overhead for Collections with Bulk Binds"](#) on page 5-32.

collection_name

This identifies a declared collection into which `select_item` values are bulk fetched. For each `select_item`, there must be a corresponding, type-compatible collection in the list.

function_name

This identifies a user-defined function.

host_array_name

This identifies an array (declared in a PL/SQL host environment and passed to PL/SQL as a bind variable) into which `select_item` values are bulk 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

This is a literal that represents a number or a value implicitly convertible to a number.

parameter_name

This identifies a formal parameter of a user-defined function.

record_name

This identifies 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

This is anything that can legally follow the `FROM` clause in a `SELECT` statement except the `SAMPLE` clause.

schema_name

This qualifier identifies the schema containing the table or view. If you omit `schema_name`, Oracle assumes the table or view is in your schema.

subquery

This is 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 13-164.

table_reference

This identifies 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 13-57.

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

This identifies 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

The **BULK COLLECT** clause tells the SQL engine to bulk-bind output collections before returning them. It bulk-binds all collections referenced in the **INTO** list. The corresponding columns can store scalar or composite values including objects.

When you use a **SELECT INTO** statement without the **BULK COLLECT** clause, it should return only one row. If it returns more than one row, PL/SQL raises the predefined exception **TOO_MANY_ROWS**.

However, if no rows are returned, PL/SQL raises **NO_DATA_FOUND** unless the **SELECT** statement called a SQL aggregate function such as **AVG** or **SUM**. (SQL aggregate functions always return a value or a null. So, a **SELECT INTO** statement that calls an aggregate function never raises **NO_DATA_FOUND**.)

The implicit cursor **SQL** and the cursor attributes **%NOTFOUND**, **%FOUND**, **%ROWCOUNT**, and **%ISOPEN** let you access useful information about the execution of a **SELECT INTO** statement.

Examples

The following `SELECT` statement returns an employee's name, job title, and salary from the `emp` database table:

```
SELECT ename, job, sal INTO my_ename, my_job, my_sal FROM emp
WHERE empno = my_empno;
```

In the following example, the SQL engine loads the entire `empno` and `ename` database columns into nested tables before returning the tables to the PL/SQL:

```
DECLARE
    TYPE NumTab IS TABLE OF emp.empno%TYPE;
    TYPE NameTab IS TABLE OF emp.ename%TYPE;
    enums NumTab; -- no need to initialize
    names NameTab;
BEGIN
    SELECT empno, ename BULK COLLECT INTO enums, names FROM emp;
    ...
END;
```

Related Topics

Assignment Statement, `FETCH` Statement, `%ROWTYPE` Attribute

SERIALLY_REUSABLE Pragma

The pragma `SERIALLY_REUSABLE` lets you mark a package as *serially reusable*. You can so mark a package 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 RPC). For more information, see *Oracle9i Application Developer's Guide - Fundamentals*.

Syntax

`serially_reusable pragma`

→ PRAGMA SERIALLY_REUSABLE → ;

Keyword and Parameter Description

PRAGMA

This keyword 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

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. If you try, Oracle generates an error.

Examples

In the following example, you create 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;
```

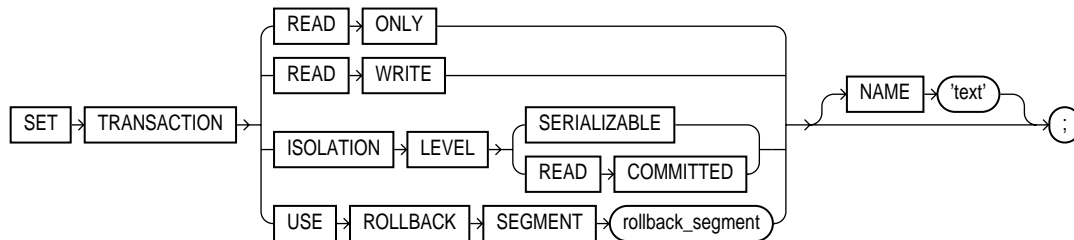
Related Topics

[AUTONOMOUS_TRANSACTION Pragma](#), [EXCEPTION_INIT Pragma](#),
[RESTRICT_REFERENCES Pragma](#)

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 6-48.

Syntax



Keyword and Parameter Description

READ ONLY

This clause establishes the current transaction as read-only. If a transaction is set 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.

READ WRITE

This clause 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

This clause specifies how transactions that modify the database are handled. When you specify `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.

When you specify `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

This clause 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

Lets you specify a name or some 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 your transaction and can appear only once in the transaction.

Example

In the following example, you establish a read-only transaction:

```
COMMIT; -- end previous transaction
SET TRANSACTION READ ONLY;
SELECT ... FROM emp WHERE ...
SELECT ... FROM dept WHERE ...
SELECT ... FROM emp WHERE ...
COMMIT; -- end read-only transaction
```

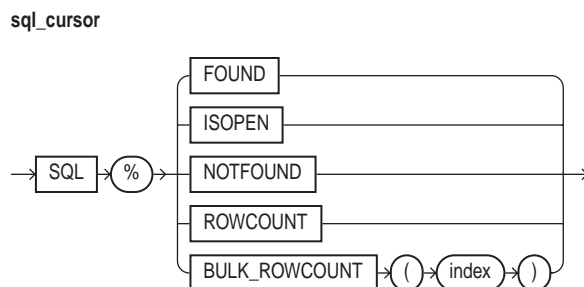
Related Topics

[COMMIT Statement](#), [ROLLBACK Statement](#), [SAVEPOINT Statement](#)

SQL Cursor

Oracle implicitly opens a cursor to process each SQL statement not associated with an explicit cursor. PL/SQL lets you refer to the most recent implicit cursor as the SQL cursor, which always has these attributes: `%FOUND`, `%ISOPEN`, `%NOTFOUND`, and `%ROWCOUNT`. They give you useful 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 ["Managing Cursors"](#) on page 6-6.

Syntax



Keyword and Parameter Description

%BULK_ROWCOUNT

This is a composite attribute designed for use with the `FORALL` statement. This attribute has the semantics of 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

%FOUND

This attribute 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, it yields `FALSE`.

%ISOPEN

This attribute always yields `FALSE` because Oracle closes the `SQL` cursor automatically after executing its associated `SQL` statement.

%NOTFOUND

This attribute is the logical opposite of `%FOUND`. It yields `TRUE` if an `INSERT`, `UPDATE`, or `DELETE` statement affected no rows, or a `SELECT INTO` statement returned no rows. Otherwise, it yields `FALSE`.

%ROWCOUNT

This attribute yields the number of rows affected by an `INSERT`, `UPDATE`, or `DELETE` statement, or returned by a `SELECT INTO` statement.

SQL

This is 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 yield `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. So, if you want to save an attribute value for later use, assign it to a Boolean 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. However, 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` yields `FALSE`.

`%BULK_ROWCOUNT` is *not* maintained for bulk inserts because that would be redundant. For example, the `FORALL` statement below inserts one row per iteration. So, after each iteration, `%BULK_ROWCOUNT` would return 1:

```
FORALL i IN 1..15
    INSERT INTO emp (sal) VALUES (sals(i));
```

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.

`%FOUND` and `%NOTFOUND` refer only to the last execution of the SQL statement. However, 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

In the following example, `%NOTFOUND` is used to insert a row if an update affects no rows:

```
UPDATE emp SET sal = sal * 1.05 WHERE empno = my_empno;
IF SQL%NOTFOUND THEN
    INSERT INTO emp VALUES (my_empno, my_ename, ...);
END IF;
```

In the next example, you use `%ROWCOUNT` to raise an exception if more than 100 rows are deleted:

```
DELETE FROM parts WHERE status = 'OBSOLETE';
IF SQL%ROWCOUNT > 100 THEN -- more than 100 rows were deleted
    RAISE large_deletion;
END IF;
```

Here is an example that uses `%BULK_ROWCOUNT`:

```
DECLARE
    TYPE NumList IS TABLE OF NUMBER;
    depts NumList := NumList(10, 20, 50);
BEGIN
    FORALL j IN depts.FIRST..depts.LAST
        UPDATE emp SET sal = sal * 1.10 WHERE deptno = depts(j);
    IF SQL%BULK_ROWCOUNT(3) = 0 THEN
        ...
    END;
END;
```

Related Topics

Cursors, Cursor Attributes

SQLCODE Function

The function `SQLCODE` returns the number code associated with the most recently raised exception. `SQLCODE` is meaningful only in an exception handler. Outside a handler, `SQLCODE` always returns 0.

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 unless you used the pragma `EXCEPTION_INIT` to associate the exception with an Oracle error number, in which case `SQLCODE` returns that error number. For more information, see ["Retrieving the Error Code and Error Message: SQLCODE and SQLERRM"](#) on page 7-18.

Syntax

`sqlcode_function`

→ `SQLCODE` →

Usage Notes

`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. First, you must assign the value of `SQLCODE` to a local variable, as follows:

```
my_sqlcode := SQLCODE;  
...  
INSERT INTO errors VALUES (my_sqlcode, ...);
```

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`.

Example

In the following example, you insert the value of `SQLCODE` into an audit table:

```
DECLARE
    my_sqlcode NUMBER;
BEGIN
    ...
EXCEPTION
    WHEN OTHERS THEN
        my_sqlcode := SQLCODE;
        INSERT INTO audits VALUES (my_sqlcode, ...);
END;
```

Related Topics

Exceptions, `SQLERRM` Function

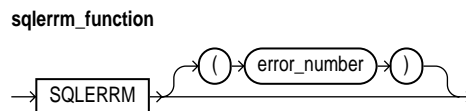
SQLERRM Function

The function `SQLERRM` returns the error message associated with its `error-number` argument or, if the argument is omitted, with the current value of `SQLCODE`. `SQLERRM` with no argument is meaningful only in an exception handler. Outside a handler, `SQLERRM` with no argument always returns the message *normal, successful completion*.

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 7-18.

Syntax



Keyword and Parameter Description

error_number

This must be a valid Oracle error number. For a list of Oracle errors, see *Oracle9i Database Error Messages*.

Usage Notes

`SQLERRM` is especially useful in the `OTHERS` exception handler because it lets you identify which internal exception was raised.

You can pass an error number to `SQLERRM`, in which case `SQLERRM` returns the message associated with that error number. The error number passed to `SQLERRM` should be negative. Passing a zero to `SQLERRM` always returns the following message:

```
ORA-0000: normal, successful completion
```


Passing a positive number to `SQLERRM` always returns the message

```
User-Defined Exception
```

unless you pass +100, in which case `SQLERRM` returns the following message:

```
ORA-01403: no data found
```

You cannot use `SQLERRM` directly in a SQL statement. First, you must assign the value of `SQLERRM` to a local variable, as follows:

```
my_sqlerrm := SQLERRM;
...
INSERT INTO errors VALUES (my_sqlerrm, ...);
```

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`.

Example

In the following example, the string function `SUBSTR` ensures that a `VALUE_ERROR` exception (for truncation) is not raised when you assign the value of `SQLERRM` to `my_sqlerrm`:

```
DECLARE
    my_sqlerrm VARCHAR2(150);
    ...
BEGIN
    ...
EXCEPTION
    ...
    WHEN OTHERS THEN
        my_sqlerrm := SUBSTR(SQLERRM, 1, 150);
        INSERT INTO audits VALUES (my_sqlerrm, ...);
END;
```

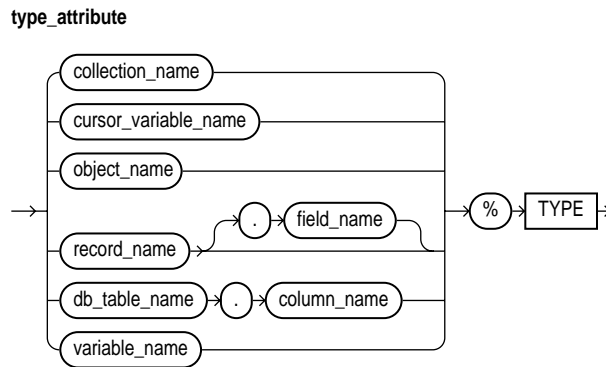
Related Topics

Exceptions, `SQLCODE` Function

%TYPE Attribute

The %TYPE attribute provides the datatype of a field, record, nested table, database column, or variable. You can use the %TYPE attribute as a datatype specifier when declaring constants, variables, fields, and parameters. For more information, see ["Using %TYPE"](#) on page 2-13.

Syntax



Keyword and Parameter Description

collection_name

This identifies a nested table, index-by table, or varray previously declared within the current scope.

cursor_variable_name

This identifies 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

This refers to a table and column that must be accessible when the declaration is elaborated.

object_name

This identifies an object (instance of an object type) previously declared within the current scope.

record_name

This identifies a user-defined or %ROWTYPE record previously declared within the current scope.

record_name.field_name

This identifies a field in a user-defined or %ROWTYPE record previously declared within the current scope.

variable_name

This identifies 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. However, the NOT NULL column constraint is *not* inherited by items declared using %TYPE.

Related Topics

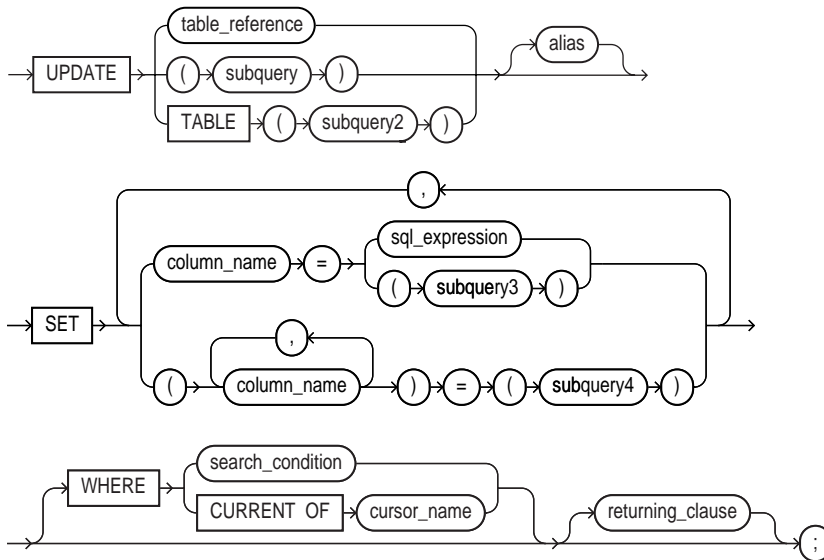
Constants and Variables, %ROWTYPE Attribute

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** statement, see *Oracle9i SQL Reference*.

Syntax

update_statement



Keyword and Parameter Description

alias

This is another (usually short) name for the referenced table or view and is typically used in the **WHERE** clause.

column_name

This is the name of 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

This clause lets you return values from updated rows, thereby eliminating the need to `SELECT` the rows afterward. You can retrieve the column values into variables and/or host variables, or into collections and/or host arrays. However, you cannot use the `RETURNING` clause for remote or parallel updates. For the syntax of `returning_clause`, see "[DELETE Statement](#)" on page 13-57.

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.

In the following example, you increase every employee's salary by 10%. The original value of the `sal` column is multiplied by 1.10, then the result is assigned to the `sal` column overwriting the original value.

```
UPDATE emp SET sal = sal * 1.10;
```

SET column_name = (subquery3)

This clause 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)

This clause 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.

In the following correlated query, the column `item_id` is assigned the value stored in `item_num`, and the column `price` is assigned the value stored in `item_price`:

```
UPDATE inventory inv -- alias
  SET (item_id, price) =
      (SELECT item_num, item_price FROM item_table
       WHERE item_name = inv.item_name);
```

sql_expression

This is any valid SQL expression. For more information, see *Oracle9i SQL Reference*.

subquery

This is 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 13-164.

table_reference

This identifies 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 13-57.

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

This clause 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

This clause chooses which rows to update in the database table. Only rows that meet the search condition are updated. If you omit the search condition, 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 (this includes implicit fetches executed in a cursor `FOR` loop), provided the associated query is `FOR UPDATE`. This statement updates the current row, that is, the one 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

In the following example, a 10% raise is given to analysts in department 20:

```
UPDATE emp SET sal = sal * 1.10
  WHERE job = 'ANALYST' AND DEPTNO = 20;
```

In the next example, an employee named Ford is promoted to the position of Analyst and her salary is raised by 15%:

```
UPDATE emp SET job = 'ANALYST', sal = sal * 1.15
  WHERE ename = 'FORD';
```

In the final example, values returned from an updated row are stored in variables:

```
UPDATE emp SET sal = sal + 500 WHERE ename = 'MILLER'
  RETURNING sal, ename INTO my_sal, my_ename;
```

Related Topics

DELETE Statement, FETCH Statement

Sample PL/SQL Programs

This appendix provides several PL/SQL programs to guide you in writing your own. The sample programs illustrate several important PL/SQL concepts and features.

This appendix discusses the following topics:

[Running the Programs](#)

[Sample 1. FOR Loop](#)

[Sample 2. Cursors](#)

[Sample 3. Scoping](#)

[Sample 4. Batch Transaction Processing](#)

[Sample 5. Embedded PL/SQL](#)

[Sample 6. Calling a Stored Procedure](#)

Running the Programs

All the sample programs in this appendix and several others throughout this guide are available online. So, they are preceded by the following comment:

```
-- available online in file '<filename>'
```

You can find the online files in the PL/SQL demo directory. For the location of the directory, see the Oracle installation or user's guide for your system. Here is a list of the files and their locations in this guide:

Filename	Location in This Guide
examp1	"Understanding the Main Features of PL/SQL" on page 1-2
examp2	"Conditional Control" on page 1-9
examp3	"Iterative Control" on page 1-10
examp4	"Using Aliases" on page 2-16
examp7	"Using Cursor FOR Loops" on page 6-13
examp8	"Passing Parameters to a Cursor FOR Loop" on page 6-15
examp5	"Some Examples of Cursor Attributes" on page 6-37
examp6	"Some Examples of Cursor Attributes" on page 6-37
examp11	"Example" on page 13-17
examp12	"Examples" on page 13-44
examp13	"Examples" on page 13-44
examp14	"Examples" on page 13-44
sample1	"Sample 1. FOR Loop" on page A-3
sample2	"Sample 2. Cursors" on page A-4
sample3	"Sample 3. Scoping" on page A-6
sample4	"Sample 4. Batch Transaction Processing" on page A-7
sample5	"Sample 5. Embedded PL/SQL" on page A-11
sample6	"Sample 6. Calling a Stored Procedure" on page A-15

You run some samples interactively from SQL*Plus, others from Pro*C programs. You can experiment with the samples from any Oracle account. However, the Pro*C examples expect you to use the `scott/tiger` account.

Before trying the samples, you must create some database tables, then load the tables with data. You do that by running two SQL*Plus scripts, `exampbld` and `exemplod`, which are supplied with PL/SQL. You can find these scripts in the PL/SQL demo directory.

The first script builds the database tables processed by the sample programs. The second script loads (or reloads) the database tables. To run the scripts, invoke SQL*Plus, then issue the following commands:

```
SQL> START exampbld
...
SQL> START exemplod
```

Sample 1. FOR Loop

The following example uses a simple FOR loop to insert ten rows into a database table. The values of a loop index, counter variable, and either of two character strings are inserted. Which string is inserted depends on the value of the loop index.

Input Table

Not applicable.

PL/SQL Block

```
-- available online in file 'sample1'
DECLARE
  x NUMBER := 100;
BEGIN
  FOR i IN 1..10 LOOP
    IF MOD(i,2) = 0 THEN      -- i is even
      INSERT INTO temp VALUES (i, x, 'i is even');
    ELSE
      INSERT INTO temp VALUES (i, x, 'i is odd');
    END IF;
    x := x + 100;
  END LOOP;
  COMMIT;
END;
```

Output Table

```
SQL> SELECT * FROM temp ORDER BY coll;
```

NUM_COL1	NUM_COL2	CHAR_COL
1	100	i is odd
2	200	i is even
3	300	i is odd
4	400	i is even
5	500	i is odd
6	600	i is even
7	700	i is odd
8	800	i is even
9	900	i is odd
10	1000	i is even

Sample 2. Cursors

The following example uses a cursor to select the five highest paid employees from the emp table.

Input Table

```
SQL> SELECT ename, empno, sal FROM emp ORDER BY sal DESC;
```

ENAME	EMPNO	SAL
KING	7839	5000
SCOTT	7788	3000
FORD	7902	3000
JONES	7566	2975
BLAKE	7698	2850
CLARK	7782	2450
ALLEN	7499	1600
TURNER	7844	1500
MILLER	7934	1300
WARD	7521	1250
MARTIN	7654	1250
ADAMS	7876	1100
JAMES	7900	950
SMITH	7369	800

PL/SQL Block

```
-- available online in file 'sample2'
DECLARE
  CURSOR c1 is
    SELECT ename, empno, sal FROM emp
      ORDER BY sal DESC;  -- start with highest paid employee
  my_ename VARCHAR2(10);
  my_empno NUMBER(4);
  my_sal    NUMBER(7,2);
BEGIN
  OPEN c1;
  FOR i IN 1..5 LOOP
    FETCH c1 INTO my_ename, my_empno, my_sal;
    EXIT WHEN c1%NOTFOUND;  /* in case the number requested */
                                /* is more than the total      */
                                /* number of employees      */
    INSERT INTO temp VALUES (my_sal, my_empno, my_ename);
    COMMIT;
  END LOOP;
  CLOSE c1;
END;
```

Output Table

```
SQL> SELECT * FROM temp ORDER BY col1 DESC;
```

NUM_COL1	NUM_COL2	CHAR_COL
5000	7839	KING
3000	7902	FORD
3000	7788	SCOTT
2975	7566	JONES
2850	7698	BLAKE

Sample 3. Scoping

The following example illustrates block structure and scope rules. An outer block declares two variables named `x` and `counter` and loops four times. Inside this loop is a sub-block that also declares a variable named `x`. The values inserted into the `temp` table show that the two `x`'s are indeed different.

Input Table

Not applicable.

PL/SQL Block

```
-- available online in file 'sample3'
DECLARE
  x NUMBER := 0;
  counter NUMBER := 0;
BEGIN
  FOR i IN 1..4 LOOP
    x := x + 1000;
    counter := counter + 1;
    INSERT INTO temp VALUES (x, counter, 'in OUTER loop');
    /* start an inner block */
    DECLARE
      x NUMBER := 0; -- this is a local version of x
    BEGIN
      FOR i IN 1..4 LOOP
        x := x + 1; -- this increments the local x
        counter := counter + 1;
        INSERT INTO temp VALUES (x, counter, 'inner loop');
      END LOOP;
    END;
  END LOOP;
  COMMIT;
END;
```

Output Table

```
SQL> SELECT * FROM temp ORDER BY col2;
```

NUM_COL1	NUM_COL2	CHAR_COL
-----	-----	-----
1000	1	in OUTER loop
	1	2 inner loop
	2	3 inner loop
	3	4 inner loop
	4	5 inner loop
2000	6	in OUTER loop
	1	7 inner loop
	2	8 inner loop
	3	9 inner loop
	4	10 inner loop
3000	11	in OUTER loop
	1	12 inner loop
	2	13 inner loop
	3	14 inner loop
	4	15 inner loop
4000	16	in OUTER loop
	1	17 inner loop
	2	18 inner loop
	3	19 inner loop
	4	20 inner loop

Sample 4. Batch Transaction Processing

In the next example the `accounts` table is modified according to instructions stored in the `action` table. Each row in the `action` table contains an account number, an action to be taken (I, U, or D for insert, update, or delete), an amount by which to update the account, and a time tag used to sequence the transactions.

On an insert, if the account already exists, an update is done instead. On an update, if the account does not exist, it is created by an insert. On a delete, if the row does not exist, no action is taken.

Input Tables

```
SQL> SELECT * FROM accounts ORDER BY account_id;
```

ACCOUNT_ID	BAL
1	1000
2	2000
3	1500
4	6500
5	500

```
SQL> SELECT * FROM action ORDER BY time_tag;
```

ACCOUNT_ID	O	NEW_VALUE	STATUS	TIME_TAG
3	u	599		18-NOV-88
6	i	20099		18-NOV-88
5	d			18-NOV-88
7	u	1599		18-NOV-88
1	i	399		18-NOV-88
9	d			18-NOV-88
10	x			18-NOV-88

PL/SQL Block

```
-- available online in file 'sample4'
DECLARE
    CURSOR c1 IS
        SELECT account_id, oper_type, new_value FROM action
        ORDER BY time_tag
        FOR UPDATE OF status;
BEGIN
    FOR acct IN c1 LOOP -- process each row one at a time

        acct.oper_type := upper(acct.oper_type);

        /*-----*/
        /* Process an UPDATE.  If the account to */
        /* be updated doesn't exist, create a new */
        /* account.                                */
        /*-----*/
        IF acct.oper_type = 'U' THEN
            UPDATE accounts SET bal = acct.new_value
            WHERE account_id = acct.account_id;
```



```

IF SQL%NOTFOUND THEN -- account didn't exist. Create it.
    INSERT INTO accounts
        VALUES (acct.account_id, acct.new_value);
    UPDATE action SET status =
        'Update: ID not found. Value inserted.'
        WHERE CURRENT OF c1;
ELSE
    UPDATE action SET status = 'Update: Success.'
        WHERE CURRENT OF c1;
END IF;

/*-----*/
/* Process an INSERT.  If the account already */
/* exists, do an update of the account      */
/* instead.                                  */
/*-----*/
ELSIF acct.oper_type = 'I' THEN
    BEGIN
        INSERT INTO accounts
            VALUES (acct.account_id, acct.new_value);
        UPDATE action set status = 'Insert: Success.'
            WHERE CURRENT OF c1;
        EXCEPTION
            WHEN DUP_VAL_ON_INDEX THEN -- account already exists
                UPDATE accounts SET bal = acct.new_value
                    WHERE account_id = acct.account_id;
                UPDATE action SET status =
                    'Insert: Acct exists. Updated instead.'
                    WHERE CURRENT OF c1;
    END;

/*-----*/
/* Process a DELETE.  If the account doesn't */
/* exist, set the status field to say that   */
/* the account wasn't found.                */
/*-----*/
ELSIF acct.oper_type = 'D' THEN
    DELETE FROM accounts
        WHERE account_id = acct.account_id;

    IF SQL%NOTFOUND THEN -- account didn't exist.
        UPDATE action SET status = 'Delete: ID not found.'
            WHERE CURRENT OF c1;
    ELSE

```

```

        UPDATE action SET status = 'Delete: Success.'
            WHERE CURRENT OF c1;
    END IF;

/*-----*/
/* The requested operation is invalid.      */
/*-----*/
ELSE -- oper_type is invalid
    UPDATE action SET status =
        'Invalid operation. No action taken.'
        WHERE CURRENT OF c1;

END IF;

END LOOP;
COMMIT;
END;

```

Output Tables

```
SQL> SELECT * FROM accounts ORDER BY account_id;
```

ACCOUNT_ID	BAL
1	399
2	2000
3	599
4	6500
6	20099
7	1599

```
SQL> SELECT * FROM action ORDER BY time_tag;
```

ACCOUNT_ID	O	NEW_VALUE	STATUS	TIME_TAG
3	u	599	Update: Success.	18-NOV-88
6	i	20099	Insert: Success.	18-NOV-88
5	d		Delete: Success.	18-NOV-88
7	u	1599	Update: ID not found. Value inserted.	18-NOV-88
1	i	399	Insert: Acct exists. Updated instead.	18-NOV-88
9	d		Delete: ID not found.	18-NOV-88
10	x		Invalid operation. No action taken.	18-NOV-88

Sample 5. Embedded PL/SQL

The following example shows how you can embed PL/SQL in a high-level host language such as C and demonstrates how a banking debit transaction might be done.

Input Table

```
SQL> SELECT * FROM accounts ORDER BY account_id;
```

ACCOUNT_ID	BAL
1	1000
2	2000
3	1500
4	6500
5	500

PL/SQL Block in a C Program

```
/* available online in file 'sample5' */
#include <stdio.h>
char buf[20];
EXEC SQL BEGIN DECLARE SECTION;
int acct;
double debit;
double new_bal;
VARCHAR status[65];
VARCHAR uid[20];
VARCHAR pwd[20];
EXEC SQL END DECLARE SECTION;

EXEC SQL INCLUDE SQLCA;

main()
{
extern double atof();

strcpy (uid.arr,"scott");
uid.len=strlen(uid.arr);
strcpy (pwd.arr,"tiger");
pwd.len=strlen(pwd.arr);
```

```
printf("\n\n\tEmbedded PL/SQL Debit Transaction Demo\n\n");
printf("Trying to connect...");
EXEC SQL WHENEVER SQLERROR GOTO errprint;
EXEC SQL CONNECT :uid IDENTIFIED BY :pwd;
printf(" connected.\n");
for (;;)          /* Loop infinitely */
{
    printf("\n** Debit which account number? (-1 to end) ");
    gets(buf);
    acct = atoi(buf);
    if (acct == -1) /* Need to disconnect from Oracle */
    {
        /* and exit loop if account is -1 */
        EXEC SQL COMMIT RELEASE;
        exit(0);
    }

    printf("   What is the debit amount? ");
    gets(buf);
    debit = atof(buf);

    /* ----- */
    /* ----- Begin the PL/SQL block ----- */
    /* ----- */
    EXEC SQL EXECUTE

    DECLARE
        insufficient_funds EXCEPTION;
        old_bal          NUMBER;
        min_bal          CONSTANT NUMBER := 500;
    BEGIN
        SELECT bal INTO old_bal FROM accounts
            WHERE account_id = :acct;
        -- If the account doesn't exist, the NO_DATA_FOUND
        -- exception will be automatically raised.
        :new_bal := old_bal - :debit;
        IF :new_bal >= min_bal THEN
            UPDATE accounts SET bal = :new_bal
                WHERE account_id = :acct;
            INSERT INTO journal
                VALUES (:acct, 'Debit', :debit, SYSDATE);
            :status := 'Transaction completed.';
        ELSE
            RAISE insufficient_funds;
        END IF;
        COMMIT;
```

```

EXCEPTION
  WHEN NO_DATA_FOUND THEN
    :status := 'Account not found.';
    :new_bal := -1;
  WHEN insufficient_funds THEN
    :status := 'Insufficient funds.';
    :new_bal := old_bal;
  WHEN OTHERS THEN
    ROLLBACK;
    :status := 'Error: ' || SQLERRM(SQLCODE);
    :new_bal := -1;
END;

END-EXEC;
/* ----- */
/* ----- End the PL/SQL block ----- */
/* ----- */

status.arr[status.len] = '\0'; /* null-terminate */
                             /* the string      */
printf("\n\n  Status:  %s\n", status.arr);
if (new_bal >= 0)
  printf("  Balance is now:  $%.2f\n", new_bal);
} /* End of loop */

errprint:
EXEC SQL WHENEVER SQLERROR CONTINUE;
printf("\n\n>>>> Error during execution:\n");
printf("%s\n", sqlca.sqlerrm.sqlerrmc);
EXEC SQL ROLLBACK RELEASE;
exit(1);
}

```

Interactive Session

Embedded PL/SQL Debit Transaction Demo

Trying to connect... connected.

```

** Debit which account number? (-1 to end) 1
   What is the debit amount? 300

```

```

Status:  Transaction completed.
Balance is now:  $700.00

```

```

** Debit which account number? (-1 to end) 1
  What is the debit amount? 900
  Status:  Insufficient funds.
  Balance is now:  $700.00

** Debit which account number? (-1 to end) 2
  What is the debit amount? 500

  Status:  Transaction completed.
  Balance is now:  $1500.00

** Debit which account number? (-1 to end) 2
  What is the debit amount? 100

  Status:  Transaction completed.
  Balance is now:  $1400.00

** Debit which account number? (-1 to end) 99
  What is the debit amount? 100

  Status:  Account not found.

** Debit which account number? (-1 to end) -1

```

Output Tables

```
SQL> SELECT * FROM accounts ORDER BY account_id;
```

ACCOUNT_ID	BAL
1	700
2	1400
3	1500
4	6500
5	500

```
SQL> SELECT * FROM journal ORDER BY date_tag;
```

ACCOUNT_ID	ACTION	AMOUNT	DATE_TAG
1	Debit	300	28-NOV-88
2	Debit	500	28-NOV-88
2	Debit	100	28-NOV-88

Sample 6. Calling a Stored Procedure

This Pro*C program connects to Oracle, prompts the user for a department number, then calls procedure `get_employees`, which is stored in package `personnel`. The procedure declares three index-by tables as `OUT` formal parameters, then fetches a batch of employee data into the index-by tables. The matching actual parameters are host arrays.

When the procedure finishes, it automatically assigns all row values in the index-by tables to corresponding elements in the host arrays. The program calls the procedure repeatedly, displaying each batch of employee data, until no more data is found.

Input Table

```
SQL> SELECT ename, empno, sal FROM emp ORDER BY sal DESC;
```

ENAME	EMPNO	SAL
-----	-----	-----
KING	7839	5000
SCOTT	7788	3000
FORD	7902	3000
JONES	7566	2975
BLAKE	7698	2850
CLARK	7782	2450
ALLEN	7499	1600
TURNER	7844	1500
MILLER	7934	1300
WARD	7521	1250
MARTIN	7654	1250
ADAMS	7876	1100
JAMES	7900	950
SMITH	7369	800

Stored Procedure

```
/* available online in file 'sample6' */
#include <stdio.h>
#include <string.h>

typedef char asciz;
```

```

EXEC SQL BEGIN DECLARE SECTION;
    /* Define type for null-terminated strings. */
EXEC SQL TYPE asciz IS STRING(20);
asciz  username[20];
asciz  password[20];
int    dept_no;      /* which department to query */
char   emp_name[10][21];
char   job[10][21];
EXEC SQL VAR emp_name is STRING (21);
EXEC SQL VAR job is STRING (21);
float  salary[10];
int    done_flag;
int    array_size;
int    num_ret;     /* number of rows returned */
int    SQLCODE;
EXEC SQL END DECLARE SECTION;

EXEC SQL INCLUDE sqlca;

int print_rows();      /* produces program output      */
int sqlerror();       /* handles unrecoverable errors */

main()
{
    int i;

    /* Connect to Oracle. */
    strcpy(username, "SCOTT");
    strcpy(password, "TIGER");

    EXEC SQL WHENEVER SQLERROR DO sqlerror();

    EXEC SQL CONNECT :username IDENTIFIED BY :password;
    printf("\nConnected to Oracle as user: %s\n\n", username);

    printf("Enter department number: ");
    scanf("%d", &dept_no);
    fflush(stdin);

    /* Print column headers. */
    printf("\n\n");
    printf("%-10.10s%-10.10s%\n", "Employee", "Job", "Salary");
    printf("%-10.10s%-10.10s%\n", "-----", "----", "-----");

```



```
/* Set the array size. */
array_size = 10;
done_flag = 0;
num_ret = 0;

/* Array fetch loop - ends when NOT FOUND becomes true. */
for (;;)
{
    EXEC SQL EXECUTE
        BEGIN personnel.get_employees
            (:dept_no, :array_size, :num_ret, :done_flag,
             :emp_name, :job, :salary);
        END;
    END-EXEC;

    print_rows(num_ret);

    if (done_flag)
        break;
}

/* Disconnect from Oracle. */
EXEC SQL COMMIT WORK RELEASE;
exit(0);
}

print_rows(n)
int n;
{
    int i;

    if (n == 0)
    {
        printf("No rows retrieved.\n");
        return;
    }

    for (i = 0; i < n; i++)
        printf("%10.10s%10.10s%6.2f\n",
              emp_name[i], job[i], salary[i]);
}
```

```
sqlerror()
{
    EXEC SQL WHENEVER SQLERROR CONTINUE;
    printf("\nOracle error detected:");
    printf("\n% .70s \n", sqlca.sqlerrm.sqlerrmc);
    EXEC SQL ROLLBACK WORK RELEASE;
    exit(1);
}
```

Interactive Session

Connected to Oracle as user: SCOTT

Enter department number: 20

Employee	Job	Salary
SMITH	CLERK	800.00
JONES	MANAGER	2975.00
SCOTT	ANALYST	3000.00
ADAMS	CLERK	1100.00
FORD	ANALYST	3000.00

CHAR versus VARCHAR2 Semantics

This appendix 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.

This appendix discusses the following topics:

- [Assigning Character Values](#)
- [Comparing Character Values](#)
- [Inserting Character Values](#)
- [Selecting 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. So, information about trailing blanks 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 declarations

```
last_name1 VARCHAR2(10) := 'COLES';  
last_name2 VARCHAR2(10) := 'COLEMAN';
```

the following IF condition is true:

```
IF last_name1 > last_name2 THEN ...
```

ANSI/ISO SQL requires that two character values being compared have equal lengths. So, if both values in a comparison have datatype `CHAR`, *blank-padding* semantics are used. That is, 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 declarations

```
last_name1 CHAR(5) := 'BELLO';
last_name2 CHAR(10) := 'BELLO  '; -- note trailing blanks
```

the following `IF` condition is true:

```
IF last_name1 = last_name2 THEN ...
```

If either value in a comparison has datatype `VARCHAR2`, *non-blank-padding* semantics are used. That is, when comparing character values of unequal length, PL/SQL makes no adjustments and uses the exact lengths. For example, given the declarations

```
last_name1 VARCHAR2(10) := 'DOW';
last_name2 VARCHAR2(10) := 'DOW  '; -- note trailing blanks
```

the following `IF` condition is false:

```
IF last_name1 = last_name2 THEN ...
```

If one value in a comparison has datatype `VARCHAR2` and the other value has datatype `CHAR`, *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. So, given the declarations

```
last_name1 VARCHAR2(10) := 'STAUB';
last_name2 CHAR(10)      := 'STAUB'; -- PL/SQL blank-pads value
```

the following `IF` condition is false because the value of `last_name2` includes five trailing blanks:

```
IF last_name1 = last_name2 THEN ...
```

All string literals have datatype `CHAR`. So, 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.

Note: The same rules apply when updating.

When inserting character values, to ensure that no trailing blanks are stored, use the function `RTRIM`, which trims trailing blanks. An example follows:

```
DECLARE
    ...
    my_name VARCHAR2(15);
BEGIN
    ...
    my_ename := 'LEE  '; -- note trailing blanks
    INSERT INTO emp
        VALUES (my_empno, RTRIM(my_ename), ...); -- inserts 'LEE'
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`.

Note: The same rules apply when fetching.

PL/SQL Wrap Utility

This appendix shows you how to run the Wrap Utility, a standalone programming utility that encrypts PL/SQL source code. You can use the Wrap Utility to deliver PL/SQL applications without exposing your source code.

This appendix discusses the following topics:

[Advantages of Wrapping PL/SQL Procedures](#)
[Running the Wrap Utility](#)
[Guidelines](#)

Advantages of Wrapping PL/SQL Procedures

By hiding application internals, the Wrap Utility prevents

- Misuse of your application by other developers
- Exposure of your algorithms to business competitors

Wrapped code is as portable as source code. The PL/SQL compiler recognizes and loads wrapped compilation units automatically. Other advantages include

- Platform independence—you need not deliver multiple versions of the same compilation unit
- Dynamic loading—users need not shut down and re-link to add a new feature
- Dynamic binding—external references are resolved at load time
- Strict dependency checking—invalidated program units are recompiled automatically

- Normal importing and exporting—the Import/Export utility accepts wrapped files

Running the Wrap Utility

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]
```

Leave no space around the equal signs because spaces delimit individual arguments.

The `wrap` command requires only one argument, which is

```
iname=input_file
```

where `input_file` is the name of the Wrap Utility input file. You need not specify the file extension because it defaults to `sql`. For example, the following commands are equivalent:

```
wrap iname=/mydir/myfile
wrap iname=/mydir/myfile.sql
```

However, you can specify a different file extension as the following example shows:

```
wrap iname=/mydir/myfile.src
```

Optionally, the `wrap` command takes a second argument, which is

```
oname=output_file
```

where `output_file` is the name of the Wrap Utility output file. You need not specify the output file because its name defaults to that of the input file and its extension defaults to `plb` (PL/SQL binary). For example, the following commands are equivalent:

```
wrap iname=/mydir/myfile
wrap iname=/mydir/myfile.sql oname=/mydir/myfile.plb
```

However, you can use the option `oname` to specify a different file name and extension, as the following example shows:

```
wrap iname=/mydir/myfile oname=/yourdir/yourfile.obj
```

Input and Output Files for the Wrap Utility

The input file can contain any combination of SQL statements. However, the Wrap Utility encrypts only the following CREATE statements, which define subprograms, packages, or object types:

```
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 ... OBJECT
CREATE [OR REPLACE] TYPE BODY type_name
```

All other SQL statements are passed intact to the output file. Comment lines are deleted unless they appear inside a subprogram, package, or object type.

When encrypted, a subprogram, package, or object type has the form

```
<header> wrapped <body>
```

where *header* begins with the reserved word CREATE and ends with the name of the subprogram, package, or object type, and *body* is an intermediate form of object code. The word *wrapped* tells the PL/SQL compiler that the subprogram, package, or object type was encrypted by the Wrap Utility.

The header can contain comments. For example, the Wrap Utility converts

```
CREATE PACKAGE
-- Author: J. Hollings
-- Date: 10/15/99
banking AS
    minimum_balance CONSTANT REAL := 25.00;
    insufficient_funds EXCEPTION;
END banking;
```

into

```
CREATE PACKAGE
-- Author: J. Hollings
-- Date: 10/15/99
banking wrapped
0
abcd ...
```

Generally, the output file is much larger than the input file.

Error Handling in the Wrap Utility

If your input file contains syntax errors, the Wrap Utility detects and reports them. However, the Wrap Utility cannot detect semantic errors because it does not resolve external references. For example, it does not report the following error (*table or view does not exist*):

```
CREATE PROCEDURE raise_salary (emp_id INTEGER, amount NUMBER) AS
BEGIN
    UPDATE emp -- should be emp
        SET sal = sal + amount WHERE empno = emp_id;
END;
```

The PL/SQL compiler resolves external references. So, semantic errors are reported when the Wrap Utility output file (.plb file) is compiled.

Version Compatibility

The Wrap Utility is upward-compatible with Oracle. So, for example, you can load files processed by the V8.1.5 Wrap Utility into a V8.1.6 Oracle database. However, the Wrap Utility is not downward-compatible with Oracle. So, for example, you cannot load files processed by the V8.1.6 Wrap Utility into a V8.1.5 Oracle database.

Guidelines

When wrapping a package or object type, wrap only the body, not the spec. That way, other developers see the information they need to use the package or type, but they do not see its implementation.

Like all encrypted files, wrapped files cannot be edited. To revise a wrapped file, you must revise and re-wrap the underlying source code. So, do not wrap a subprogram, package, or object type until it is ready for shipment to end-users.

PL/SQL Name Resolution

This appendix explains how PL/SQL resolves references to names in potentially ambiguous SQL and procedural statements.

This appendix discusses the following topics:

[What Is Name Resolution?](#)

[Various Forms of References](#)

[Name-Resolution Algorithm](#)

[Understanding Capture](#)

[Avoiding Capture](#)

[Accessing Attributes and Methods](#)

[Calling Subprograms and Methods](#)

[Name Resolution for SQL Versus PL/SQL](#)

What Is Name Resolution?

During compilation, the PL/SQL compiler associates identifiers such as the name of a variable with an address (memory location), datatype, or actual value. This process is called *binding*. The association lasts through all subsequent executions until a recompilation occurs, which might cause a rebinding.

Before binding the names, PL/SQL must resolve all references to them in the compilation unit. This process is called *name resolution*. PL/SQL considers all names to be in the same namespace. So, one declaration or definition in an inner scope can hide another in an outer scope. In the following example, the declaration of variable `client` hides the definition of datatype `Client` because PL/SQL is not case sensitive except within string literals:

```
BEGIN
  <<block1>>
  DECLARE
    TYPE Client IS RECORD (...);
    TYPE Customer IS RECORD (...);
  BEGIN
    DECLARE
      client Customer;          -- hides definition of type Client
                                -- in outer scope
      lead1 Client;            -- illegal; Client resolves to the
                                -- variable client
      lead2 block1.Client;    -- OK; refers to type Client
    BEGIN
      NULL;
    END;
  END;
END;
```

However, you can still refer to datatype `Client` by qualifying the reference with block label `block1`.

In the `CREATE TYPE person1` statement below, the compiler resolves the second reference to `manager` as the name of the attribute you are trying to declare. In the `CREATE TYPE person2` statement, the compiler resolves the second reference to `manager` as the name of the attribute you just declared. In both cases, the reference to `manager` generates an error because the compiler expects a type name.

```
CREATE TYPE manager AS OBJECT (dept NUMBER);
CREATE TYPE person1 AS OBJECT (manager manager);
CREATE TYPE person2 AS OBJECT (manager NUMBER, mgr manager);
```

Various Forms of References

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. Some examples of legal references follow:

```
CREATE PACKAGE pkg1 AS
    m NUMBER;
    TYPE t1 IS RECORD (a NUMBER);
    v1 t1;
    TYPE t2 IS TABLE OF t1 INDEX BY BINARY_INTEGER;
    v2 t2;
    FUNCTION f1 (p1 NUMBER) RETURN t1;
    FUNCTION f2 (q1 NUMBER) RETURN t2;
END pkg1;

CREATE PACKAGE BODY pkg1 AS
    FUNCTION f1 (p1 NUMBER) RETURN t1 IS
        n NUMBER;
    BEGIN
        n := m;           -- (1) unqualified name
        n := pkg1.m;      -- (2) dot-separated chain of identifiers
                        -- (package name used as scope
                        --   qualifier followed by variable name)
        n := pkg1.f1.p1;  -- (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 := v1.a;       -- (4) dot-separated chain of identifiers
                        -- (variable name followed by
                        --   component selector)
        n := pkg1.v1.a;  -- (5) dot-separated chain of identifiers
                        -- (package name used as scope
                        --   qualifier followed by
                        --   variable name followed by component
                        --   selector)
        n := v2(10).a;   -- (6) indexed name followed by component
                        --   selector
        n := f1(10).a;   -- (7) function call followed by component
                        --   selector
        n := f2(10)(10).a; -- (8) function call followed by indexing
                        --   followed by component selector
        n := scott.pkg1.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 := scott.pkg1.f1.n;
-- (10) dot-separated chain of identifiers
--      (schema name used as scope qualifier
--      followed by package name also used
--      as scope qualifier followed by
--      function name also used as scope
--      qualifier followed by local
--      variable name)
...
END f1;

FUNCTION f2 (q1 NUMBER) RETURN t2 IS
BEGIN
...
END f2;
END pkg1;
```

Name-Resolution Algorithm

Let us take a look at the name-resolution algorithm.

The first part of name resolution involves finding the basis. The *basis* is the smallest prefix to a dot-separated chain of identifiers that can be resolved by looking in the current scope, then moving outward to schema-level scopes.

In the previous examples, the basis for (3) `pkg1.f1.p1` is `pkg1`, the basis for (4) `scott.pkg1.f1.n` is `scott.pkg1`, and the basis for (5) `v1.a` is `v1`. In (5), the `a` in `v1.a` is a component selector and resolves as field `a` of variable `v1` because `v1` is of type `t1`, which has a field called `a`.

If a basis is not found, the compiler generates a *not declared* error. If the basis is found, the compiler attempts to resolve the complete reference. If it fails, the compiler generates an error.

The length of the basis is always 1, 2, or 3. And, it can be 3 only inside SQL scope when the compiler resolves a three-part name as

```
schema_name.table_name.column_name
```

Here are more examples of bases:

```
variable_name
type_name
package_name
schema_name.package_name
schema_name.function_name
table_name
table_name.column_name
schema_name.table_name
schema_name.table_name.column_name
```

Finding the Basis

Now, let us look at the algorithm for finding the basis.

If the compiler is resolving a name in SQL scope (which includes everything in a DML statement except items in the `INTO` clause and schema-level table names), it first attempts to find the basis in that scope. If it fails, it attempts to find the basis in PL/SQL local scopes and at the schema level just as it would for names in non-SQL scopes.

Here are the rules for finding the basis in SQL scope when the compiler expects to find a column name:

- Given one identifier, the compiler attempts to find a basis of length 1 using the identifier as an unqualified column name in one of the tables listed in any `FROM` clauses that are in scope, starting with the current scope and moving outward.
- Given a of chain two identifiers, the compiler attempts to find a basis of length 2 using the identifiers as a column name qualified by a table name or table alias, starting with the current scope and moving outward.
- Given a chain of three identifiers, the compiler attempts to find in each scope that it searches, starting with the current scope and moving outward, either
 - a basis of length 3 using the three identifiers as a column name qualified by a table name qualified by a schema name, or
 - a basis of length 2 using the first two identifiers as a column name of some user-defined type qualified by a table alias

- Given a chain of four identifiers, the compiler attempts to find a basis of length 2, using the first two identifiers as a column name of some user-defined type qualified by a table alias, starting with the current scope and moving outward.

Once the compiler finds the basis as a column name, it attempts to resolve the complete reference by finding a component of the basis and so on depending upon the type of column name.

Here are the rules for finding the basis in SQL scope when the compiler expects to find a row expression (which is a table alias that can appear by itself; it can be used only with an object table and operator `REF` or `VALUE`, or in an `INSERT` or `UPDATE` statement for an object table):

- Given one identifier, the compiler attempts to find a basis of length 1 as a table alias, starting with the current scope and moving outward. If the table alias does not correspond to an object table, the compiler generates an error.
- Given a chain of two or more identifiers, the compiler generates an error.

If the name being resolved either

- does not appear in SQL scope, or
- appears in SQL scope but the compiler cannot find a basis for it in that scope

the compiler attempts to find the basis by searching all PL/SQL scopes local to the compilation unit, starting with the current scope and moving outward. If the name is found, the length of the basis is 1. If the name is not found, the compiler attempts to find the basis by searching for schema objects using the following rules:

1. First, the compiler attempts to find a basis of length 1 by searching the current schema for a schema object whose name matches the first identifier in the chain of identifiers. The schema object found might be a package specification, function, procedure, table, view, sequence, synonym, or schema-level datatype. If it is a synonym, the basis will be resolved as the base object designated by the synonym.
2. If the previous search fails, the compiler attempts to find a basis of length 1 by searching for a public synonym whose name matches the first identifier in the chain. If this succeeds, the basis will be resolved as the base object designated by the synonym.
3. If the previous search fails and there are at least two identifiers in the chain, the compiler attempts to find a basis of length 2 by searching for a schema object whose name matches the second identifier in the chain and which is owned by a schema whose name matches the first identifier in the chain.

4. If the compiler finds a basis as a schema object, it checks the privileges on the base object. If the base object is not visible, the compiler generates a *not declared* error because an *insufficient privileges* error would acknowledge the existence of the object, which is a security violation.
5. If the compiler fails to find a basis by searching for schema objects, it generates a *not declared* error.
6. If the compiler finds a basis, it attempts to resolve the complete reference depending on how the basis was resolved. If it fails to resolve the complete reference, the compiler generates an error.

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 that once resolved to an entity in an outer scope, either

- gets resolved to an entity in an inner scope, or
- causes an error because the basis of the identifier chain got captured in an inner scope and the complete reference could not be resolved

If the situation was resolved without error in an inner scope, the capture might occur without your knowing. 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);
CREATE TABLE tab2 (col1 NUMBER);
CREATE PROCEDURE proc AS
    CURSOR c1 IS SELECT * FROM tab1
        WHERE EXISTS (SELECT * FROM tab2 WHERE col2 = 10);
BEGIN
    . . .
END;
```

In the last example, if you add a column named `col2` to table `tab2`, as follows

```
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`.

The use of collections and object types allows for more inner capture situations. In the following example, the reference to `s.tab2.a` resolves to attribute `a` of column `tab2` in table `tab1` through table alias `s`, which is visible in the outer scope of the query:

```
CREATE TYPE type1 AS OBJECT (a NUMBER);
CREATE TABLE tab1 (tab2 type1);
CREATE TABLE tab2 (x NUMBER);
SELECT * FROM tab1 s -- alias with same name as schema name
       WHERE EXISTS (SELECT * FROM s.tab2 WHERE x = s.tab2.a);
                        -- note lack of alias
```

In the last example, suppose you add a column named `a` to table `s.tab2`, which appears in the inner subquery. When the query is processed, an inner capture occurs because the reference to `s.tab2.a` resolves to column `a` of table `tab2` in schema `s`. You can avoid inner captures by following the rules given in "[Avoiding Capture](#)" on page D-9. According to those rules, you should revise the query as follows:

```
SELECT * FROM s.tab1 p1
       WHERE EXISTS (SELECT * FROM s.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 in the same scope, and that column has the same name as a column in the other table. Consider the following query (and refer to the previous example):

```
PROCEDURE proc IS
    CURSOR c1 IS SELECT * FROM tab1, tab2 WHERE col2 = 10;
```

In this example, the reference to `col2` in the query binds to column `col2` in table `tab1`. If you add a column named `col2` to table `tab2`, the query compiles with errors. Thus, the reference to `col2` is captured by an error.

Outer Capture

An outer capture occurs when a name in an inner scope, which once resolved to an entity in an inner scope, gets resolved to an entity in an outer scope. Fortunately, SQL and PL/SQL are designed to prevent outer captures.

Avoiding Capture

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 DML statement references tables that have columns of a user-defined object type.

Accessing 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:

- All references to attributes and methods must be qualified by a table alias. So, 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 illegal if they are prefixed with a table name:

```
CREATE TYPE t1 AS OBJECT (x NUMBER);
CREATE TABLE tbl (col t1);
SELECT col.x FROM tbl;                -- illegal
SELECT tbl.col.x FROM tbl;           -- illegal
SELECT scott.tbl.col.x FROM scott.tbl; -- illegal
SELECT t.col.x FROM tbl t;
UPDATE tbl SET col.x = 10;           -- illegal
UPDATE scott.tbl SET scott.tbl.col.x=10; -- illegal
UPDATE tbl t set t.col.x = 1;
DELETE FROM tbl WHERE tbl.col.x = 10; -- illegal
DELETE FROM tbl t WHERE t.col.x = 10;
```

- 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;                -- object table
SELECT REF(ot1) FROM ot1;              -- illegal
SELECT REF(o) FROM ot1 o;
SELECT VALUE(ot1) FROM ot1;           -- illegal
SELECT VALUE(o) FROM ot1 o;
DELETE FROM ot1 WHERE VALUE(ot1) = (t1(10)); -- illegal
DELETE FROM ot1 o WHERE VALUE(o) = (t1(10));
UPDATE ot1 SET ot1 = ...                -- illegal
UPDATE ot1 o SET o = ....

```

The following ways to insert into an object table are legal and do not require an alias because there is no column list:

```

INSERT INTO ot1 VALUES (t1(10)); -- no row expression
INSERT INTO ot1 VALUES (10);    -- no row expression

```

Calling Subprograms and Methods

In calls to a parameterless subprogram, an empty parameter list is optional, as the following examples show:

```

CREATE FUNCTION func1 RETURN NUMBER AS
BEGIN
    RETURN 10;
END;

CREATE PACKAGE pkg2 AS
    FUNCTION func1 RETURN NUMBER;
    PRAGMA RESTRICT_REFERENCES ( func1 ,WNDS ,RNDS ,WNPS ,RNPS );
END pkg2;

CREATE PACKAGE BODY pkg2 AS
    FUNCTION func1 RETURN NUMBER IS
    BEGIN
        RETURN 20;
    END;
END pkg2;

```

```

SELECT func1 FROM dual;
SELECT func1() FROM dual;

SELECT pkg2.func1 FROM dual;
SELECT pkg2.func1() FROM dual;

DECLARE
    x NUMBER;
BEGIN
    x := func1;
    x := func1();
    SELECT func1 INTO x FROM dual;
    SELECT func1() INTO x FROM dual;
    SELECT pkg2.func1 INTO x FROM dual;
    SELECT pkg2.func1() INTO x FROM dual;
END;

```

In calls to a parameterless method, an empty parameter list is optional within PL/SQL scopes. However, an empty parameter list is required within SQL scopes. Some examples follow:

```

CREATE TYPE type1 AS OBJECT (
    a NUMBER,
    MEMBER FUNCTION f RETURN number,
    PRAGMA RESTRICT_REFERENCES(f, WNDS, RNDS, WNPS, RNPS)
);

CREATE TYPE BODY type1 AS
    MEMBER FUNCTION f RETURN number IS
    BEGIN
        RETURN 1;
    END;
END;

CREATE TABLE tabl (col1 type1);
INSERT INTO tabl VALUES (type1(10));

SELECT x.col1.f FROM tabl x;    -- illegal
SELECT x.col1.f() FROM tabl x;

```

```
DECLARE
    n NUMBER;
    y type1;
BEGIN
    /* In PL/SQL scopes, an empty parameter list is optional. */
    n := y.f;
    n := y.f();
    /* In SQL scopes, an empty parameter list is required. */
    SELECT x.coll.f INTO n FROM tabl x;      -- illegal
    SELECT x.coll.f() INTO n FROM tabl x;
    SELECT y.f INTO n FROM dual;            -- illegal
    SELECT y.f() INTO n FROM dual;
END;
```

Name Resolution for SQL Versus PL/SQL

The name-resolution rules for SQL and PL/SQL are similar. However, there are a few minor differences, which are not noticeable if you follow the capture avoidance rules.

For compatibility, the SQL rules are more permissive than the PL/SQL rules. That is, the SQL rules, which are mostly context sensitive, recognize as legal more situations and DML statements than the PL/SQL rules do.

PL/SQL Program Limits

PL/SQL is designed primarily for high-speed transaction processing. That design imposes some program limits, which are discussed in this appendix.

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), which is a tree-structured intermediate language. It is defined using a meta-notation called Interface Definition Language (IDL). DIANA provides for communication internal to 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 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 E-1](#).

Table E-1 PL/SQL Compiler Limits

Item	Limit
bind variables passed to a program unit	32K
exception handlers in a program unit	64K
fields in a record	64K
levels of block nesting	255
levels of record nesting	32
levels of subquery nesting	254
levels of label nesting	98
magnitude of a <code>BINARY_INTEGER</code> value	2G

Table E-1 PL/SQL Compiler Limits

Item	Limit
magnitude of a PLS_INTEGER value	2G
objects referenced by a program unit	64K
parameters passed to an explicit cursor	64K
parameters passed to a function or procedure	64K
precision of a FLOAT value (binary digits)	126
precision of a NUMBER value (decimal digits)	38
precision of a REAL value (binary digits)	63
size of an identifier (characters)	30
size of a string literal (bytes)	32K
size of a CHAR value (bytes)	32K
size of a LONG value (bytes)	32K-7
size of a LONG RAW value (bytes)	32K-7
size of a RAW value (bytes)	32K
size of a VARCHAR2 value (bytes)	32K
size of an NCHAR value (bytes)	32K
size of an NVARCHAR2 value (bytes)	32K
size of a BFILE value (bytes)	4G
size of a BLOB value (bytes)	4G
size of a CLOB value (bytes)	4G
size of an NCLOB value (bytes)	4G

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. In the following example, you get the parsed size of a package (displayed on the package spec line):

```
CREATE PACKAGE pkg1 AS
    PROCEDURE procl;
END pkg1;
/

CREATE PACKAGE BODY pkg1 AS
    PROCEDURE procl IS
    BEGIN
        NULL;
    END;
END pkg1;
```

/

```
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 *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.

PL/SQL Reserved Words

The words listed in this appendix are reserved by PL/SQL. That is, they have a special syntactic meaning to PL/SQL. So, you should not use them to name program objects such as constants, variables, or cursors. Some of these words (marked by an asterisk) are also reserved by SQL. So, you should not use them to name schema objects such as columns, tables, or indexes.

ALL*	ELSE*	MINUS*	RECORD
ALTER*	ELSIF	MINUTE	REF
AND*	END	MLSLABEL*	RELEASE
ANY*	EXCEPTION	MOD	RETURN
ARRAY	EXCLUSIVE*	MODE*	REVERSE
AS*	EXECUTE	MONTH	ROLLBACK
ASC*	EXISTS*	NATURAL	ROW*
AT	EXIT	NATURALN	ROWID*
AUTHID	EXTENDS	NEW	ROWNUM*
AVG	EXTRACT	NEXTVAL	ROWTYPE
BEGIN	FALSE	NOCOPY	SAVEPOINT
BETWEEN*	FETCH	NOT*	SECOND
BINARY_INTEGER	FLOAT*	NOWAIT*	SELECT*
BODY	FOR*	NULL*	SEPARATE
BOOLEAN	FORALL	NULLIF	SET*
BULK	FROM*	NUMBER*	SHARE*
BY*	FUNCTION	NUMBER_BASE	SMALLINT*
CASE	GOTO	OCIROWID	SPACE
CHAR*	GROUP*	OF*	SQL
CHAR_BASE	HAVING*	ON*	SQLCODE
CHECK*	HEAP	OPAQUE	SQLERRM
CLOSE	HOURL	OPEN	START*
CLUSTER*	IF	OPERATOR	STDDEV
COALESCE	IMMEDIATE*	OPTION*	SUBTYPE
COLLECT	IN*	OR*	SUCCESSFUL*
COMMENT*	INDEX*	ORDER*	SUM
COMMIT	INDICATOR	ORGANIZATION	SYNONYM*
COMPRESS*	INSERT*	OTHERS	SYSDATE*
CONNECT*	INTEGER*	OUT	TABLE*
CONSTANT	INTERFACE	PACKAGE	THEN*
CREATE*	INTERSECT*	PARTITION	TIME
CURRENT*	INTERVAL	PCTFREE*	TIMESTAMP
CURRVAL	INTO*	PLS_INTEGER	TIMEZONE_REGION
CURSOR	IS*	POSITIVE	TIMEZONE_ABBR
DATE*	ISOLATION	POSITIVEN	TIMEZONE_MINUTE
DAY	JAVA	PRAGMA	TIMEZONE_HOUR
DECLARE	LEVEL*	PRIOR*	TO*
DECIMAL*	LIKE*	PRIVATE	TRIGGER*
DEFAULT*	LIMITED	PROCEDURE	TRUE
DELETE*	LOCK*	PUBLIC*	TYPE
DESC*	LONG*	RAISE	UI
DISTINCT*	LOOP	RANGE	
DO	MAX	RAW*	
DROP*	MIN	REAL	

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