

PL/SQL™

User's Guide and Reference

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PL/SQL User's Guide and Reference

Part No. A58236-01

Release 8.0

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Contents

Send Us Your Comments	xiii
Preface.....	xv
1 Overview	
Main Features	1-2
Block Structure	1-2
Variables and Constants	1-3
Cursors	1-5
Cursor FOR Loops	1-6
Cursor Variables	1-6
Attributes	1-7
Control Structures	1-8
Modularity	1-11
Data Abstraction	1-14
Information Hiding	1-16
Error Handling.....	1-17
Architecture.....	1-18
In the Oracle Server	1-19
In Oracle Tools	1-20
Advantages of PL/SQL.....	1-21
Support for SQL.....	1-21
Support for Object-Oriented Programming	1-21
Better Performance	1-22
Portability	1-23

Higher Productivity.....	1-23
Integration with Oracle.....	1-23

2 Fundamentals

Character Set	2-2
Lexical Units	2-2
Delimiters.....	2-3
Identifiers.....	2-4
Literals.....	2-7
Comments.....	2-9
Datatypes	2-10
Number Types.....	2-11
Character Types.....	2-14
NLS Character Types.....	2-17
LOB Types.....	2-19
Other Types.....	2-21
User-Defined Subtypes	2-22
Defining Subtypes.....	2-23
Using Subtypes.....	2-24
Datatype Conversion	2-25
Explicit Conversion.....	2-25
Implicit Conversion.....	2-26
Implicit versus Explicit Conversion.....	2-27
DATE Values.....	2-27
RAW and LONG RAW Values.....	2-28
NLS Values.....	2-28
Declarations	2-28
Using DEFAULT.....	2-29
Using NOT NULL.....	2-30
Using %TYPE.....	2-30
Using %ROWTYPE.....	2-31
Restrictions.....	2-34
Naming Conventions	2-34
Synonyms.....	2-35
Scoping.....	2-35

Case Sensitivity	2-35
Name Resolution	2-35
Scope and Visibility	2-37
Assignments	2-40
Boolean Values	2-40
Database Values	2-41
Expressions and Comparisons	2-41
Operator Precedence	2-42
Logical Operators	2-43
Comparison Operators	2-44
Concatenation Operator	2-46
Boolean Expressions	2-46
Handling Nulls	2-48
Built-In Functions	2-51

3 Control Structures

Overview	3-2
Conditional Control: IF Statements	3-2
IF-THEN	3-3
IF-THEN-ELSE	3-3
IF-THEN-ELSIF	3-4
Guidelines	3-5
Iterative Control: LOOP and EXIT Statements	3-6
LOOP	3-6
WHILE-LOOP	3-9
FOR-LOOP	3-10
Sequential Control: GOTO and NULL Statements	3-15
GOTO Statement	3-15
NULL Statement	3-19

4 Collections and Records

What Is a Collection?	4-2
Understanding Nested Tables	4-2
Understanding Varrays	4-4
Varrays versus Nested Tables	4-4

Defining and Declaring Collections	4-5
Declaring Collections	4-7
Initializing and Referencing Collections	4-9
Referencing Collection Elements.....	4-11
Assigning and Comparing Collections	4-12
Comparing Whole Collections.....	4-13
Manipulating Collections	4-14
Some Nested Table Examples	4-14
Some Varray Examples	4-16
Manipulating Individual Elements.....	4-18
Using Collection Methods	4-21
Using EXISTS.....	4-22
Using COUNT	4-22
Using LIMIT	4-22
Using FIRST and LAST	4-23
Using PRIOR and NEXT.....	4-23
Using EXTEND	4-24
Using TRIM.....	4-25
Using DELETE	4-26
Applying Methods to Collection Parameters	4-27
Avoiding Collection Exceptions	4-27
What Is a Record?	4-28
Defining and Declaring Records	4-29
Declaring Records.....	4-30
Initializing and Referencing Records	4-31
Referencing Records.....	4-31
Assigning and Comparing Records	4-33
Comparing Records.....	4-35
Manipulating Records	4-35

5 Interaction with Oracle

SQL Support	5-2
Data Manipulation.....	5-2
Transaction Control.....	5-2
SQL Functions	5-3

SQL Pseudocolumns	5-4
SQL Operators.....	5-6
SQL92 Conformance	5-7
Using DDL and Dynamic SQL	5-7
Efficiency versus Flexibility	5-7
Some Limitations	5-8
Overcoming the Limitations	5-8
Managing Cursors	5-9
Explicit Cursors.....	5-9
Implicit Cursors	5-14
Packaging Cursors	5-15
Using Cursor FOR Loops	5-16
Using Subqueries.....	5-17
Using Aliases.....	5-17
Passing Parameters.....	5-18
Using Cursor Variables	5-18
What Are Cursor Variables?	5-19
Why Use Cursor Variables?	5-19
Defining REF CURSOR Types	5-20
Declaring Cursor Variables.....	5-20
Controlling Cursor Variables.....	5-22
Example 1.....	5-27
Example 2.....	5-28
Example 3.....	5-29
Example 4.....	5-31
Reducing Network Traffic.....	5-33
Avoiding Exceptions.....	5-34
Guarding Against Aliasing	5-36
Restrictions	5-37
Using Cursor Attributes	5-38
Explicit Cursor Attributes	5-38
Implicit Cursor Attributes.....	5-42
Processing Transactions	5-44
How Transactions Guard Your Database	5-45
Using COMMIT	5-46

Using ROLLBACK.....	5-47
Using SAVEPOINT.....	5-48
Implicit Rollbacks	5-49
Ending Transactions.....	5-49
Using SET TRANSACTION.....	5-50
Overriding Default Locking.....	5-51
Improving Performance.....	5-54
Dealing with Size Limitations.....	5-60
Ensuring Backward Compatibility.....	5-61

6 Error Handling

Overview	6-2
Advantages of Exceptions	6-3
Predefined Exceptions	6-4
User-Defined Exceptions	6-6
Declaring Exceptions.....	6-6
Scope Rules	6-7
Using EXCEPTION_INIT	6-8
Using raise_application_error.....	6-9
Redeclaring Predefined Exceptions	6-10
How Exceptions Are Raised	6-11
Using the RAISE Statement.....	6-11
How Exceptions Propagate	6-12
Reraising an Exception	6-14
Handling Raised Exceptions	6-15
Exceptions Raised in Declarations	6-16
Exceptions Raised in Handlers	6-17
Branching to or from an Exception Handler.....	6-17
Using SQLCODE and SQLERRM.....	6-18
Unhandled Exceptions	6-19
Useful Techniques	6-20
Continuing after an Exception Is Raised	6-20
Retrying a Transaction	6-21
Using Locator Variables.....	6-22

7 Subprograms

What Are Subprograms?	7-2
Advantages of Subprograms	7-3
Procedures	7-3
Functions	7-5
Restriction	7-6
RETURN Statement	7-7
Declaring Subprograms	7-8
Forward Declarations.....	7-8
Stored Subprograms.....	7-10
Actual versus Formal Parameters	7-11
Positional and Named Notation	7-12
Positional Notation.....	7-12
Named Notation	7-12
Mixed Notation	7-12
Parameter Modes	7-13
IN Mode	7-13
OUT Mode	7-13
IN OUT Mode	7-14
Parameter Default Values	7-15
Parameter Aliasing	7-17
Overloading	7-18
Restrictions	7-19
How Calls Are Resolved.....	7-21
Recursion	7-23
Recursive Subprograms.....	7-24
Mutual Recursion	7-26
Recursion versus Iteration.....	7-27

8 Packages

What Is a Package?	8-2
Advantages of Packages	8-4
The Package Specification	8-5
Referencing Package Contents	8-6
The Package Body	8-7

Some Examples	8-8
Private versus Public Items	8-14
Overloading	8-14
Package STANDARD	8-15
Product-specific Packages	8-16
DBMS_STANDARD.....	8-16
DBMS_OUTPUT.....	8-16
DBMS_PIPE.....	8-17
UTL_FILE.....	8-17
UTL_HTTP.....	8-17
DBMS_SQL.....	8-17
DBMS_ALERT.....	8-18
Guidelines	8-18

9 Object Types

The Role of Abstraction	9-2
What Is an Object Type?	9-3
Why Use Object Types?	9-5
Structure of an Object Type	9-5
Components of an Object Type	9-7
Attributes.....	9-7
Methods.....	9-8
Pragma RESTRICT_REFERENCES.....	9-12
Defining Object Types	9-14
Object Type <i>Stack</i>	9-14
Object Type <i>Ticket_Booth</i>	9-17
Object Type <i>Bank_Account</i>	9-19
Object Type <i>Rational</i>	9-21
Declaring and Initializing Objects	9-23
Declaring Objects.....	9-23
Initializing Objects.....	9-24
How PL/SQL Treats Uninitialized Objects.....	9-25
Accessing Attributes	9-25

Calling Constructors and Methods	9-26
Passing Parameters to a Constructor	9-27
Calling Methods.....	9-27
Sharing Objects	9-28
Using Refs.....	9-29
Forward Type Definitions	9-30
Manipulating Objects	9-31
Selecting Objects	9-32
Inserting Objects	9-36
Updating Objects	9-38
Deleting Objects	9-38

10 External Procedures

What Is an External Procedure?	10-2
Creating an External Procedure	10-2
Registering an External Procedure	10-3
Understanding the EXTERNAL Clause	10-4
An Example	10-5
Calling an External Procedure	10-5
An Example	10-7
How PL/SQL Calls an External Procedure	10-7
Environment Variables	10-8
Passing Parameters to an External Procedure	10-9
Specifying Datatypes.....	10-9
Using the PARAMETERS Clause.....	10-12
Using the WITH CONTEXT Clause.....	10-16
Using Service Routines	10-17
OCIExtProcAllocCallMemory	10-17
OCIExtProcRaiseExcp	10-19
OCIExtProcRaiseExcpWithMsg	10-20
OCIExtProcGetEnv	10-21
Doing Callbacks	10-22
Restrictions on Callbacks.....	10-23
Debugging External Procedures	10-24
Using Package DEBUG_EXTPROC	10-24

Demo Program	10-24
Guidelines for External Procedures	10-25
Restrictions on External Procedures	10-25

11 Language Elements

Assignment Statement	11-3
Blocks	11-7
CLOSE Statement	11-14
Collection Methods	11-16
Collections	11-21
Comments	11-26
COMMIT Statement	11-27
Constants and Variables	11-29
Cursor Attributes	11-33
Cursor Variables	11-38
Cursors	11-45
DELETE Statement	11-49
EXCEPTION_INIT Pragma	11-52
Exceptions	11-54
EXIT Statement	11-57
Expressions	11-59
External Procedures	11-70
FETCH Statement	11-76
Functions	11-79
GOTO Statement	11-83
IF Statement	11-85
INSERT Statement	11-88
Literals	11-91
LOCK TABLE Statement	11-94
LOOP Statements	11-96
NULL Statement	11-102
Object Types	11-103
OPEN Statement	11-111
OPEN-FOR Statement	11-113
Packages	11-117

Procedures	11-121
RAISE Statement	11-126
Records	11-128
RETURN Statement	11-132
ROLLBACK Statement	11-134
%ROWTYPE Attribute	11-136
SAVEPOINT Statement	11-138
SELECT INTO Statement	11-139
SET TRANSACTION Statement	11-142
SQL Cursor	11-144
SQLCODE Function	11-146
SQLERRM Function	11-147
%TYPE Attribute	11-149
UPDATE Statement	11-151

A New Features

External Procedures	A-2
Object Types	A-2
Collections	A-2
LOB Types	A-3
NLS Types	A-3

B Sample Programs

Running the Programs	B-2
Sample 1. FOR Loop	B-11
Sample 2. Cursors	B-12
Sample 3. Scoping	B-13
Sample 4. Batch Transaction Processing	B-15
Sample 5. Embedded PL/SQL	B-19
Sample 6. Calling a Stored Procedure	B-23

C CHAR versus VARCHAR2 Semantics

Assigning Character Values	C-2
Comparing Character Values	C-2

Inserting Character Values	C-4
Selecting Character Values	C-4

D PL/SQL Wrapper

Advantages of Wrapping	D-2
Running the PL/SQL Wrapper	D-2

E Name Resolution

What Is Name Resolution?	E-2
Various Forms of References	E-3
Name-Resolution Algorithm	E-5
Understanding Capture	E-8
Avoiding Capture	E-10
Accessing Attributes and Methods	E-10
Calling Subprograms and Methods	E-11
SQL versus PL/SQL	E-13

F Reserved Words

Index

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PL/SQL User's Guide and Reference, Release 8.0

Part No. A58236-01

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Preface

PL/SQL is Oracle's procedural extension to SQL, the standard database access language. A full-fledged programming language, PL/SQL offers modern software engineering features such as data encapsulation, overloading, 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 effectively, and you learn why PL/SQL is ideal for building enterprise-wide applications.

Major Topics

- What's New in This Edition?
- How This Guide Is Organized
- Notational Conventions
- Sample Database Tables

Audience

Anyone developing 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 the following subjects:

- a procedural programming language such as Ada, C, or COBOL
- the SQL database language
- Oracle concepts and terminology

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.

What's New in This Edition?

Release 8.0 of PL/SQL offers an array of new features that help you build powerful database applications. For example, now you can benefit from

- an interface for calling routines written in other languages
- support for object-oriented programming based on object types
- the collection types TABLE and VARRAY, which allow you to declare nested tables and variable-size arrays
- the LOB (large object) datatypes BFILE, BLOB, CLOB, and NCLOB, which let you manipulate blocks of unstructured data up to four gigabytes in size
- extended National Language Support (NLS) including national character sets and the datatypes NCHAR and NVARCHAR2, which store NLS data

For more information, see Appendix A

Note: This guide applies to Oracle8 and the Oracle8 Enterprise Edition. They have the same basic features. However, several advanced features are available only with the Enterprise Edition, and some of these are optional. For example, to use object types, you must have the Enterprise Edition and the Objects Option. To find out which features are available to you, see *Getting to Know Oracle8 and the Oracle8 Enterprise Edition*.

How This Guide Is Organized

The PL/SQL User's Guide and Reference has 11 chapters and 6 appendices. Chapters 1 through 10 introduce you to PL/SQL and shows you how to use its many features. Chapter 11 serves as a reference to PL/SQL commands, syntax, and semantics. Appendices A through F provide a survey of new features, sample programs, supplementary technical information, and a list of reserved words.

Chapter 1: Overview 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 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: 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 and WHILE-LOOP.

Chapter 4: 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. You also learn how to treat related but dissimilar data as a logical unit.

Chapter 5: Interaction with 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 6: Error Handling 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 7: Subprograms This chapter shows you how to write and use subprograms. It discusses procedures, functions, forward declarations, actual versus formal parameters, positional and named notation, parameter modes, parameter default values, aliasing, overloading, and recursion.

Chapter 8: 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 9: 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 10: External Procedures This chapter presents a new PL/SQL interface for calling routines written in other languages. It shows you how dynamic link libraries (DLLs) already written and available in another language can be called directly from PL/SQL programs.

Chapter 11: 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: New Features This appendix surveys the major new features in Release 8.0 of PL/SQL.

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

Appendix C: CHAR versus VARCHAR2 Semantics This appendix explains the subtle but important semantic differences between the CHAR and VARCHAR2 base types.

Appendix D: PL/SQL Wrapper This appendix shows you how to run the PL/SQL Wrapper, a stand-alone utility that enables you to deliver PL/SQL applications without exposing your source code.

Appendix E: Name Resolution This appendix explains how PL/SQL resolves references to names in potentially ambiguous procedural and SQL statements.

Appendix F: Reserved Words This appendix lists those words reserved for use by PL/SQL.

Notational Conventions

This guide uses the following notation in code examples:

< >	Angle brackets enclose the name of a syntactic element.
--	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.
...	An ellipsis shows that statements or clauses irrelevant to the discussion were left out.
lower case	Lower case denotes user-defined items such as variables, parameters, and exceptions.
UPPER CASE	Upper case denotes PL/SQL keywords.

Terms being defined for the first time, words being emphasized, error messages, and book titles are *italicized*.

The syntax of PL/SQL is described using a simple variant of Backus-Naur Form (BNF), which has the following symbols and lexical conventions:

[]	Brackets enclose optional items.
{ }	Braces enclose items only one of which is required.
	A vertical bar separates alternatives within brackets or braces.
...	An ellipsis shows that the preceding syntactic element can be repeated.
lower case	Lower case denotes a syntactic element for which you must substitute a literal, identifier, or construct, whichever is appropriate.
UPPER CASE	Upper case denotes PL/SQL keywords, which must be spelled as shown but can be entered in lower or mixed case.
punctuation	Punctuation other than brackets, braces, vertical bars, and ellipses must be entered as shown.

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
40	OPERATIONS	BOSTON

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

Your Comments Are Welcome

We appreciate your comments and suggestions. In fact, your opinions are the most important feedback we receive. We encourage you to use the Reader's Comment Form at the front of this guide. You can also send comments to us by

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Overview

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.

Major Topics

Main Features

Architecture

Advantages of PL/SQL

Main Features

A good way to get acquainted with PL/SQL is to look at a sample program. The program below processes an order for tennis rackets. 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

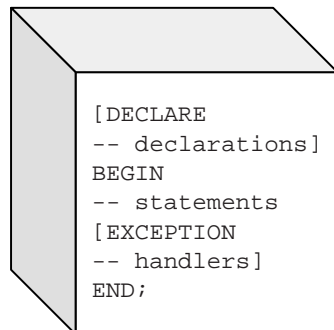
PL/SQL is a *block-structured* language. That is, the basic units (procedures, functions, and anonymous blocks) that make up a PL/SQL program are logical blocks, which can contain any number of nested sub-blocks. Typically, each logical block corresponds to a problem or subproblem to be solved. Thus, 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 allows you to 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, and NUMBER, or any PL/SQL datatype, such as BOOLEAN and 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 two 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 to the right. Some examples follow:

```
tax := price * tax_rate;
bonus := current_salary * 0.10;
amount := TO_NUMBER(SUBSTR('750 dollars', 1, 3));
valid := FALSE;
```

The second way to assign values to a variable is to select or fetch database values into it. In the following example, you have Oracle compute a 10% bonus when you select the salary of an employee:

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

Then, you can use the variable `bonus` in another computation or insert its value into a database table.

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

Result Set			
7369	SMITH	CLERK	
7566	JONES	MANAGER	
7788	SCOTT	ANALYST	Current Row
7876	ADAMS	CLERK	
7902	FORD	ANALYST	

An arrow labeled "cursor" points to the row containing 7788, SCOTT, ANALYST.

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 in a database table, 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 (field) 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 IN 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;
```

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`, you 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 in 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

	<code>emp_rec</code>
<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`, `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;
```

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. This can improve performance and simplify the integrity checks built into Oracle Forms applications.

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, suppose that you are a manufacturer of custom-made cars and that each car has a serial number. To keep track of which customer buys each car, you might use the following `FOR` loop:

```
FOR i IN 1..order_qty LOOP
    UPDATE sales SET custno = customer_id
        WHERE serial_num = serial_num_seq.NEXTVAL;
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 yields `TRUE`, the sequence of statements is executed, then control resumes at the top of the loop. If the condition yields `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 \$4000 and is higher in the chain of command than employee 7902:

```
-- available online in file 'examp3'
DECLARE
    salary          emp.sal%TYPE;
    mgr_num         emp.mgr%TYPE;
    last_name      emp.ename%TYPE;
    starting_empno CONSTANT NUMBER(4) := 7902;
BEGIN
    SELECT sal, mgr INTO salary, mgr_num FROM emp
        WHERE empno = starting_empno;
    WHILE salary < 4000 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;
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 yields `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 logic 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*. Besides blocks and subprograms, PL/SQL provides the package, which allows you to group related program items into larger units.

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
    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
    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.

External Procedures

Some programming tasks are more quickly or easily done in a lower-level language such as C, which is more efficient at machine-precision calculations. For example, a Fast Fourier Transform (FFT) routine written in C runs faster than one written in PL/SQL.

To support such special-purpose processing, PL/SQL provides an interface for calling routines written in other languages. This makes the strengths and capabilities of those languages available to you.

An external procedure is a third-generation-language routine stored in a dynamic link library (DLL), registered with PL/SQL, and called by you to do special-purpose processing. At run time, PL/SQL loads the library dynamically, then calls the routine as if it were a PL/SQL subprogram.

Typically, external procedures are used to interface with embedded systems, solve scientific and engineering problems, analyze data, or control real-time devices and processes. In the following example, you write a PL/SQL stand-alone function named `interp` that registers the C routine `c_interp` as an external function:

```
CREATE FUNCTION interp (
-- find the value of y at x degrees using Lagrange interpolation
  x FLOAT,
  y FLOAT)
RETURN FLOAT AS EXTERNAL
  LIBRARY mathlib
  NAME "c_interp"
  LANGUAGE C;
```

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 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, you 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-96')(5);
    ...
END;
```

Collections work like the arrays found in most third-generation programming languages. They 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.

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 (minutes SMALLINT, hours SMALLINT);
  TYPE MeetingTyp IS RECORD (
    day      DATE,
    time     TimeRec, -- nested record
    place    VARCHAR2(20),
    purpose  VARCHAR2(50));
```

Notice that you can nest records. That is, a record can be the 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 allows you to 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 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
    ELSE
        bonus := (salary * 0.10) + (commission * 0.15);
    END IF;
EXCEPTION
    WHEN comm_missing THEN
        -- process error
```

Architecture

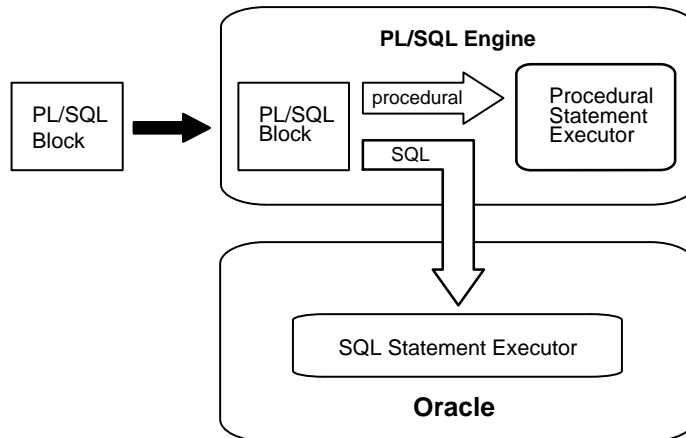
The PL/SQL runtime system is a technology, not an independent product. Think of this technology as an engine that executes PL/SQL blocks and subprograms. The engine can be installed in an Oracle server or in an application development tool such as Oracle Forms or Oracle Reports. So, PL/SQL can reside in two environments:

- the Oracle server
- Oracle tools

These two environments are independent. PL/SQL might be available in the Oracle server but unavailable in tools, or the other way around. 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 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 *stand-alone* subprograms. (Subprograms defined within another subprogram or within a PL/SQL block are called *local* subprograms. They 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 stand-alone procedure `create_dept` from SQL*Plus as follows:

```
SQL> EXECUTE 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 table. You can have Oracle automatically fire the database trigger before or after an `INSERT`, `UPDATE`, or `DELETE` statement affects the table. One of the many uses for database triggers is to audit data modifications. For example, the following database 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;
```

You can use all the SQL data manipulation statements and any procedural statement in the executable part of a database trigger.

In Oracle Tools

When it contains the PL/SQL engine, an application development tool can process PL/SQL blocks. 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
- portability
- higher productivity
- integration with Oracle

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 `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.

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.

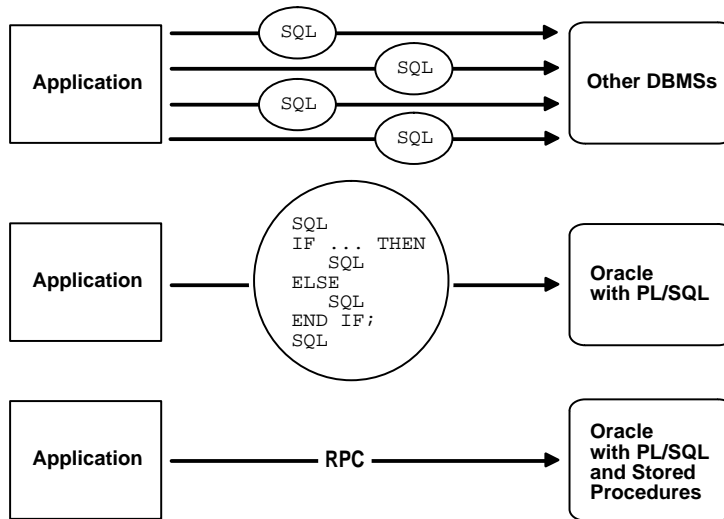
In addition, object types allow for realistic data modeling. Complex real-world entities and relationships map directly into object types. That helps your programs better reflect the world they are trying to simulate.

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.

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.

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.

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 hands of programmers.

Moreover, 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.

Integration with Oracle

Both PL/SQL and Oracle are based on SQL. Moreover, PL/SQL supports all the SQL datatypes. Combined with the direct access that SQL provides, these shared datatypes integrate PL/SQL with the Oracle data dictionary.

The `%TYPE` and `%ROWTYPE` attributes further integrate PL/SQL with the data dictionary. 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 at run time. This provides data independence, reduces maintenance costs, and allows programs to adapt as the database changes to meet new business needs.

Fundamentals

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.

Major Topics

Character Set

Lexical Units

Datatypes

User-Defined Subtypes

Datatype Conversion

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

PL/SQL is not case sensitive, so lowercase letters are equivalent to corresponding uppercase 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

For example, the line

```
bonus := salary * 0.10; -- compute bonus
```

contains the following lexical units:

- identifiers `bonus` and `salary`
- compound symbol `:=`
- simple symbols `*` and `;`
- numeric literal `0.10`
- comment `-- compute bonus`

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 illegal because the reserved words `END` and `IF` are joined:

```
IF x > y THEN high := x; ENDIF; -- illegal
```

However, you cannot embed spaces in lexical units except for string literals and comments. For example, the following line is illegal because the compound symbol for assignment (`:=`) is split:

```
count := count + 1; -- illegal
```

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

<pre>IF x>y THEN max:=x;ELSE max:=y;END IF;</pre>		<pre>IF x > y THEN max := x; ELSE max := y; END IF;</pre>
--	--	--

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

Simple symbols consist of one character; a list follows:

- + 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

Compound symbols consist of one character; a list follows:

- ** exponentiation operator
- <> relational operator
- != relational operator
- ~= relational operator
- <= relational operator
- >= relational operator
- := assignment operator
- => association operator
- .. range operator
- || concatenation operator
- << (beginning) label delimiter
- >> (ending) label delimiter
- single-line comment indicator
- /* (beginning) multi-line comment delimiter
- */ (ending) multi-line comment delimiter

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 illegal, as the following examples show:

```
mine&yours    -- illegal ampersand
debit-amount  -- illegal hyphen
on/off        -- illegal slash
user id       -- illegal space
```

The next examples show that adjoining and trailing dollar signs, underscores, and number signs are legal:

```
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 length 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; -- illegal; causes compilation error
```

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

```
DECLARE
  end_of_game BOOLEAN; -- legal
```

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 legal:

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

The maximum length 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 the next example, it shifts three places to the left:

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

Character Literals

A character literal is an individual character enclosed by single quotes (apostrophes). Several examples follow:

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

Character literals include all the printable characters in the PL/SQL character set: letters, numerals, spaces, and special symbols.

PL/SQL is case sensitive within character literals. For example, PL/SQL considers the literals 'Z' and 'z' to be different.

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 and FALSE and the non-value 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.

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

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

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;
```

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

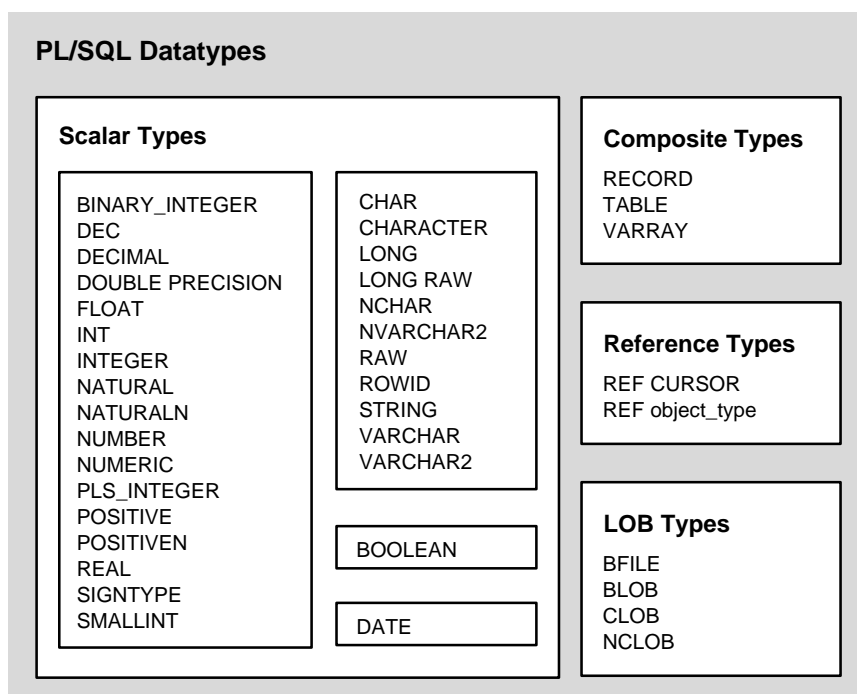
You cannot nest comments. Also, you cannot use single-line comments in a PL/SQL block that will be processed dynamically by an Oracle Precompiler program because end-of-line characters are ignored. As a result, single-line comments extend to the end of the block, not just to the end of a line. So, use multi-line comments instead.

Datatypes

Every constant and variable has a *datatype*, which specifies a storage format, constraints, and valid range of values. PL/SQL provides a variety of 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 *locators*, that specify the location of large objects (graphic images for example) stored out-of-line.

Figure 2-1 shows the predefined datatypes available for your use. An additional scalar type, `MLSLABEL`, is available with Trusted Oracle, a specially secured version of Oracle. The scalar types fall into four families, which store number, character, Boolean, and date/time data, respectively.

Figure 2–1 Built-in Datatypes



This section discusses the scalar types and LOB types. The composite types are discussed in Chapter 4. The reference types are discussed in Chapter 5 and Chapter 9.

Number Types

Number types allow you to 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 `-2147483647 .. 2147483647`. Like `PLS_INTEGER` values, `BINARY_INTEGER` values require less storage than `NUMBER` values. However, most `BINARY_INTEGER` operations are slower than `PLS_INTEGER` operations. (See “`PLS_INTEGER`” on page 2-13.)

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 of virtually any size. Its magnitude range is 1.0E-130 .. 9.99E125. 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 -2147483647 .. 2147483647. **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 better performance, 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 allow you to 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, which might be 7-bit ASCII or EBCDIC Code Page 500, for example.

The `CHAR` datatype takes an optional parameter that lets you specify a maximum length up to 32767 bytes. The syntax follows:

```
CHAR[ (maximum_length) ]
```

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

If you do not specify a maximum length, it defaults to 1. Remember, you specify the maximum length in bytes, not characters. So, if a `CHAR(n)` variable stores multi-byte characters, its maximum length is less than n characters. The maximum width of a `CHAR` database column is 2000 bytes. So, you cannot insert `CHAR` values longer than 2000 bytes into a `CHAR` column.

You can insert any `CHAR(n)` value into a `LONG` database column because the maximum width of a `LONG` column is 2147483647 bytes or 2 gigabytes. However, you cannot retrieve a value longer than 32767 bytes from a `LONG` column into a `CHAR(n)` variable.

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

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

You can insert any `LONG` value into a `LONG` database column because the maximum width of a `LONG` column is 2147483647 bytes. However, you cannot retrieve a value longer than 32760 bytes from a `LONG` column into a `LONG` 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 *Oracle8 SQL Reference*.

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, Net8 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 length up to 32767 bytes. The syntax follows:

```
RAW(maximum_length)
```

You cannot use a constant or variable to specify the maximum length; 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 2147483647 bytes. However, you cannot retrieve a value longer than 32767 bytes from a `LONG RAW` column into a `RAW` variable.

LONG RAW

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 length of a `LONG RAW` value is 32760 bytes.

You can insert any LONG RAW value into a LONG RAW database column because the maximum width of a LONG RAW column is 2147483647 bytes. However, you cannot retrieve a value longer than 32760 bytes from a LONG RAW column into a LONG RAW variable.

ROWID

Internally, every database table has a ROWID pseudocolumn, which stores hexadecimal strings called *rowids*. Each rowid represents the storage address of a row. You use the ROWID datatype to store rowids.

You can compare a ROWID 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 5-53.

With Oracle8, rowids have been extended to support partitioned tables and indexes. Extended rowids include a *data object number*, which identifies the database segment. Schema objects in the same segment (for example, a cluster of tables) have the same object number.

A rowid contains the following information, which is needed to locate a row:

- data object number
- data file (the first file is 1)
- data block in the data file
- row in the data block (the first row is 0)

Rowids provide the fastest way to access particular rows. Normally, a rowid uniquely identifies a row. However, rows in different tables stored in the same cluster can have the same rowid.

To manipulate rowids, you use the supplied package DBMS_ROWID, which is described in *Oracle8 Application Developer's Guide*.

VARCHAR2

You use the VARCHAR2 datatype to store variable-length character data. How the data is represented internally depends on the database character set, which might be 7-bit ASCII or EBCDIC Code Page 500, for example.

The VARCHAR2 datatype takes a required parameter that specifies a maximum length up to 32767 bytes. The syntax follows:

```
VARCHAR2(maximum_length)
```


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

Remember, you specify the maximum length of a `VARCHAR2(n)` variable in bytes, not characters. So, if a `VARCHAR2(n)` variable stores multi-byte characters, its maximum length is less than n characters. The maximum width of a `VARCHAR2` database column is 4000 bytes. Therefore, you cannot insert `VARCHAR2` values longer than 4000 bytes into a `VARCHAR2` column.

You can insert any `VARCHAR2(n)` value into a `LONG` database column because the maximum width of a `LONG` column is 2147483647 bytes. However, you cannot retrieve a value longer than 32767 bytes from a `LONG` column into a `VARCHAR2(n)` variable.

Semantic differences between the `CHAR` and `VARCHAR2` base types are discussed in Appendix C.

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`.

NLS Character Types

Although the widely used 7- or 8-bit ASCII and EBCDIC character sets are adequate to represent the Roman alphabet, some Asian languages, such as Japanese, contain thousands of characters. These languages require 16 bits (two bytes) to represent each character. How does Oracle deal with such dissimilar languages?

Oracle provides National Language Support (NLS), which lets you process single-byte and multi-byte character data and convert between character sets. It also lets your applications run in different language environments.

With NLS, number and date formats adapt automatically to the language conventions specified for a user session. Thus, NLS allows users around the world to interact with Oracle in their native languages. For more information about NLS, see *Oracle8 SQL Reference*.

PL/SQL V2 supports just one character set called the *database character set*, which is used for identifiers and source code. But, PL/SQL V8 supports a second character set called the *national character set*, which is used for NLS data. The datatypes NCHAR and NVARCHAR2 store character strings formed from the national character set.

NCHAR

You use the NCHAR datatype to store fixed-length (blank-padded if necessary) NLS character data. How the data is represented internally depends on the national character set, which might use a fixed-width encoding such as US7ASCII or a variable-width encoding such as JA16SJIS.

The NCHAR datatype takes an optional parameter that lets you specify a maximum length up to 32767 bytes. The syntax follows:

```
NCHAR[ (maximum_length) ]
```

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

If you do not specify a maximum length, it defaults to 1. How you specify the maximum length depends on the national character set. For fixed-width character sets, you specify the maximum length in characters. For variable-width character sets, you specify it in bytes. In the following example, the character set is JA16EUCFIXED (which is fixed-width), so you specify the maximum length in characters:

```
my_string NCHAR(100); -- maximum length 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. Remember, for fixed-width, multi-byte character sets, you cannot insert NCHAR values longer than the number of characters that fit in 2000 bytes.

If the NCHAR value is shorter than the defined width of the NCHAR column, Oracle blank-pads the value to the defined width. You cannot insert CHAR values into an NCHAR column. Likewise, you cannot insert NCHAR values into a CHAR column.

NVARCHAR2

You use the `NVARCHAR2` datatype to store variable-length NLS character data. How the data is represented internally depends on the national character set, which might use a fixed-width encoding such as `WE8EBCDIC37C` or a variable-width encoding such as `JA16DBCS`.

The `NVARCHAR2` datatype takes a required parameter that specifies a maximum length up to 32767 bytes. The syntax follows:

```
NVARCHAR2(maximum_length)
```

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

How you specify the maximum length depends on the national character set. For fixed-width character sets, you specify the maximum length in characters. For variable-width character sets, you specify it in bytes. In the following example, the character set is `JA16SJIS` (which is variable-width), so you specify the maximum length in bytes:

```
my_string NVARCHAR2(200); -- maximum length is 200 bytes
```

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. Remember, for fixed-width, multi-byte character sets, you cannot insert `NVARCHAR2` values longer than the number of characters that fit in 4000 bytes.

You cannot insert `VARCHAR2` values into an `NVARCHAR2` column. Likewise, you cannot insert `NVARCHAR2` values into a `VARCHAR2` column.

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, piecewise 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 values, called *locators*, that specify the location of 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 retrieve a `BLOB` column value, only a locator is returned. Locators cannot span transactions or sessions. So, you cannot save a locator in a PL/SQL variable during one transaction or session, then use it in another transaction or session. To manipulate LOBs, you use the supplied package `DBMS_LOB`. For more information about LOBs and package `DBMS_LOB`, see *Oracle8 Application Developer's Guide*.

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. You cannot modify them. The maximum number of open `BFILES` is set by the Oracle initialization parameter `SESSION_MAX_OPEN_FILES`, which is system dependent.

Also, `BFILES` do not participate in transactions. The underlying operating system maintains file integrity. The size of a `BFILE` is system dependent but cannot exceed four gigabytes ($2^{32} - 1$ bytes). Your DBA makes sure that the `BFILE` exists and that Oracle has read permissions on it.

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. Changes made by package `DBMS_LOB` or the OCI can be committed or rolled back. However, `BLOB` locators cannot span transactions or sessions.

CLOB

You use the `CLOB` datatype to store large blocks of single-byte character data in the database, in-line or out-of-line. (Variable-width character sets are not 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. Changes made by package `DBMS_LOB` or the OCI can be committed or rolled back. However, CLOB locators cannot span transactions or sessions.

NCLOB

You use the `NCLOB` datatype to store large blocks of single-byte or fixed-width multi-byte `NCHAR` data in the database, in-line or out-of-line. (Variable-width character sets are not 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.

`NCLOB`s participate fully in transactions. Changes made by package `DBMS_LOB` or the OCI can be committed or rolled back. However, `NCLOB` locators cannot span transactions or sessions.

Other Types

The following types allow you to store and manipulate logical (true, false) values, date/time values, and Trusted Oracle operating system labels.

BOOLEAN

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

The `BOOLEAN` datatype takes no parameters. Only the values `TRUE` and `FALSE` and the non-value `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.

DATE

You use the `DATE` datatype to store fixed-length date/time values. `DATE` values 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.

Valid dates range from January 1, 4712 BC to December 31, 4712 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 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.

For more information about date functions and format models, see *Oracle8 SQL Reference*.

MLSLABEL

Trusted Oracle provides the `MLSLABEL` datatype, which stores Trusted Oracle's internal representation of labels generated by multi-level secure operating systems. Trusted Oracle uses the labels to control database access.

For compatibility with Trusted Oracle applications, the Oracle server lets you use `MLSLABEL` to define database columns. However, such columns can store only nulls. For more information, see your Trusted Oracle documentation.

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.

PL/SQL predefines several subtypes in package `STANDARD`. For example, PL/SQL predefines the subtype `CHARACTER`, as follows:

```
SUBTYPE CHARACTER IS CHAR;
```

The subtype `CHARACTER` specifies the same set of values as its base type `CHAR`. Thus, `CHARACTER` is an *unconstrained* subtype.

Subtypes can increase reliability, provide compatibility with ANSI/ISO types, and improve readability by indicating the intended use of constants and variables.

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;
```

where *subtype_name* is a type specifier used in subsequent declarations and *base_type* is any scalar or user-defined PL/SQL type. To specify *base_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, cursor variable, or database table. Some examples follow:

```
DECLARE
  SUBTYPE EmpDate IS DATE;           -- based on DATE type
  SUBTYPE Counter IS NATURAL;        -- based on NATURAL subtype
  TYPE NameList IS TABLE OF VARCHAR2(10);
  SUBTYPE EmpRoster IS NameList;     -- based on TABLE type
  TYPE TimeRec IS RECORD (minutes INTEGER, hours INTEGER);
  SUBTYPE Time IS TimeRec;           -- based on RECORD type
  SUBTYPE ID_Num IS emp.empno%TYPE;  -- based on column type
  CURSOR c1 IS SELECT * FROM dept;
  SUBTYPE DeptFile IS c1%ROWTYPE;    -- based on cursor rowtype
```

However, you cannot specify a constraint on the base type. For example, the following definitions are illegal:

```
DECLARE
  SUBTYPE Accumulator IS NUMBER(7,2); -- illegal; must be NUMBER
  SUBTYPE Delimiter IS CHAR(1);       -- illegal; must be CHAR
  SUBTYPE Word IS VARCHAR2(15);       -- illegal
```

Although you cannot define constrained subtypes directly, you can use a simple workaround to define size-constrained subtypes indirectly. Simply declare a size-constrained variable, then use %TYPE to provide its datatype, as shown in the following example:

```
DECLARE
  temp VARCHAR2(15);
  SUBTYPE Word IS temp%TYPE; -- maximum size of Word is 15
```

Likewise, if you define a subtype using %TYPE to provide the datatype of a database column, the subtype adopts the size constraint (if any) of the column. However, the subtype does *not* adopt 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 two variables of type *Counter*. Notice how the subtype name indicates the intended use of the variables.

```
DECLARE
    SUBTYPE Counter IS NATURAL;
    rows      Counter;
    employees 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 *Scale* to storing integers in the range -9 .. 9. If your program tries to store a number outside that range in a *Scale* variable, PL/SQL raises an exception.

```
DECLARE
    temp NUMBER(1,0);
    SUBTYPE Scale IS temp%TYPE;
    x_axis Scale; -- magnitude range is -9 .. 9
    y_axis Scale;
BEGIN
    x_axis := 10; -- raises VALUE_ERROR
```

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;
```


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;
```

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;
  SUBTYPE Text IS VARCHAR2;
  verb Word;
  sentence Text;
BEGIN
  ...
  sentence := verb;
```

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 *Oracle8 SQL Reference*.

Implicit Conversion

When it makes sense, PL/SQL can convert the datatype of a value implicitly. This allows you to 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,'SSSS') INTO start_time FROM sys.dual;
    -- do something
    /* Get system time again. */
    SELECT TO_CHAR(SYSDATE,'SSSS') 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 2-1 shows which implicit conversions PL/SQL can do.

Table 2–1 Implicit Conversions

	BIN_INT	CHAR	DATE	LONG	NUMBER	PLS_INT	RAW	ROWID	VARCHAR2
BIN_INT		X		X	X	X			X
CHAR	X		X	X	X	X	X	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
ROWID		X							X
VARCHAR2	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.

NLS Values

When passed an uppercase character set name, the built-in function NLS_CHARSET_ID returns the corresponding character set ID number. Conversely, when passed a character set ID number, the function NLS_CHARSET_NAME returns the corresponding character set name.

If you pass the value 'CHAR_CS' or 'NCHAR_CS' to NLS_CHARSET_ID, it returns the database or national character set ID number, respectively. For a list of character set names, see *Oracle8 Reference*.

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`. For example, the following declarations are equivalent:

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

In constant declarations, 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 declarations

```
blood_type CHAR := 'O';
valid      BOOLEAN := FALSE;
```

can be rewritten as follows:

```
blood_type CHAR DEFAULT 'O';
valid      BOOLEAN DEFAULT FALSE;
```

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 illegal:

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

Recall that the subtypes `NATURALN` and `POSITIVEN` 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 illegal:

```
line_items POSITIVEN; -- illegal; 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.

Note, however, that a `NOT NULL` column constraint does *not* apply to variables declared using `%TYPE`. 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. In the following example, you select column values into a record named `emp_rec`:

```
DECLARE
    emp_rec emp%ROWTYPE;
    ...
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
  /* Declare cursor specification. */
  CURSOR c1 RETURN emp%ROWTYPE;
  ...
END emp_actions;

CREATE PACKAGE BODY emp_actions AS
  /* Define cursor body. */
  CURSOR c1 RETURN emp%ROWTYPE IS
    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 legal:

```
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 illegal:

```
dept_rec2 := dept_rec3; -- illegal
```


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 deptno, dname, loc INTO dept_rec FROM dept
        WHERE deptno = 30;
```

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

```
record_name := (value1, value2, value3, ...); -- illegal
```

Although you can retrieve entire records, you cannot insert or update them. For example, the following statement is illegal:

```
INSERT INTO dept VALUES (dept_rec); -- illegal
```

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

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 illegal:

```
maxi INTEGER := 2 * mini; -- illegal
mini INTEGER := 15;
```

However, PL/SQL does allow the forward declaration of subprograms. For more information, see “Forward Declarations” on page 7-8.

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 illegal:

```
i, j, k SMALLINT; -- illegal
```

The legal version follows:

```
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, stand-alone 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 procedures.

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. For example, two of the following declarations are illegal:

```
DECLARE
  valid_id BOOLEAN;
  valid_id VARCHAR2(5); -- illegal duplicate identifier
  FUNCTION bonus (valid_id IN INTEGER) RETURN REAL IS ...
                    -- illegal triplicate identifier
```

For the scoping rules that apply to identifiers, see “Scope and Visibility” on page 2-37.

Case Sensitivity

Like other 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
  ZIP_CODE INTEGER; -- same as zip_code and Zip_Code
```

Name Resolution

In potentially ambiguous SQL statements, the names of local variables and formal parameters take precedence over the names of database tables. For example, the following `UPDATE` statement fails because PL/SQL assumes that `emp` refers to the loop counter:

```
FOR emp IN 1..5 LOOP
  ...
  UPDATE emp SET bonus = 500 WHERE ...
END LOOP;
```

Likewise, the following `SELECT` statement fails because PL/SQL assumes that `emp` refers to the formal parameter:

```
PROCEDURE calc_bonus (emp NUMBER, bonus OUT REAL) IS
    avg_sal REAL;
BEGIN
    SELECT AVG(sal) INTO avg_sal FROM emp WHERE ...
```

In such cases, you can prefix the table name with a username, as follows, but a better programming practice is to rename the variable or formal parameter:

```
PROCEDURE calc_bonus (emp NUMBER, bonus OUT REAL) IS
    avg_sal REAL;
BEGIN
    SELECT AVG(sal) INTO avg_sal FROM scott.emp WHERE ...
```

Unlike the names of tables, the names of 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 `enames` 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 E.

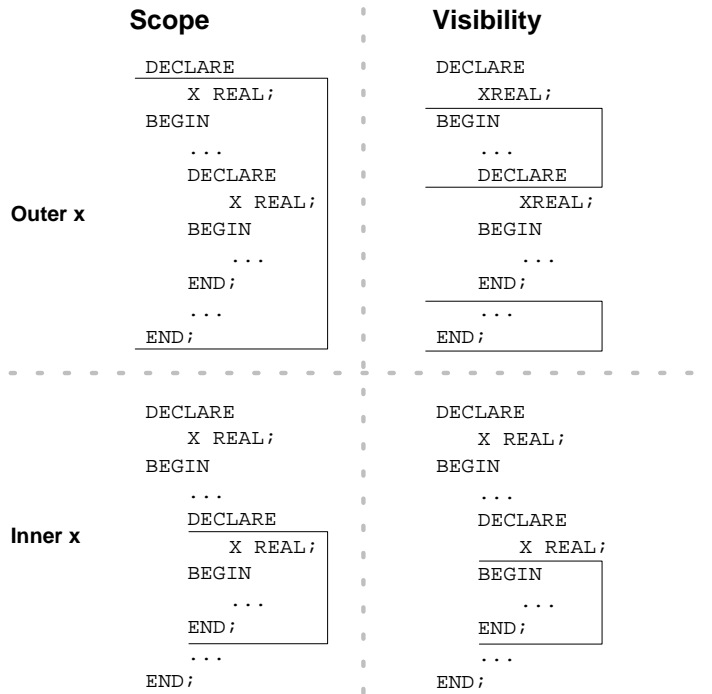
Scope and Visibility

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 2-2 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 2–2 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;
```

```

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;
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` and `FALSE` and the non-value `NULL` can be assigned to a Boolean variable. For example, given the declaration

```
DECLARE
    done BOOLEAN;
```

the following statements are legal:

```
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 legal:

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


Database Values

Alternatively, 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
  my_empno emp.empno%TYPE;
  my_ename emp.ename%TYPE;
  wages    NUMBER(7,2);
BEGIN
  ...
  SELECT ename, sal + comm
         INTO last_name, wages FROM emp
         WHERE empno = emp_id;
```

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 2–2 shows the default order of operations from first to last (top to bottom).

Table 2–2 *Order of Operations*

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

Operators with higher precedence are applied first. For example, both of the following expressions yield 8 because division has a higher precedence than addition:

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

Operators with the same precedence are applied in no particular order.

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

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

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

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

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

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

Logical Operators

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

Table 2–3 Logic Truth Table

x	y	x AND y	x OR y	NOT x
TRUE	TRUE	TRUE	TRUE	FALSE
TRUE	FALSE	FALSE	TRUE	
TRUE	NULL	NULL	TRUE	
FALSE	TRUE	FALSE	TRUE	TRUE
FALSE	FALSE	FALSE	FALSE	
FALSE	NULL	FALSE	NULL	
NULL	TRUE	NULL	TRUE	NULL
NULL	FALSE	FALSE	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 Nulls” on page 2-48.

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 allows you to 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 the `WHERE` clause of SQL data manipulation statements and in conditional control statements.

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`. Therefore, to test for *nullity* (the state of being null), do not use the statement

```
IF variable = NULL THEN ...
```

Instead, use the following statement:

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

LIKE Operator

You use the `LIKE` operator to compare 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.

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 yields `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 yields `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 to another, as the following example shows:

```
'suit' || 'case' = 'suitcase'
```

If both operands have datatype `CHAR`, the concatenation operator returns a `CHAR` value. 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.

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 yields `TRUE`:

```
number1 > number2
```

Character Expressions

Likewise, you can compare character values for equality or inequality. Comparisons are based on the collating sequence used for the database character set. 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. For example, given the assignments

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

the following expression yields `TRUE`:

```
string1 > string2
```

However, there are semantic differences between the `CHAR` and `VARCHAR2` base types that come into play when you compare character values. For more information, refer to Appendix C.

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 yields `TRUE`:

```
date1 > date2
```

Guidelines

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 ...
```

It is a good idea to use parentheses when doing comparisons. For example, the following expression is illegal because `100 < tax` yields `TRUE` or `FALSE`, which cannot be compared with the number 500:

```
100 < tax < 500 -- illegal
```

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;
```

Handling Nulls

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

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:

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

The sequence of statements in the `ELSE` clause is executed when the `IF` condition yields `FALSE` or `NULL`. So, if either or both x and y are null, the first `IF` statement assigns the value of y to $high$, but the second `IF` statement assigns the value of x to $high$. If neither x nor y is null, both `IF` statements assign the same value 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_VARCHAR2('');
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' = '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
- conversion
- date
- miscellaneous

Table 2-4 shows the functions in each category. For descriptions of the error-reporting functions, see Chapter 11. For descriptions of the other functions, see *Oracle8 SQL Reference*.

You can use all the functions in SQL statements except the error-reporting functions `SQLCODE` and `SQLERRM`. Also, you can use all the functions in procedural statements except the miscellaneous functions `DECODE`, `DUMP`, and `VSIZE`.

The SQL group functions `AVG`, `MIN`, `MAX`, `COUNT`, `SUM`, `STDDEV`, and `VARIANCE` are not built into PL/SQL. Nevertheless, you can use them in SQL statements (but not in procedural statements).

Table 2–4 Built-in Functions

Error	Number	Character	Conversion	Date	Misc
SQLCODE	ABS	ASCII	CHARTOROWID	ADD_MONTHS	DECODE
SQLERRM	ACOS	CHR	CONVERT	LAST_DAY	DUMP
	ASIN	CONCAT	HEXTORAW	MONTHS_BETWEEN	GREATEST
	ATAN	INITCAP	NLS_CHARSET_ID	NEW_TIME	GREATEST_LB
	ATAN2	INSTR	NLS_CHARSET_NAME	NEXT_DAY	LEAST
	CEIL	INSTRB	RAWTOHEX	ROUND	LEAST_UB
	COS	LENGTH	ROWIDTOCHAR	SYSDATE	NVL
	COSH	LENGTHB	TO_CHAR	TRUNC	UID
	EXP	LOWER	TO_DATE		USER
	FLOOR	LPAD	TO_LABEL		USERENV
	LN	LTRIM	TO_MULTI_BYTE		VSIZE
	LOG	NLS_INITCAP	TO_NUMBER		
	MOD	NLS_LOWER	TO_SINGLE_BYTE		
	POWER	NLS_UPPER			
	ROUND	NLSORT			
	SIGN	REPLACE			
	SIN	RPAD			
	SINH	RTRIM			
	SQRT	SOUNDEX			
	TAN	SUBSTR			
	TANH	SUBSTRB			
	TRUNC	TRANSLATE			
		UPPER			

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. And, their proper use leads naturally to a well-structured program.

Major Topics

Overview

Conditional Control: IF Statements

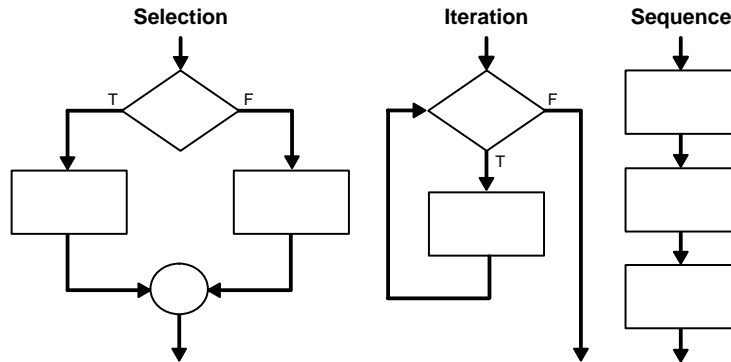
Iterative Control: LOOP and EXIT Statements

Sequential Control: GOTO and NULL Statements

Overview

According to the *structure theorem*, any computer program can be written using the basic control structures shown in Figure 3-1. They can be combined in any way necessary to deal with a given problem.

Figure 3-1 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 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.

IF-THEN

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 yields TRUE. If the condition yields 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

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 yields FALSE or NULL. Thus, the ELSE clause ensures that a sequence of statements is executed. In the following example, the first or second UPDATE statement is executed when the condition is true or false, respectively:

```
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

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 yields **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 yields **TRUE**, its associated sequence of statements is executed and control passes to the next statement. If all conditions yield **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 more 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 yields TRUE, its associated statement is executed and control passes to the INSERT statement.

Guidelines

Avoid clumsy IF statements like those in the following example:

```
DECLARE
    ...
    overdrawn BOOLEAN;
BEGIN
    ...
    IF new_balance < minimum_balance THEN
        overdrawn := TRUE;
    ELSE
        overdrawn := FALSE;
    END IF;
    ...
    IF overdrawn = TRUE THEN
        RAISE insufficient_funds;
    END IF;
END;
```

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:

<pre>IF condition1 THEN statement1; ELSE IF condition2 THEN statement2; ELSE IF condition3 THEN statement3; END IF; END IF; END IF;</pre>	<pre>IF condition1 THEN statement1; ELSIF condition2 THEN statement2; ELSIF condition3 THEN statement3; END IF;</pre>
---	---

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

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 “[RETURN Statement](#)” on page 7-7.

EXIT-WHEN

The `EXIT-WHEN` statement allows a loop to complete conditionally. When the `EXIT` statement is encountered, the condition in the `WHEN` clause is evaluated. If the condition yields `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 yields `TRUE`, the loop cannot complete. So, statements within the loop must change the value of the condition. In the last example, if the `FETCH` statement returns a row, the condition yields `FALSE`. When the `FETCH` statement fails to return a row, the condition yields `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, you can 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 yields `TRUE`, the sequence of statements is executed, then control resumes at the top of the loop. If the condition yields `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. Since the condition is tested at the top of the loop, the sequence might execute zero times. In the last example, if the initial value of `total` is greater than 25000, the condition yields `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. (Cursor `FOR` loops, which iterate over the result set of a cursor, are discussed in Chapter 5.) 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, if you use the keyword `REVERSE`, iteration proceeds downward from the higher bound to the lower bound, as the example below shows. After each iteration, the loop counter is decremented.

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

Nevertheless, you write the range bounds in ascending (not descending) order.

Inside a `FOR` loop, the loop counter can be referenced like a constant. So, the loop counter can appear in expressions 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 integers. For example, the following iteration schemes are legal:

```
j IN -5..5
k IN REVERSE first..last
step IN 0..TRUNC(high/low) * 2
code IN ASCII('A')..ASCII('J')
```

As you can see, the lower bound need not be 1. However, the loop counter increment (or decrement) must be 1. Some languages provide a STEP clause, which lets you specify a different increment. An example written in BASIC follows:

```
FOR J = 5 TO 15 STEP 5 :REM assign values 5,10,15 to J
    sequence_of_statements -- J has values 5,10,15
NEXT J
```

PL/SQL has no such structure, but you can easily build one. Consider the following example:

```
FOR j IN 5..15 LOOP -- assign values 5,6,7,... to j
    IF MOD(j, 5) = 0 THEN -- pass multiples of 5
        sequence_of_statements; -- j has values 5,10,15
    END IF;
END LOOP;
```

This loop is logically equivalent to the previous BASIC loop. Within the sequence of statements, the loop counter has only the values 5, 10, and 15.

You might prefer the less elegant but more efficient method shown in the example below. Within the sequence of statements, each reference to the loop counter is multiplied by the increment.

```
FOR j IN 1..3 LOOP -- assign values 1,2,3 to j
    sequence_of_statements; -- each j becomes j*5
END LOOP;
```

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 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 allows a `FOR` loop to 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 make the meaning and action of conditional statements clear and so improve readability.

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, simply add the NULL statement, as follows:

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

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, `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;
```

Also, a `GOTO` statement cannot branch from one `IF` statement clause to another, as the following example shows:

```
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 meets this requirement. So, you can use the `NULL` statement 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 receive 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 allows you to 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;
```

Collections and Records

Knowledge is that area of ignorance that we arrange and classify.

Ambrose Bierce

Increasingly, programmers are using collection types such as arrays, bags, lists, nested tables, sets, and trees in traditional database applications. To meet the growing demand, PL/SQL provides the datatypes `TABLE` and `VARRAY`, which allow you to declare 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.

Major Topics

- What Is a Collection?
- Initializing and Referencing Collections
- Assigning and Comparing Collections
- Manipulating Collections
- Using Collection Methods
- Avoiding Collection Exceptions
- What Is a Record?
- Defining and Declaring Records
- Initializing and Referencing Records
- Assigning and Comparing 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 kinds of collections: nested tables and varrays (short for variable-size arrays).

Collections work like the arrays found in most third-generation programming languages. However, 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.)

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. Furthermore, you can define collection types in a PL/SQL package, then use them programmatically in your applications.

Note: To use nested tables and varrays, you must have the Oracle8 Enterprise Edition and the Objects Option. For more information, see *Getting to Know Oracle8 and the Oracle8 Enterprise Edition*.

Understanding Nested Tables

Items of type `TABLE` are called *nested tables*. Within the database, they can be viewed as 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.

Within PL/SQL, nested tables are like one-dimensional arrays. However, nested tables differ from arrays in two important ways. First, arrays have a fixed upper bound, but nested tables are unbounded (see Figure 4-1). So, the size of a nested table can increase dynamically.

Figure 4–1 Array versus Nested Table**Array of Integers**

321	17	99	407	83	622	105	19	67	278
x(1)	x(2)	x(3)	x(4)	x(5)	x(6)	x(7)	x(8)	x(9)	x(10)

Fixed
Upper
Bound**Nested Table after Deletions**

321		99	407		622	105	19		278
x(1)		x(3)	x(4)		x(6)	x(7)	x(8)		x(10)

Unbounded
→

Second, arrays must be *dense* (have consecutive subscripts). So, you cannot delete individual elements from an array. Initially, nested tables are dense, but they can be *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.

Differences Between Nested Tables and Index-by Tables

Nested tables differ from Version 2 PL/SQL tables (called *index-by* tables from here on) in the following ways:

- In SQL, you can manipulate nested tables but not index-by tables.
- Nested tables are initially dense, but index-by tables are initially sparse.
- The following element types are allowed for index-by tables but not for nested tables: `BINARY_INTEGER`, `BOOLEAN`, `LONG`, `LONG RAW`, `NATURAL`, `NATURALN`, `PLS_INTEGER`, `POSITIVE`, `POSITIVEN`, `SIGNTYPE`, and `STRING`.
- Unlike nested table types, index-by table types are defined using the clause `INDEX BY BINARY_INTEGER`.
- 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.
- At run time, index-by tables become non-null automatically. But, nested tables become non-null only when explicitly assigned a value.
- Nested tables can be null, but index-by tables cannot. So, the predefined exception `COLLECTION_IS_NULL` applies only to nested tables.

- For nested tables, the legal subscript range is 1 .. 2147483647. But, for index-by tables, the range is -2147483647 .. 2147483647. So, unlike nested tables, index-by tables can have negative subscripts.
- Subscripts for a nested table are constrained, but subscripts for an index-by table are not. So, the predefined exceptions `SUBSCRIPT_OUTSIDE_LIMIT` and `SUBSCRIPT_BEYOND_COUNT` apply only to nested tables.
- 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.
- The built-in procedures `EXTEND` and `TRIM` can be applied only to nested tables.

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 4–2). For example, `Grade(3)` references the third element in varray `Grades`.

Figure 4–2 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, or 10. 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.

- Oracle stores varray data in-line (in the same tablespace). But, 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 storage 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 more than subsets. 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, you use the syntax

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

and for varrays, you use the following 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
BOOLEAN
LONG
LONG RAW
NATURAL
NATURALN
NCHAR
NCLOB
NVARCHAR2
```

object types with `TABLE` or `VARRAY` attributes

```
PLS_INTEGER
POSITIVE
POSITIVEN
```

```
REF CURSOR
SIGNTYPE
STRING
TABLE
VARRAY
```

If *element_type* is a record type, every field in the record must be a scalar type or an object type.

For index-by tables, you use the syntax

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

Though not allowed for nested tables or varrays, the following element types are allowed for index-by tables: `BINARY_INTEGER`, `BOOLEAN`, `LONG`, `LONG RAW`, `NATURAL`, `NATURALN`, `PLS_INTEGER`, `POSITIVE`, `POSITIVEN`, `SIGNTYPE`, and `STRING`. That is because nested tables and varrays are intended primarily to be columns of database tables. As such, they cannot access PL/SQL-specific types. When declared locally, they could theoretically use those types, but the restriction is preserved for consistency.

Unlike nested tables, which are initially dense, index-by tables are initially sparse. That enables you, for example, to store reference data in a temporary 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) 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;
```

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

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 TABLE 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);
    
```

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 collection is atomically null (that is, the collection itself is null, not its elements). To initialize a collection, 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');
```

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));
```

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.

If you did not 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, 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', ...);
```

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
```

Except for index-by tables, PL/SQL never calls a constructor implicitly, so you must call it explicitly. Constructor calls are allowed wherever function calls are allowed. That includes the SELECT, VALUES, and SET clauses. 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 Brighton 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', 13500),
                Project(2, 'Find Missing Computer Chips', 2750),
                Project(3, 'Inspect Emergency Exits', 1900)));
```

Referencing Collection Elements

Every element reference 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 a positive integer. For nested tables, the integer must lie in the range 1 .. 2147483647. For varrays, the integer must lie in the range 1 .. `maximum_size`.

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 ...
```

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 Caruso', 'R Singh', ...);
    i BINARY_INTEGER;
BEGIN
    ...
    verify_name(names(i)); -- call procedure
```

When calling a function that returns a collection, you use the following syntax to reference elements in the collection:

```
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
        ...
    END;
BEGIN
    staffer := new_hires('16-OCT-96')(3); -- call function
```

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; -- illegal; 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
```

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 exception `VALUE_ERROR`. If the collection is atomically null, PL/SQL raises `COLLECTION_IS_NULL`. Some examples follow:

```
DECLARE
    TYPE NumList IS TABLE OF INTEGER;
    nums NumList := NumList(10,20,30);
    ints NumList;
    ...
BEGIN
    ...
    nums(1) := TRUNC(high/low);
    nums(3) := nums(1);
    nums(2) := ASCII('B');
    /* Assume that execution continues despite the raised exception. */
    nums('A') := 40; -- raises VALUE_ERROR
    ints(1) := 15;   -- raises COLLECTION_IS_NULL
```

Comparing Whole Collections

Collections 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;
```

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

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

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. Within SQL, you can manipulate whole collections easily.

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 (in another tablespace).

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 the Workplace', 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)));
```

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(4720, 'Advanced Workshop in Fiction', 5),
            Course(4725, 'Advanced Workshop in Poetry', 5));
BEGIN
    UPDATE department
        SET courses = new_courses WHERE name = 'English';

```

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';

```

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 Computer Chips', 2750),
        Project(3, 'Upgrade Alarm System', 3350),
        Project(4, 'Inspect Emergency Exits', 1900)));
```

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 Statistics', 825));
BEGIN
    UPDATE department
        SET projects = new_projects WHERE dept_id = 60;
```

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;
```

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

```
BEGIN
    DELETE FROM department WHERE dept_id = 30;
```

Manipulating Individual Elements

So far, you have manipulated whole collections. Within SQL, to manipulate the individual elements of a nested table, you must use the operator `THE`. However, `THE` cannot operate on varrays. So, to manipulate the individual elements of a varray, you must use PL/SQL procedural statements.

Some Nested Table Examples

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

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

The operand of `THE` is a subquery that returns a single column value for you to manipulate. The column value must be a nested table. Otherwise, you get a runtime error. Because the value is a nested table, not a scalar value, Oracle must be informed, which is what operator `THE` does.

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

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

In the next 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 THE(SELECT courses FROM department
            WHERE name = 'History')
        WHERE course_no = 3105;
```

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

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

Some Varray Examples

Remember, within SQL, you cannot manipulate the individual elements of a varray. 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
  /* Retrieve project list into local varray. */
  SELECT projects INTO my_projects FROM department
    WHERE dept_no = dept_id FOR UPDATE OF projects;
  /* Extend varray to make room for new project. */
  my_projects.EXTEND;
  /* Move varray elements forward. */
  FOR i IN REVERSE position..my_projects.LAST - 1 LOOP
    my_projects(i + 1) := my_projects(i);
  END LOOP;
  /* Insert new project. */
  my_projects(position) := new_project;
  /* Update department table. */
  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;

```

In the final example, you call stand-alone procedure *update_project* to revise the cost of a project:

```
DECLARE
    dept_num NUMBER;
    proj_num NUMBER;
    ...
BEGIN
    ...
    update_project(dept_num, proj_num, new_cost => 3750);
```

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 can be called from procedural statements but not from SQL statements. *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. Also, *EXISTS*, *PRIOR*, *NEXT*, *TRIM*, *EXTEND*, and *DELETE* take parameters. Each parameter must be an expression that yields an integer.

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

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

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

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

Using COUNT

`COUNT` returns the number of elements that a collection currently contains. For instance, if varray *projects* contains 15 elements, the following `IF` condition is true:

```
IF projects.COUNT = 15 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 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 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 20 more elements to varray `projects`:

```
IF (projects.COUNT + 20) < projects.LIMIT THEN
    -- add 20 more elements
```

Using FIRST and 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, 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 PRIOR and NEXT

`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)); -- assigns element 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 EXTEND

To increase the size of a collection, you use `EXTEND`. This procedure has three forms. `EXTEND` appends one null element to a collection. `EXTEND(n)` appends n null elements to a collection. `EXTEND(n, i)` appends n copies of the i th element to a collection. 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, medial, or trailing) are treated alike.

Using 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. For example, the following 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 DELETE

This procedure has three forms. `DELETE` removes all elements from a collection. `DELETE(n)` removes the n th element from a nested table. If n is null, `DELETE(n)` does nothing. `DELETE(m,n)` removes all elements in the range $m..n$ from a 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` allows you to 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 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;
```

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 that 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 ...
COLLECTION_IS_NULL	collection is atomically null
NO_DATA_FOUND	subscript designates an element that was deleted
SUBSCRIPT_BEYOND_COUNT	subscript exceeds number of elements in collection
SUBSCRIPT_OUTSIDE_LIMIT	subscript is outside the legal range
VALUE_ERROR	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; -- does not raise NO_DATA_FOUND
  DBMS_OUTPUT.PUT_LINE(nums.COUNT); -- prints 3

```

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 type *field_type*.

Note: Unlike `TABLE` and `VARRAY` 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(15),
        dept_loc   VARCHAR2(15));
```

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 which is 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));
```

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      INTEGER
        last_name   VARCHAR2(15),
        dept_num   INTEGER(2),
        job_title   VARCHAR2(15),
        salary      REAL(7,2));
    ...
    FUNCTION nth_highest_salary (n INTEGER) RETURN EmpRec IS ...
```

Declaring Records

Once you define a `RECORD` type, you can declare records of that type, as the following example shows:

```
DECLARE
    TYPE StockItem IS RECORD (
        item_no     INTEGER(3),
        description VARCHAR2(50),
        quantity    INTEGER,
        price        REAL(7,2));
    item_info StckItem; -- declare record
```

The identifier `item_info` represents an entire record.

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(15),
        salary      NUMBER(7,2));
    ...
    PROCEDURE raise_salary (emp_info EmpRec);
```

Initializing and Referencing 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 (
    seconds SMALLINT := 0,
    minutes SMALLINT := 0,
    hours    SMALLINT := 0);
```

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));
```

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, you 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, you use the following syntax to reference fields in the record:

```
function_name(parameters).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 CHAR(14),
```

```

        salary    REAL(7,2);
middle_sal REAL;
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

```

When calling a parameterless function, you use the following syntax:

```
function_name().field_name -- note empty parameter list
```

To reference nested fields in a record returned by a function, you use extended dot notation. 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

```

You 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 ...

```

Assigning and Comparing 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),
        location  VARCHAR2(13));
    TYPE DeptItem IS RECORD (
        dept_num  NUMBER(2),
        dept_name VARCHAR2(14),
        location  VARCHAR2(13));
    dept1_info DeptRec;
    dept2_info DeptItem;
BEGIN
    ...
    dept1_info := dept2_info; -- illegal; different datatypes

```

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 CHAR(14),
        location CHAR(13));
    dept1_info DeptRec;
    dept2_info dept%ROWTYPE;
BEGIN
    SELECT * INTO dept2_info FROM dept WHERE deptno = 10;
    dept1_info := dept2_info;
```

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 CHAR(14),
        location CHAR(13));
    dept_info DeptRec;
BEGIN
    SELECT deptno, dname, loc INTO dept_info FROM dept WHERE deptno = 20;
```

However, you cannot use the `INSERT` statement to insert user-defined records into a database table. So, the following statement is illegal:

```
INSERT INTO dept VALUES (dept_info); -- illegal
```

Also, 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 (minutes SMALLINT, hours SMALLINT);
    TYPE MeetingRec IS RECORD (
        day DATE,
```

```

        time    TimeRec, -- nested record
        room_no INTEGER(4);
    TYPE PartyRec IS RECORD (
        day    DATE,
        time   TimeRec, -- nested record
        place  VARCHAR2(25));
    seminar MeetingRec;
    party    PartyRec;
BEGIN
    ...
    party.time := seminar.time;

```

Comparing Records

Records cannot be tested for nullity, equality, or inequality. For instance, the following `IF` conditions are illegal:

```

BEGIN
    ...
    IF emp_info IS NULL THEN ... -- illegal
    IF dept2_info > dept1_info THEN ... -- illegal

```

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'), ...));
```

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;
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 with 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.

Major Topics

- SQL Support
- Using DDL and Dynamic SQL
- Managing Cursors
- Packaging Cursors
- Using Cursor FOR Loops
- Using Cursor Variables
- Using Cursor Attributes
- Processing Transactions

SQL Support

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 supports all SQL data manipulation commands (except `EXPLAIN PLAN`), transaction control commands, functions, pseudocolumns, and operators. Also, PL/SQL conforms to SQL92, the current ANSI/ISO SQL standard.

Note: PL/SQL does not support data definition commands such as `ALTER` and `CREATE`. For an explanation and workaround, see “Using DDL and Dynamic SQL” on page 5-7.

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` establishes a read-only transaction.

SQL Functions

PL/SQL lets you use all the SQL functions including the following group functions, which summarize entire columns of Oracle data: AVG, COUNT, MAX, MIN, STDDEV, SUM, and VARIANCE.

The group functions GLB and LUB are available only with Trusted Oracle. GLB and LUB return the greatest lower bound and least upper bound of two or more operating system labels, respectively. For more information, see your Trusted Oracle documentation.

You can use the group functions in SQL statements, but *not* in procedural statements. Group 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 group function treats all returned rows as a single group.

You call a group function using the syntax

```
function_name([ALL | DISTINCT] expr)
```

where *expr* is an expression that refers to one or more database columns. If you specify the ALL option (the default), the group function considers all column values including duplicates. For example, the following statement returns the sample standard deviation (s) of all values in the *comm* column:

```
SELECT STDDEV(comm) INTO comm_sigma FROM emp;
```

If you specify the DISTINCT option, the group function considers only distinct values. For example, the following statement returns the number of different job titles in the *emp* table:

```
SELECT COUNT(DISTINCT job) INTO job_count FROM emp;
```

The COUNT function lets you specify the asterisk (*) option, which returns the number of rows in a table. For example, the following statement returns the number of employees in the *emp* table:

```
SELECT COUNT(*) INTO emp_count FROM emp;
```

Except for COUNT (*), all group functions ignore nulls.

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 values into, update values in, or delete values from a pseudocolumn.

You can use pseudocolumns in SQL statements, but *not* in procedural statements. In the following example, you use the database sequence `empno_seq` and the pseudocolumn `NEXTVAL` (which returns the next value in a database sequence) to insert a new employee number into the `emp` table:

```
INSERT INTO emp VALUES (empno_seq.NEXTVAL, new_ename, ...);
```

Brief descriptions of the pseudocolumns follow. For more information, see *Oracle8 SQL Reference*.

CURRVAL and NEXTVAL

A *sequence* is a schema object that generates sequential numbers. When you create a sequence, you can specify its initial value and an increment.

`CURRVAL` returns the current value in a specified sequence. Before you can reference `CURRVAL` in a session, you must use `NEXTVAL` to generate a number. A reference to `NEXTVAL` stores the current sequence number in `CURRVAL`. `NEXTVAL` increments the sequence and returns the next value. To 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.

You specify the direction in which the query walks the tree (down from the root or up from the branches) with the `PRIOR` operator. In the `START WITH` clause, you specify a condition that identifies the root of the tree.

ROWID

`ROWID` returns the rowid (binary address) of a row in a database table. Recall that PL/SQL provides a datatype also named `ROWID`. You can use variables of type `ROWID` to store rowids in a readable format. In the following example, you declare a variable named `row_id` for that purpose:

```
DECLARE
    row_id ROWID;
```

When you select or fetch a rowid into a `ROWID` variable, you can use the function `ROWIDTOCHAR`, which converts the binary value to an 18-byte character string. Then, you can compare the `ROWID` 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 5-53.

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 use of `ROWNUM` in a `WHERE` clause is

```
... 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 *Oracle8 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 yields `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`.

<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</code> , <code>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. You must use this operator in the `CONNECT BY` clause of such a query to define the parent-child relationship.

SQL92 Conformance

In late 1992, the American National Standards Institute (ANSI) and the International Organization for Standardization (ISO) adopted the current SQL standard known informally as SQL92, which greatly extends SQL89, the previous SQL standard.

SQL92 specifies a “conforming SQL language” and, to allow implementation in stages, defines three language levels:

- Full SQL
- Intermediate SQL (a subset of Full SQL)
- Transitional SQL (a subset of Intermediate SQL)
- Entry SQL (a subset of Transitional SQL)

A conforming SQL implementation must support at least Entry SQL. PL/SQL fully supports Entry SQL.

Using DDL and Dynamic SQL

This section explains why PL/SQL does not support SQL data definition language (DDL) or dynamic SQL, then shows how to solve the problem.

Efficiency versus Flexibility

Before a PL/SQL program can be executed, it must be compiled. The PL/SQL compiler resolves references to Oracle schema objects by looking up their definitions in the data dictionary. Then, the compiler assigns storage addresses to program variables that will hold Oracle data so that Oracle can look up the addresses at run time. This process is called *binding*.

How a database language implements binding affects runtime efficiency and flexibility. Binding at compile time, called *static* or *early* binding, increases efficiency because the definitions of schema objects are looked up then, not at run time. On the other hand, binding at run time, called *dynamic* or *late* binding, increases flexibility because the definitions of schema objects can remain unknown until then.

Designed primarily for high-speed transaction processing, PL/SQL increases efficiency by bundling SQL statements and avoiding runtime compilation. Unlike SQL, which is compiled and executed statement-by-statement at run time (late binding), PL/SQL is processed into machine-readable p-code at compile time (early binding). At run time, the PL/SQL engine simply executes the p-code.

Some Limitations

However, this design imposes some limitations. For example, the p-code includes references to schema objects such as tables and stored procedures. The PL/SQL compiler can resolve such references only if the schema objects are known at compile time. In the following example, the compiler cannot process the procedure because the table is undefined until the procedure is executed at run time:

```
CREATE PROCEDURE create_table AS
BEGIN
    CREATE TABLE dept (deptno NUMBER(2), ...); -- illegal
    ...
END;
```

In the next example, the compiler cannot bind the table reference in the DROP TABLE statement because the table name is unknown until the procedure is executed:

```
CREATE PROCEDURE drop_table (table_name IN VARCHAR2) AS
BEGIN
    DROP TABLE table_name; -- illegal
    ...
END;
```

Overcoming the Limitations

However, the package DBMS_SQL, which is supplied with Oracle, allows PL/SQL to execute SQL data definition and data manipulation statements dynamically at run time. For example, when called, the following stored procedure drops a specified database table:

```
CREATE PROCEDURE drop_table (table_name IN VARCHAR2) AS
    cid INTEGER;
```

```
BEGIN
  /* Open new cursor and return cursor ID. */
  cid := DBMS_SQL.OPEN_CURSOR;
  /* Parse and immediately execute dynamic SQL statement built by
  concatenating table name to DROP TABLE command. */
  DBMS_SQL.PARSE(cid, 'DROP TABLE ' || table_name, dbms_sql.v7);
  /* Close cursor. */
  DBMS_SQL.CLOSE_CURSOR(cid);
EXCEPTION
  /* If an exception is raised, close cursor before exiting. */
  WHEN OTHERS THEN
    DBMS_SQL.CLOSE_CURSOR(cid);
    RAISE; -- reraise the exception
END drop_table;
```

For more information about package `DBMS_SQL`, see *Oracle8 Application Developer's Guide*.

Managing Cursors

Recall from Chapter 1 that 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 or use a cursor `FOR` loop.

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. 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 use the `FETCH` statement to retrieve the first row. You can execute `FETCH` repeatedly until all rows have been retrieved. 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} expr]
```

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 `NOT NULL` constraint 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 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. (See “Positional and Named Notation” on page 7-12.) The datatypes of each actual parameter and its corresponding formal parameter must be compatible.

Fetching with a Cursor

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 of the `FETCH` statement 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 variable in the `INTO` list. Also, their datatypes must be compatible. Typically, you use the `FETCH` statement as follows:

```
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 each 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 5-38.

Closing a Cursor

The `CLOSE` statement disables the cursor, and the result set becomes undefined. An example of the `CLOSE` statement follows:

```
CLOSE c1;
```

Once a cursor is closed, you can reopen it. Any other operation on a closed cursor raises the predefined exception `INVALID_CURSOR`.

Using Subqueries

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 per table, a *correlated subquery* is evaluated once per 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;
```

Implicit Cursors

Oracle implicitly opens a cursor to process each SQL statement not associated with an explicitly declared cursor. PL/SQL lets you refer to the most recent implicit cursor as the `SQL` cursor.

You cannot use the `OPEN`, `FETCH`, and `CLOSE` statements to control the `SQL` cursor. But, you can use cursor attributes to get information about the most recently executed SQL statement. See "Using Cursor Attributes" on page 5-38.

Packaging Cursors

You can separate a cursor specification from its body for placement in a package. That way, you can change the cursor body without having to change the cursor specification. You code the cursor specification in the package specification using the 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_actions AS
    /* Declare cursor specification. */
    CURSOR c1 RETURN emp%ROWTYPE;
    ...
END emp_actions;

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

The cursor specification has no `SELECT` statement because the `RETURN` clause defines the datatype of the result value. However, the cursor body must have a `SELECT` statement and the same `RETURN` clause as the cursor specification. Also, the number and datatypes of select items in the `SELECT` statement must match the `RETURN` clause.

Packaged cursors increase flexibility. For instance, you can change the cursor body in the last example, as follows, without having to change the cursor specification:

```
CREATE PACKAGE BODY emp_actions AS
    /* Define cursor body. */
    CURSOR c1 RETURN emp%ROWTYPE IS
        SELECT * FROM emp WHERE deptno = 20; -- new WHERE clause
    ...
END emp_actions;
```

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.coll%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 that was already opened by an `OPEN` statement or by an enclosing cursor `FOR` loop. Before each iteration of the `FOR` loop, PL/SQL fetches into the implicitly declared record, which is equivalent to a record explicitly declared as follows:

```
c1_rec c1%ROWTYPE;
```

The record is defined only inside the loop. You cannot refer to its fields outside the loop. For example, the following reference is illegal:

```
FOR c1_rec IN c1 LOOP
    ...
END LOOP;
result := c1_rec.n2 + 3; -- illegal
```

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

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 Aliases

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 query 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 next 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, you use the alias instead of a column name, as follows:

```
IF emp_rec.wages < 1000 THEN ...
```

Passing Parameters

You can pass parameters to the cursor used 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 how many have 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 subprograms, including subprograms stored in an Oracle database. 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 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 via 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
```

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 ...
```

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 one at a time. When all the rows are processed, you `CLOSE` the cursor variable.

Opening a Cursor Variable

The `OPEN-FOR` statement associates a cursor variable with a multi-row query, executes the query, and identifies the result set. The statement syntax is

```
OPEN {cursor_variable_name | :host_cursor_variable_name}
  FOR select_statement;
```

where `host_cursor_variable_name` identifies a cursor variable declared in a PL/SQL host environment such as an OCI or Pro*C program.

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. The query can reference host variables and PL/SQL variables, parameters, and functions but cannot be `FOR UPDATE`.

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.

In a Stored Procedure

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 stand-alone procedure to open the cursor variable. Simply define the `REF CURSOR` type in a separate package, then reference that type in the stand-alone procedure. For instance, if you create the following (bodiless) package, you can create stand-alone 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 following example, you create a stand-alone 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. (In this context, a *selector* is a variable used to select one of several alternatives in a conditional control statement.) When called, the procedure opens the cursor variable *emp_cv* for the chosen query.

```
CREATE PACKAGE emp_data AS
    TYPE GenericCurTyp IS REF CURSOR;
    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;
```

For more flexibility, you can pass a cursor variable and selector to a stored procedure that executes queries with different return types. Consider the following example:

```
CREATE PACKAGE BODY emp_data AS
    PROCEDURE open_cv (generic_cv IN OUT GenericCurTyp,
                      choice      IN 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 open_cv;
END emp_data;

```

Using 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 one at a time from the result set of a multi-row query. The statement syntax follows:

```
FETCH {cursor_variable_name | :host_cursor_variable_name}
      INTO {variable_name[, variable_name]... | record_name};
```

In the next example, you fetch rows 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;
```

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. The statement syntax follows:

```
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`.

Example 1

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 (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;
```

Example 2

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;
```

Example 3

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. */
    }

```

Example 4

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, you 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.

Note: If you declare a host variable with the same name as a PL/SQL program variable, the latter takes precedence.

To reference a host variable in PL/SQL, you must prefix its name with a colon (:), as the following example shows:

```

:return_code := 0;
IF credit_check_ok(acct_no) THEN
    :return_code := 1;
END IF;

```

To display the value of a host variable in SQL*Plus, you use the `PRINT` command, as follows:

```
SQL> PRINT return_code
```

```

RETURN_CODE
-----
          1

```

In the script below, you declare a host variable of type `REFCURSOR`. (The `SQL*Plus` datatype `REFCURSOR` lets you declare cursor variables, which you can use to return query results from stored subprograms.) 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  CHAR(10),
    job_title CHAR(9),
    dept_name CHAR(14),
    dept_loc  CHAR(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, 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 Exceptions

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 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.

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 stand-alone 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.

```

/* bodiless package */
CREATE PACKAGE cv_types AS
  TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
  ...
END cv_types;

/* stand-alone procedure */
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 because emp and
                  -- dept tables have different rowtypes
END;
END-EXEC;
```

Guarding Against Aliasing

Like all pointers, cursor variables introduce 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 get_emp_data;
```

Aliasing also occurs when the same actual parameter appears twice in a subprogram call. Unless both formal parameters are *IN* parameters, the result is indeterminate, as the following example shows:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    emp_cv EmpCurTyp;
    emp_rec emp%ROWTYPE;
    PROCEDURE open_emp_cv (cv1 IN OUT EmpCurTyp,
                          cv2 IN OUT EmpCurTyp) IS
    BEGIN
        OPEN cv1 FOR SELECT * FROM emp WHERE ename = 'KING';
        OPEN cv2 FOR SELECT * FROM emp WHERE ename = 'BLACK';
    END open_emp_cv;
BEGIN
    open_emp_cv(emp_cv, emp_cv);
    FETCH emp_cv INTO emp_rec; -- indeterminate; might return
                              -- row for 'KING' or 'BLACK'
```

Restrictions

Currently, cursor variables are subject to the following restrictions, some of which future releases of PL/SQL will remove:

- You cannot declare cursor variables in a package because they do not have persistent state.
- 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.
- The query associated with a cursor variable in an `OPEN-FOR` statement cannot be `FOR UPDATE`.
- 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 a nested table, index-by table, or varray cannot store the values of cursor variables.
- You cannot use cursor variables with dynamic SQL.
- 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 illegal:

```

DECLARE
    CURSOR emp_cur IS SELECT * FROM emp; -- static cursor
    TYPE EmpCurTyp IS REF CURSOR RETURN emp%ROWTYPE;
    emp_cv EmpCurTyp; -- cursor variable
BEGIN
    ...
    FOR emp_rec IN emp_cv LOOP ... -- illegal
    ...
END LOOP;
END;
```

Using Cursor Attributes

Each cursor or 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.

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 one at a time.

%FOUND

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

`%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

%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 ci%NOTFOUND IS NULL;
```

If a cursor or cursor variable is not open, referencing it with **%NOTFOUND** raises **INVALID_CURSOR**.

%ROWCOUNT

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 5–1 shows what each cursor attribute yields before and after you execute an OPEN, FETCH, or CLOSE statement.

Table 5–1 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

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

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.col1%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; -- yields 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;
END;

```

```
        END IF;
    END LOOP;

    CLOSE bin_cur;

    INSERT INTO temp
        VALUES (NULL, bins_looked_at, '<- bins looked at');
    COMMIT;
END;
```

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.

%FOUND

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

Oracle closes the SQL cursor automatically after executing its associated SQL statement. As a result, %ISOPEN always yields FALSE.

%NOTFOUND

%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

%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

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**:

```
UPDATE parts SET quantity = quantity - 1 WHERE partno = part_id;
check_status(part_id); -- procedure call
IF SQL%NOTFOUND THEN -- dangerous!
```

You can debug the code as follows:

```
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 ...
```

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 group function never raises `NO_DATA_FOUND` because group 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
```

Processing Transactions

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

Oracle is transaction oriented; that is, it uses transactions to ensure data integrity. A *transaction* is a series of one or more logically related SQL statements that accomplish a task. 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.

Using 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 `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
```

Using 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.

Using 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 rollback 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 per session is unlimited. An *active savepoint* is one marked since the last commit or rollback.

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;
```

Using 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;
    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

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 `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.

You can explicitly lock entire tables using the `LOCK TABLE` statement.

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 `FOR UPDATE` clause 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 the table has 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 table is available. The wait has no limit unless the table is remote, in which case the Oracle initialization parameter `DISTRIBUTED_LOCK_TIMEOUT` sets a limit.

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 5-53.)

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;
```

You use the `CURRENT OF` clause in an `UPDATE` or `DELETE` statement to refer to the latest row fetched from a cursor, as the following example shows:

```
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 *Oracle8 Application Developer's Guide*.

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

Remember, 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 `ROWID` 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 ROWID;
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;
    CLOSE c1;
END;
```

Improving Performance

This section gives several techniques for improving performance and explains how your applications can use them.

Use Object Types and Collections

Collection types (see Chapter 4) and object types (see Chapter 9) 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 so on.

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 architecturally with the database, so it can take advantage of the many scalability and performance improvements built into Oracle8.

Use 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. The results are fewer network round trips, less server CPU use, and (because fewer cursors are used) less server memory use.

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;
END;
```

Use 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, a PL/SQL client-to-server RPC, 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 less 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 packages without a body, you code the pragma in the package specification using the following syntax:

```
PRAGMA SERIALLY_REUSABLE;
```

For packages with a body, you must code the pragma in the specification 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 OR REPLACE PACKAGE sr_pkg IS
    PRAGMA SERIALLY_REUSABLE;
    num NUMBER := 0;
    PROCEDURE init_pkg_state(n NUMBER);
    PROCEDURE print_pkg_state;
END sr_pkg;
/
CREATE OR REPLACE PACKAGE BODY sr_pkg IS
    PRAGMA SERIALLY_REUSABLE;
    /* Initialize package state. */
    PROCEDURE init_pkg_state (n NUMBER) IS
    BEGIN
        sr_pkg.num := n;
    END;
    /* Print package state. */
    PROCEDURE print_pkg_state IS
    BEGIN
        DEMS_OUTPUT.PUT_LINE('Num is: ' || sr_pkg.num);
    END;
END sr_pkg;
/
BEGIN
    /* Initialize package state. */
    sr_pkg.init_pkg_state(4);
    /* On same server call, print package state. */
    sr_pkg.print_pkg_state; -- prints 4
END;
/
```

```

-- subsequent server call
BEGIN
  -- package's public variable will be initialized to its
  -- default value automatically
  sr_pkg.print_pkg_state; -- prints 0
END;
/

```

For more information, see *Oracle8 Application Developer's Guide*.

Use External Procedures

External procedures (see Chapter 10) extend 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 (for example). Also, 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).

Use the DBMS_SQL Array Interface

The PL/SQL package `DBMS_SQL` supports an array interface that gives you OCI-like array bind functionality. You can fetch multiple rows from a database table into a PL/SQL index-by table in one call to the server. Conversely, you can insert all rows from an index-by table into a database table in one call.

This reduces server CPU use significantly because fewer calls are made to the SQL engine. For client-side PL/SQL execution, fewer round trips are needed, which increases throughput. In the following example, you use the array interface to fetch employee names from the `emp` database table into an index-by table:

```

DECLARE
  src_cur  PLS_INTEGER;
  num_rows PLS_INTEGER;
  emp_tbl  DBMS_SQL.VARCHAR2_TABLE;
BEGIN

```

```
/* Open and parse cursor. */
src_cur := DBMS_SQL.OPEN_CURSOR;
DBMS_SQL.PARSE(src_cur, 'SELECT ename FROM emp', DBMS_SQL.V7);
/* Define select item 1 as an array-fetch into emp_tbl.
   Rows will be fetched 10 at a time, starting at index 1. */
DBMS_SQL.DEFINE_ARRAY(src_cur, 1, emp_tbl, 10, 1);
/* Execute the cursor. */
num_rows := DBMS_SQL.EXECUTE(src_cur);
/* Fetch all rows. */
LOOP
    num_rows := DBMS_SQL.FETCH_ROWS(src_cur);
    DBMS_SQL.COLUMN_VALUE(src_cur, 1, emp_tbl);
    IF (num_rows < 10) THEN EXIT; END IF;
END LOOP;
-- at this point the data is available in emp_tbl(1..emp_tbl.COUNT)
END;
```

For more information, see *Oracle8 Application Developer's Guide*.

Use the PLS_INTEGER Datatype

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, which are represented internally as 22-byte Oracle numbers. 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.

Avoid the NOT NULL Constraint

In PL/SQL, using the `NOT NULL` constraint incurs a performance cost. Consider the following example:

```
PROCEDURE calc_m IS
    m NUMBER NOT NULL;
    a NUMBER;
    b NUMBER;
BEGIN
    ...
    m := a + b;
```


Because m is constrained by NOT NULL, the result of 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 expression result 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
```

Note that the subtypes NATURALN and POSTIVEN are defined as NOT NULL. So, using them incurs the same performance cost.

Avoid 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
```

Another example follows:

```
DECLARE
  c CHAR(5);
BEGIN
  c := 25; -- converted
  c := '25'; -- not converted
```

Dealing with Size Limitations

PL/SQL was designed primarily for high-speed transaction processing. As a result, the compiler limits the number of tokens (identifiers, keywords, operators, and so on) that a program unit (block, subprogram, or package) can contain. Units that exceed the limit cause a *program too large* compilation error. Generally, units larger than 128K exceed the token limit. However, smaller units can also exceed the limit if they contain many variables or complex SQL statements.

Typically, this problem occurs with package bodies or anonymous blocks. With a package, the best solution is to divide it into smaller packages. With a block, the best solution is to redefine it as a series of subprograms, which can be stored in the database. For more information, see Chapter 7.

Another solution is to break the block into two sub-blocks. Consider the SQL*Plus script below. Before the first block terminates, it inserts any data the second block needs into a database table called *temp*. When the second block starts executing, it selects the data from *temp*. This approximates the passing of parameters from one procedure to another.

```
DECLARE
    mode    NUMBER;
    median  NUMBER;
BEGIN
    ...
    INSERT INTO temp (col1, col2, col3)
        VALUES (mode, median, 'blockA');
END;
/
DECLARE
    mode    NUMBER;
    median  NUMBER;
BEGIN
    SELECT col1, col2 INTO mode, median FROM temp
        WHERE col3 = 'blockA';
    ...
END;
/
```

The previous method works unless you must re-execute the first block while the second block is still executing, or unless two or more users must run the script concurrently.

Alternatively, you can embed the blocks in a host language such as C, COBOL, or FORTRAN. That way, you can re-execute the first block using flow-of-control statements. Also, you can store data in global host variables instead of a database table. In the following example, you embed two blocks in a Pro*C program:

```
EXEC SQL BEGIN DECLARE SECTION;
    int   my_empno;
    float my_sal, my_comm;
    short comm_ind;
    ...
EXEC SQL END DECLARE SECTION;
...
EXEC SQL EXECUTE
    BEGIN
        SELECT sal, comm INTO :my_sal, :my_comm:comm_ind FROM emp
           WHERE empno = :my_empno;
        IF :my_comm:comm_ind IS NULL THEN
            ...
        END IF;
    END;
END-EXEC;
EXEC SQL EXECUTE
    BEGIN
        ...
        IF :my_comm:comm_ind > 1000 THEN
            :my_sal := :my_sal * 1.10;
            UPDATE emp SET sal = :my_sal WHERE empno = :my_empno;
        END IF;
    END;
END-EXEC;
```

Ensuring Backward Compatibility

PL/SQL Version 2 allows some abnormal behavior that Version 8 disallows. Specifically, Version 2 allows you to

- 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 specification
- 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 Version 8 behavior is allowed.

On the client side, a command-line option sets the flag. For example, in the Oracle Precompilers environment, you specify the runtime option `DBMS` on the command line, as follows:

```
... DBMS=V7 ...
```

Error Handling

There is nothing more exhilarating than to be shot at without result.

Winston Churchill

Runtime 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 runtime 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.

Major Topics

Overview

Advantages of Exceptions

Predefined Exceptions

User-Defined Exceptions

How Exceptions Are Raised

How Exceptions Propagate

Reraising an Exception

Handling Raised Exceptions

Useful Techniques

Overview

In PL/SQL, a warning or error condition is called an *exception*. Exceptions can be internally defined (by the runtime system) or user defined. Examples of internally defined exceptions include *division by zero* and *out of memory*. Some common internal exceptions have predefined names, such as `ZERO_DIVIDE` and `STORAGE_ERROR`. The other internal exceptions can be given names.

You can define exceptions of your own in the declarative part of any PL/SQL block, subprogram, or package. For example, you might define an exception named *insufficient_funds* to flag overdrawn bank accounts. Unlike internal exceptions, user-defined exceptions *must* be given names.

When an error occurs, an exception is *raised*. That is, normal execution stops and control transfers to the exception-handling part of your PL/SQL block or subprogram. Internal exceptions are raised implicitly (automatically) by the runtime 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 Exceptions

Using exceptions for error handling has several advantages. Without exception handling, every time you issue a command, you must check for execution errors, as follows:

```
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 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 error-reporting 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 numbers. (See “Using `EXCEPTION_INIT`” on page 6-8.)

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 shown in the list below. Also shown are the corresponding Oracle error codes and `SQLCODE` return values.

Exception	Oracle Error	SQLCODE Value
<code>ACCESS_INTO_NULL</code>	ORA-06530	-6530
<code>COLLECTION_IS_NULL</code>	ORA-06531	-6531
<code>CURSOR_ALREADY_OPEN</code>	ORA-06511	-6511
<code>DUP_VAL_ON_INDEX</code>	ORA-00001	-1
<code>INVALID_CURSOR</code>	ORA-01001	-1001
<code>INVALID_NUMBER</code>	ORA-01722	-1722
<code>LOGIN_DENIED</code>	ORA-01017	-1017
<code>NO_DATA_FOUND</code>	ORA-01403	+100
<code>NOT_LOGGED_ON</code>	ORA-01012	-1012
<code>PROGRAM_ERROR</code>	ORA-06501	-6501
<code>ROWTYPE_MISMATCH</code>	ORA-06504	-6504
<code>STORAGE_ERROR</code>	ORA-06500	-6500
<code>SUBSCRIPT_BEYOND_COUNT</code>	ORA-06533	-6533
<code>SUBSCRIPT_OUTSIDE_LIMIT</code>	ORA-06532	-6532
<code>TIMEOUT_ON_RESOURCE</code>	ORA-00051	-51
<code>TOO_MANY_ROWS</code>	ORA-01422	-1422
<code>VALUE_ERROR</code>	ORA-06502	-6502
<code>ZERO_DIVIDE</code>	ORA-01476	-1476

Brief descriptions of the predefined exceptions follow:

Exception	Raised when ...
ACCESS_INTO_NULL	you try to assign values to the attributes of an uninitialized (atomically null) object.
COLLECTION_IS_NULL	you try to apply collection methods other than EXISTS to an uninitialized (atomically null) nested table or varray, or you try to assign values to the elements of an uninitialized nested table or varray.
CURSOR_ALREADY_OPEN	you try to open an already open cursor. You must close a cursor before you can reopen it. A cursor FOR loop automatically opens the cursor to which it refers. So, you cannot open that cursor inside the loop.
DUP_VAL_ON_INDEX	you try to store duplicate values in a database column that is constrained by a unique index.
INVALID_CURSOR	you try an illegal cursor operation such as closing an unopened cursor.
INVALID_NUMBER	in a SQL statement, the conversion of character string to a number fails because the character string does not represent a valid number. In procedural statements, VALUE_ERROR is raised.
LOGIN_DENIED	you try logging on to Oracle with an invalid username and/or password.
NO_DATA_FOUND	a SELECT INTO statement returns no rows, or you reference a deleted element in a nested table, or you reference an uninitialized element in an index-by table. The FETCH statement is expected to return no rows eventually, so when that happens, no exception is raised. SQL group functions such as AVG and SUM <i>always</i> return a value or a null. So, a SELECT INTO statement that calls a group function will never raise NO_DATA_FOUND.
NOT_LOGGED_ON	your PL/SQL program issues a database call without being connected to Oracle.
PROGRAM_ERROR	PL/SQL has an internal problem.

Exception	Raised when ...
ROWTYPE_MISMATCH	the host cursor variable and PL/SQL cursor variable involved in an assignment have incompatible return types. For example, when you pass an open host cursor variable to a stored subprogram, the return types of the actual and formal parameters must be compatible.
STORAGE_ERROR	PL/SQL runs out of memory or memory is corrupted.
SUBSCRIPT_BEYOND_COUNT	you reference a nested table or varray element using an index number larger than the number of elements in the collection.
SUBSCRIPT_OUTSIDE_LIMIT	you reference a nested table or varray element using an index number that is outside the legal range (-1 for example).
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 you select 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 to a number fails. In SQL statements, INVALID_NUMBER is raised.
ZERO_DIVIDE	you try to divide a number by zero.

User-Defined 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 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

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 next 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.

Using `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. Pragmas (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 allows you to 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 part, 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;
```

Using `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`, you 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 it.

An application can call `raise_application_error` only from an executing stored subprogram. 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, increase NUMBER) AS
    current_salary NUMBER;
BEGIN
    SELECT sal INTO current_salary FROM emp
        WHERE empno = emp_id;
    IF current_salary IS NULL THEN
        /* Issue user-defined error message. */
        raise_application_error(-20101, 'Salary is missing');
    ELSE
        UPDATE emp SET sal = current_salary + increase
            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 follows:

```
EXEC SQL EXECUTE
  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(:emp_number, :amount);
  EXCEPTION
    WHEN null_salary THEN
      INSERT INTO emp_audit VALUES (:emp_number, ...);
    ...
  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.

```
EXCEPTION
  WHEN invalid_number OR STANDARD.INVALID_NUMBER THEN
    -- handle the error
    ...
  WHEN OTHERS THEN ...
END;
```

How Exceptions Are Raised

Internal exceptions are raised implicitly by the runtime 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.

Using 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;
    ...
END;
```

```

EXCEPTION
  WHEN INVALID_NUMBER THEN
    ROLLBACK;
  ...
END;

```

How 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 “Using raise_application_error” on page 6-9.

Figure 6-1, Figure 6-2, and Figure 6-3 illustrate the basic propagation rules.

Figure 6-1 Propagation Rules: Example 1

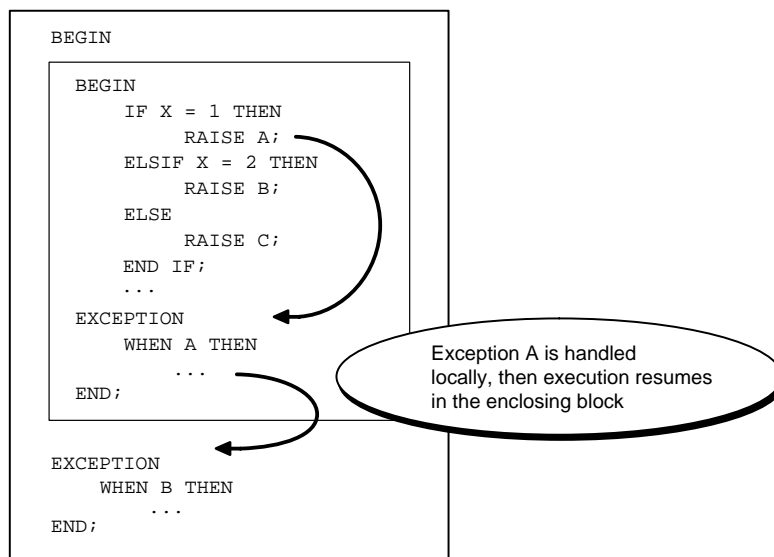
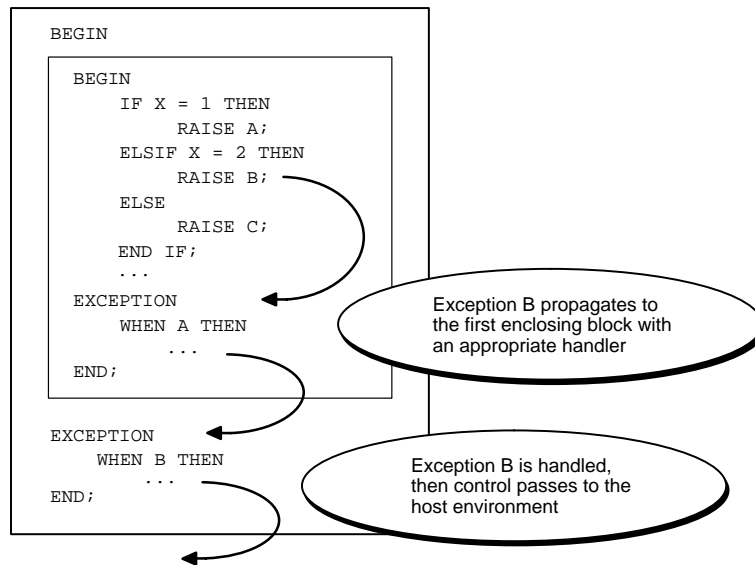
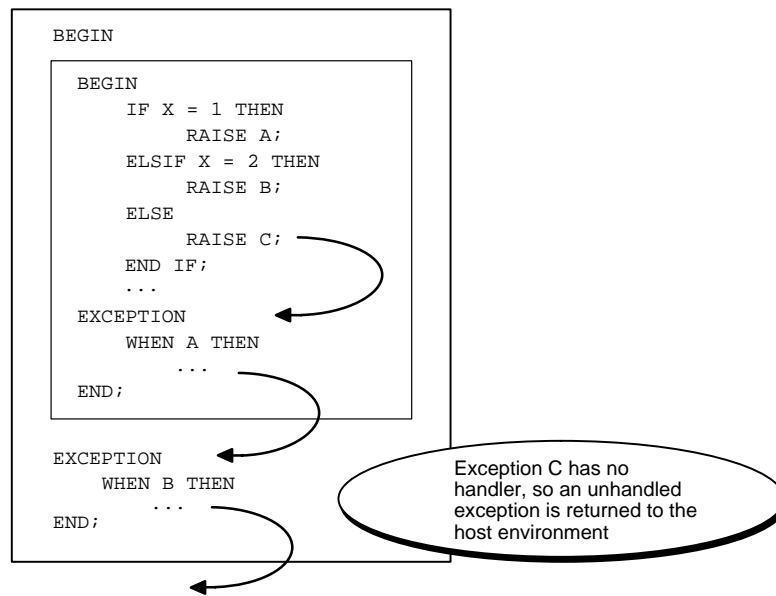


Figure 6–2 Propagation Rules: Example 2**Figure 6–3 Propagation Rules: Example 3**

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 it was declared has no handler for the exception named *past_due*, it 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.

Reraising an 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 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

```

To catch raised exceptions, you must 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.

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 `limit` cannot store numbers larger than 999:

```
DECLARE
  limit CONSTANT NUMBER(3) := 5000; -- raises an exception
BEGIN
  ...
EXCEPTION
  WHEN OTHERS THEN ... -- cannot catch the exception
```

Handlers in the current block cannot catch the raised exception because an exception raised in a declaration propagates *immediately* to the enclosing block.

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
```

Branching to or from an Exception Handler

A GOTO statement cannot branch to an exception handler; nor can it 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
```

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

Using SQLCODE and SQLERRM

In an exception handler, you can use the 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 this message:

```
ORA-01403: no data found
```

Passing a zero to `SQLERRM` always returns the following message:

```
ORA-0000: 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 the following example shows:

```
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);
```

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`. `SQLCODE` and `SQLERRM` are especially useful in the `OTHERS` exception handler because they tell you which internal exception was raised.

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. 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 block and subprogram.

Useful Techniques

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 terminates. 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 ...
```

Though PL/SQL does not support *continuable* exceptions, 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
    ...
```


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.

Retrying a Transaction

After an exception is raised, rather than abandon your transaction, you might want to retry it. The technique you use is simple. First, encase the transaction in a sub-block. Then, place the sub-block inside a loop that repeats the transaction.

Before starting the transaction, you mark a savepoint. If the transaction succeeds, you 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    CHAR(20);
    ans1    CHAR(3);
    ans2    CHAR(3);
    ans3    CHAR(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 (because there is a unique
            -- index on the name column)
            COMMIT;
            EXIT;
        EXCEPTION
            WHEN DUP_VAL_ON_INDEX THEN
                ROLLBACK TO start_transaction; -- undo changes
                suffix := suffix + 1;          -- try to fix
    END LOOP;

```

```
        name := name || TO_CHAR(suffix); -- problem
    ...
    END; -- sub-block ends
END LOOP;
END;
```

Using Locator Variables

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;
```

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.

Major Topics

- What Are Subprograms?
- Advantages of Subprograms
- Procedures
- Functions
- RETURN Statement
- Declaring Subprograms
- Actual versus Formal Parameters
- Positional and Named Notation
- Parameter Modes
- Parameter Default Values
- Parameter Aliasing
- Overloading
- Recursion

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 CHAR, new_loc CHAR) 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 logic modules. This supports top-down design and the stepwise refinement approach to problem solving.

Also, subprograms promote *reusability* and *maintainability*. Once validated, a subprogram can be used with confidence in any number of applications. Furthermore, only the subprogram is affected if its definition changes. This simplifies maintenance and enhancement.

Finally, subprograms aid *abstraction*, the mental separation 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.

Procedures

A procedure is a subprogram that performs a specific action. You write procedures using the syntax

```
PROCEDURE name [(parameter[, parameter, ...])] IS
    [local declarations]
BEGIN
    executable statements
[EXCEPTION
    exception handlers]
END [name];
```

where *parameter* stands for the following syntax:

```
parameter_name [IN | OUT | IN OUT] datatype [{:= | DEFAULT} expression]
```

You cannot impose the NOT NULL constraint on a parameter.

Also, you cannot specify a constraint on the datatype. For example, the following declaration of *emp_id* is illegal because it imposes a size constraint:

```
PROCEDURE raise_salary (emp_id NUMBER(4)) IS ... -- illegal; should be NUMBER
```

A procedure has two parts: the specification and the body. The procedure specification 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` 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:

```
PROCEDURE raise_salary (emp_id INTEGER, increase 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 + increase
            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_num, amount);
```

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 functions using the syntax

```
FUNCTION name [(parameter[, parameter, ...])] RETURN datatype IS
    [local declarations]
BEGIN
    executable statements
[EXCEPTION
    exception handlers]
END [name];
```

where *parameter* stands for the following syntax:

```
parameter_name [IN | OUT | IN OUT] datatype [{:= | DEFAULT} expression]
```

Remember, you cannot impose the `NOT NULL` constraint on a parameter, and you cannot specify a constraint on the datatype.

Like a procedure, a function has two parts: the specification and the body. The function specification begins with the keyword `FUNCTION` and ends with the `RETURN` clause, which specifies the datatype of the result value. Parameter declarations are optional. Functions that take no parameters are written without parentheses.

The function body begins with the keyword `IS` 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 an employee salary is out of range:

```
FUNCTION sal_ok (salary REAL, title REAL) 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. For example, the function `sal_ok` might be called as follows:

```
IF sal_ok(new_sal, new_title) THEN ...
```

The function identifier acts like a variable whose value depends on the parameters passed to it.

Restriction

To be callable from SQL expressions, a stored function must obey certain rules meant to control side effects. For stand-alone functions, Oracle can enforce these rules by checking the function body. However, the body of a packaged function is hidden. So, for packaged functions, you must use the pragma `RESTRICT_REFERENCES` to enforce the rules. For more information, see *Oracle8 Application Developer's Guide*.

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, which specifies the datatype of the result value in a function specification.)

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, 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;
```

A function must contain at least one `RETURN` statement. Otherwise, PL/SQL raises the predefined exception `PROGRAM_ERROR` at run time.

Declaring Subprograms

You can declare subprograms in any PL/SQL block, subprogram, or package. However, you must declare subprograms at the end of a declarative section after all other program items. For example, the following procedure declaration is misplaced:

```
DECLARE
    PROCEDURE award_bonus (...) IS -- misplaced; must come last
    BEGIN
        ...
    END;
    rating NUMBER;
    CURSOR c1 IS SELECT * FROM emp;
```

Forward Declarations

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 alphabetical order. PL/SQL solves this problem by providing a special subprogram declaration called a *forward declaration*. You can use forward declarations to

- define subprograms in logical or alphabetical order
- define mutually recursive subprograms (see “Recursion” on page 7-23)
- group subprograms in a package

A forward declaration consists of a subprogram specification 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
    ...
    /* Define subprograms in alphabetical order. */
    PROCEDURE award_bonus ( ... ) IS
    BEGIN
        calc_rating( ... );
        ...
    END;
    PROCEDURE calc_rating ( ... ) IS
    BEGIN
        ...
    END;
```

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.

In Packages

Forward declarations also let you group logically related subprograms in a package. The subprogram specifications go in the package specification, 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 specification
    PROCEDURE hire_employee (emp_id INTEGER, name VARCHAR2, ...);
    PROCEDURE fire_employee (emp_id INTEGER);
    PROCEDURE raise_salary (emp_id INTEGER, increase 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 (empno, ename, ...);
    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, increase REAL) IS
    salary REAL;
BEGIN
    SELECT sal INTO salary FROM emp
        WHERE empno = emp_id;
    ...
END raise_salary;
...
END emp_actions;
```

You can define subprograms in a package body without declaring their specifications in the package specification. However, such subprograms can be called only from inside the package. For more information about packages, see Chapter 8.

Stored Subprograms

Generally, tools (such as Oracle Forms) that incorporate the PL/SQL engine can store subprograms locally for later, strictly local execution. However, to become available for general use by all tools, subprograms must be stored in an Oracle database.

To create subprograms and store them permanently in an Oracle database, you use the `CREATE PROCEDURE` and `CREATE FUNCTION` statements, which you can execute interactively from SQL*Plus or Enterprise Manager. For example, you might create the procedure `fire_employee`, as follows:

```
CREATE PROCEDURE fire_employee (emp_id NUMBER) AS
BEGIN
    DELETE FROM emp WHERE empno = emp_id;
END;
```

When creating subprograms, you can use the keyword `AS` instead of `IS` in the specification for readability. For more information about creating and using stored subprograms, see *Oracle8 Application Developer's Guide*.

Actual versus Formal 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 specification and referenced in the subprogram body are *formal* parameters. For example, the following procedure declares two formal parameters named *emp_id* and *increase*:

```
PROCEDURE raise_salary (emp_id INTEGER, increase REAL) IS
    current_salary REAL;
    ...
BEGIN
    SELECT sal INTO current_salary FROM emp WHERE empno = emp_id;
    ...
    UPDATE emp SET sal = sal + increase 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 result values are assigned to the corresponding formal parameters. Before assigning the value of an actual parameter to a formal parameter, PL/SQL converts the datatype of the value if necessary. For example, the following call to *raise_salary* is legal:

```
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 value 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
```

For more information, see “Datatype Conversion” on page 2-25.

Positional and Named Notation

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. For example, 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
```

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*.

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. Therefore, you need not know the order in which the formal parameters are listed.

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
```

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.

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 := 10.0;
    service_charge    CONSTANT REAL := 0.50;
BEGIN
    ...
    IF amount < minimum_purchase THEN
        amount := amount + service_charge; -- causes syntax error
    END IF;
```

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 “Parameter Default Values” on page 7-15.

OUT Mode

An `OUT` parameter lets you return values to the caller of a subprogram. Inside the subprogram, an `OUT` parameter acts like an uninitialized variable. Therefore, its value cannot be assigned to another variable or reassigned to itself. For instance, the following assignment statement causes a compilation error:

```
PROCEDURE calc_bonus (emp_id IN INTEGER, bonus OUT REAL) IS
    hire_date DATE;
BEGIN
    SELECT sal * 0.10, hiredate INTO bonus, hire_date FROM emp
    WHERE empno = emp_id;
```

```
IF MONTHS_BETWEEN(SYSDATE, hire_date) > 60 THEN
    bonus := bonus + 500; -- causes syntax error
END IF;
```

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, the value is lost when you call the subprogram. Inside the subprogram, an OUT formal parameter cannot be used in an expression; the only operation allowed on the parameter is to assign it a value.

Like variables, OUT formal parameters are initialized to NULL. So, 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.

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. That means you can use an IN OUT formal parameter as if it were a normal 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 IN 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 `IN OUT` formal parameter must be a variable; it cannot be a constant or an expression. Table 7-1 summarizes all you need to know about the parameter modes.

Table 7-1 Parameter Modes

IN	OUT	IN OUT
the default	must be specified	must be specified
passes values to a subprogram	returns values to the caller	passes initial values to a subprogram and returns updated values to the caller
formal parameter acts like a constant	formal parameter acts like an uninitialized variable	formal parameter acts like an initialized variable
formal parameter cannot be assigned a value	formal parameter cannot be used in an expression and 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)	actual parameter is passed by value (a copy of the value is passed in and out)

Parameter Default Values

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 CHAR DEFAULT 'TEMP',
    new_loc   CHAR DEFAULT 'TEMP') IS
BEGIN
    INSERT INTO dept
        VALUES (deptno_seq.NEXTVAL, new_dname, new_loc);
```

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 illegal:

```
create_dept( , 'NEW YORK'); -- illegal
```

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
```

the following function call does not assign a null to `ot_hours`:

```
IF gross_pay(emp_num) > max_pay THEN ... -- illegal
```

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 bind variables in the `DEFAULT` clause. The following SQL*Plus example raises a *bad bind variable* exception 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, ...
```

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.

Passing large composite types by value is inefficient. So, in most cases—but *never* across client/server boundaries—PL/SQL passes composite types by reference, which saves time.

The easy-to-avoid problem of *aliasing* occurs 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 Dictionary) IS
  BEGIN
    /* At this point, if the varray was passed by reference,
       it has two names. Hence, the term 'aliasing'. */
    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. So, changing the value of *lexicon(1)* also changes the value of *word_list(1)*.

Overloading

PL/SQL lets you *overload* subprogram names. 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;
```

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.

Consider the example below. If you call *initialize* with a *DateTabTyp* parameter, PL/SQL uses the first version of *initialize*. But, if you call *initialize* with a *RealTabTyp* parameter, PL/SQL uses the second version.

```
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;
    ...
BEGIN
    indx := 50;
    initialize(hiredate_tab, indx); -- calls first version
    initialize(comm_tab, indx); -- calls second version
    ...
END;
```

Restrictions

Only local or packaged subprograms can be overloaded. Therefore, you cannot overload stand-alone 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:

```
PROCEDURE reconcile (acct_no IN INTEGER) IS
BEGIN
    ...
END;
```

```
PROCEDURE reconcile (acct_no OUT INTEGER) IS
BEGIN
    ...
END;
```

Furthermore, 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:

```
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 result value) even if the types are in different families. For example, you cannot overload the following functions:

```
FUNCTION acct_ok (acct_id INTEGER) RETURN BOOLEAN IS
BEGIN
    ...
END;

FUNCTION acct_ok (acct_id INTEGER) RETURN INTEGER IS
BEGIN
    ...
END;
```

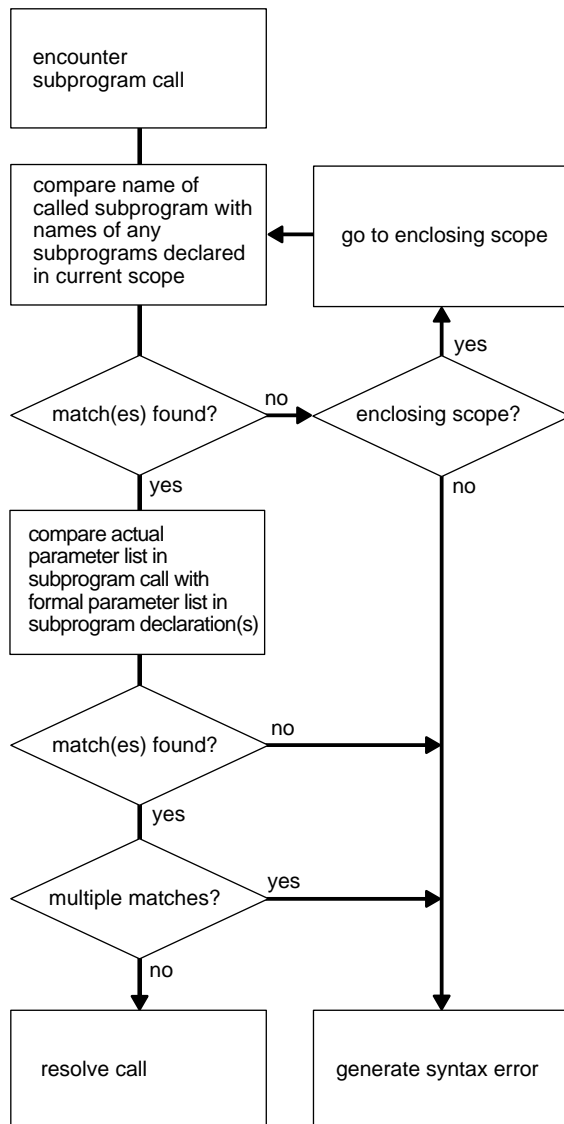
How Calls Are Resolved

Figure 7–1 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 syntax error.

In the following example, you call the enclosing procedure *swap* from within the function *valid*. However, the compiler generates an error because neither declaration of *swap* within the current scope matches the procedure call:

```
PROCEDURE swap (d1 DATE, d2 DATE) IS
    date1 DATE;
    date2 DATE;
FUNCTION valid (d DATE) RETURN BOOLEAN IS
    PROCEDURE swap (n1 INTEGER, n2 INTEGER) IS BEGIN ... END swap;
    PROCEDURE swap (n1 REAL, n2 REAL) IS BEGIN ... END swap;
BEGIN
    ...
    swap(date1, date2);
END valid;
BEGIN
    ...
```

Figure 7-1 How the PL/SQL Compiler Resolves Calls

Avoiding Errors

PL/SQL declares built-in functions globally in package `STANDARD`. Redefining them locally is error prone because your local declaration overrides the global declaration. Consider the following example, in which you declare a function named `sign`, then within the scope of that declaration, try to call the built-in function `SIGN`:

```
DECLARE
    x NUMBER;
    ...
BEGIN
    DECLARE
        FUNCTION sign (n NUMBER) RETURN NUMBER IS
        BEGIN
            IF n < 0 THEN RETURN -1; ELSE RETURN 1; END IF;
        END;
    BEGIN
        ...
        x := SIGN(0); -- assigns 1 to x
    END;
    ...
    x := SIGN(0); -- assigns 0 to x
END;
```

Inside the sub-block, PL/SQL uses your function definition, *not* the built-in definition. To call the built-in function from inside the sub-block, you must use dot notation, as follows:

```
x := STANDARD.SIGN(0); -- assigns 0 to x
```

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 (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 in terms of simpler versions of itself. Consider the definition of n factorial ($n!$), the product of all integers from 1 to n :

$$n! = n * (n - 1)!$$

Recursive Subprograms

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. That is, 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 `STORAGE_ERROR`.

Example 1

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.

Example 2

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. 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.

```
PROCEDURE find_staff (mgr_no NUMBER, tier NUMBER := 1) IS
    boss_name CHAR(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;
```

Unlike the initial call, each recursive call passes a second actual parameter (the next tier) to the procedure.

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.

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. (See “Forward Declarations” on page 7-8.)

```
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 the following 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.

Good as it is to inherit a library, it is better to collect one.

Augustine Birrell

This chapter shows you how to bundle related PL/SQL programming constructs into a package. The packaged constructs 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, like a library unit, its contents can be shared by many applications.

Major Topics

What Is a Package?

Advantages of Packages

The Package Specification

The Package Body

Some Examples

Private versus Public Items

Overloading

Package STANDARD

Product-specific Packages

What Is a 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* 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 specification.

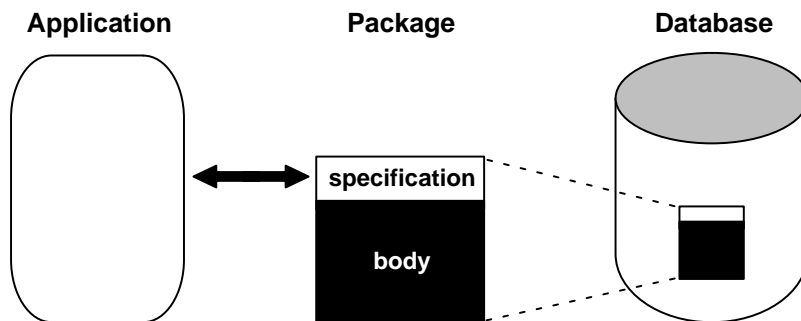
Unlike subprograms, packages cannot be called, parameterized, or nested. Still, the format of a package is similar to that of a subprogram:

```
CREATE PACKAGE name AS -- specification (visible part)
    -- public type and item declarations
    -- subprogram specifications
END [name];
```

```
CREATE PACKAGE BODY name AS -- body (hidden part)
    -- private type and item declarations
    -- subprogram bodies
[BEGIN
    -- initialization statements]
END [name];
```

The specification holds *public* declarations, which are visible to your application. The body holds implementation details and *private* declarations, which are hidden from your application. As Figure 8–1 shows, you can think of the specification as an operational interface and of the body as a “black box”:

Figure 8–1 Package Interface



You can debug, enhance, or replace a package body without changing the interface (package specification) to the package body.

To create packages and store them permanently in an Oracle database, you use the `CREATE PACKAGE` and `CREATE PACKAGE BODY` statements, which you can execute interactively from SQL*Plus or Enterprise Manager. For more information, see *Oracle8 Application Developer's Guide*.

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 PACKAGE emp_actions AS -- specification
    TYPE EmpRecTyp IS RECORD (emp_id INTEGER, 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 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 specification 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 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 specifications. You can code and compile a specification 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 definition of the private subprogram so that only the package (not your application) is affected if the definition 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.

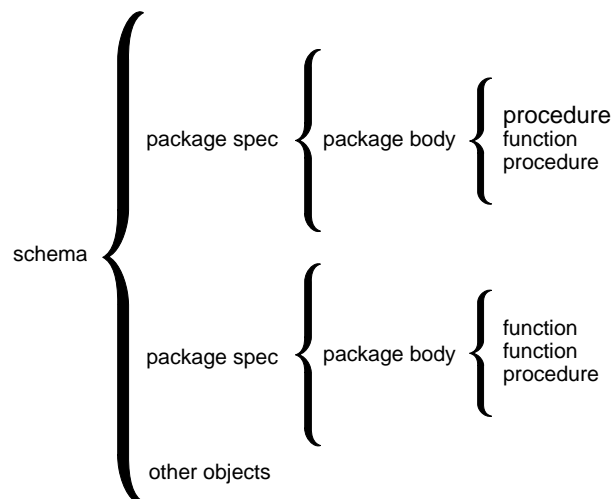
Better Performance

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 so avoid unnecessary recompiling. For example, if you change the definition of a packaged function, Oracle need not recompile the calling subprograms because they do not depend on the package body.

The Package Specification

The package specification 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 8–2 illustrates the scoping.

Figure 8–2 *Package Scope*



The specification lists the package resources available to applications. All the information your application needs to use the resources is in the specification. 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 the underlying implementation of *fac* (whether it is iterative or recursive, for example).

Only subprograms and cursors have an underlying implementation or *definition*. So, if a specification declares only types, constants, variables, and exceptions, the package body is unnecessary. Consider the following bodiless package:

```
-- a bodiless package
CREATE PACKAGE trans_data AS
  TYPE TimeRec IS RECORD (
    minutes SMALLINT,
    hours    SMALLINT);
  TYPE TransRec IS RECORD (
    category VARCHAR2,
    account  INTEGER,
    amount   REAL,
    time     TimeRec);
  minimum_balance CONSTANT REAL := 10.00;
  number_processed INTEGER;
  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, and subprograms declared within a package specification, you use dot notation, as follows:

```
package_name.type_name
package_name.item_name
package_name.subprogram_name
```

You can reference package contents from a database trigger, a stored subprogram, an Oracle Precompiler application, an OCI application, or an Oracle tool such as SQL*Plus. For example, you might call the packaged procedure *hire_employee* from SQL*Plus, as follows:

```
SQL> EXECUTE 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 *name* and *title* are host variables.

```
EXEC SQL EXECUTE
  BEGIN
    emp_actions.hire_employee(:name, :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, you cannot reference variables declared in a host environment (bind variables) inside a package.

The Package Body

The package body implements the package specification. That is, the package body contains the definition of every cursor and subprogram declared in the package specification. Keep in mind that subprograms defined in a package body are accessible outside the package only if their specifications also appear in the package specification.

To match subprogram specifications 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_bunus (date_hired DATE, ...) IS
    -- parameter declaration raises an exception because 'DATE'
    -- does not match 'emp.hiredate%TYPE' word for word
```

```
BEGIN
    ...
END calc_bonus;
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 specification, 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.

Recall that if a specification declares only types, constants, variables, and exceptions, the package body is unnecessary. However, the body can still be used to initialize items declared in the specification.

Some Examples

Consider the package below named *emp_actions*. The package specification declares the following types, items, and subprograms:

- types *EmpRecTyp* and *DeptRecTyp*
- cursor *desc_salary*
- exception *salary_missing*
- functions *hire_employee*, *nth_highest_salary*, and *rank*
- 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 INTEGER, salary REAL);
    TYPE DeptRecTyp IS RECORD (dept_id INTEGER, location VARCHAR2);
    CURSOR desc_salary RETURN EmpRecTyp;
    salary_missing EXCEPTION;

    /* Declare externally callable subprograms. */
    FUNCTION hire_employee (
        ename VARCHAR2,
        job VARCHAR2,
        mgr NUMBER,
        sal NUMBER,
        comm NUMBER,
        deptno NUMBER) RETURN INTEGER;
    PROCEDURE fire_employee (emp_id INTEGER);
    PROCEDURE raise_salary (emp_id INTEGER, increase NUMBER);
    FUNCTION nth_highest_salary (n INTEGER) RETURN EmpRecTyp;
END emp_actions;

CREATE PACKAGE BODY emp_actions AS
    number_hired INTEGER; -- 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 NUMBER,
        sal NUMBER,
        comm NUMBER,
        deptno NUMBER) RETURN INTEGER IS
        new_empno INTEGER;
    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 INTEGER) IS
BEGIN
    DELETE FROM emp WHERE empno = emp_id;
END fire_employee;

PROCEDURE raise_salary (emp_id INTEGER, increase NUMBER) IS
    current_salary NUMBER;
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 + increase
            WHERE empno = emp_id;
    END IF;
END raise_salary;

FUNCTION nth_highest_salary (n INTEGER) 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;

/* Define local function, available only in package. */
FUNCTION rank (emp_id INTEGER, job_title VARCHAR2)
    RETURN INTEGER IS
/* Return rank (highest = 1) of employee in a given
   job classification based on performance rating. */
    head_count INTEGER;
    score NUMBER;
BEGIN
    SELECT COUNT(*) INTO head_count FROM emp
        WHERE job = job_title;
    SELECT rating INTO score FROM reviews
        WHERE empno = emp_id;
    score := score / 100; -- maximum score is 100
    RETURN (head_count + 1) - ROUND(head_count * score);
END rank;
```



```

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 via automatic teller machines, then applied to accounts the next morning.

```

CREATE PACKAGE bank_transactions AS
    /* Declare externally visible constant. */
    minimum_balance CONSTANT NUMBER := 100.00;
    /* Declare externally callable procedures. */
    PROCEDURE apply_transactions;
    PROCEDURE enter_transaction (
        acct NUMBER,
        kind CHAR,
        amount NUMBER);
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 NUMBER, credit REAL);
    PROCEDURE debit_account (acct NUMBER, 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    NUMBER,
    kind    CHAR,
    amount  NUMBER) 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    NUMBER,
    kind    CHAR,
    new_bal NUMBER) 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 NUMBER, credit REAL) IS
/* Credit account unless account number is bad. */
    old_balance NUMBER;
```

```

    new_balance NUMBER;
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 NUMBER, debit REAL) IS
/* Debit account unless account number is bad or
account has insufficient funds. */
    old_balance NUMBER;
    new_balance NUMBER;
    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

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 specification 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 termed *private*.

However, items declared in the specification of *emp_actions* such as the exception *salary_missing* are visible outside the package. Therefore, any PL/SQL code can reference the exception *salary_missing*. Such items are termed *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 retained between calls to *hire_employee*. Remember, however, that the value of *number_hired* is session specific.

If you must also make the items public, place them in the package specification. For example, the constant *minimum_balance* declared in the specification of the package *bank_transactions* is available for general use.

Note: When you call a packaged subprogram remotely, the whole package is reinstantiated and its previous state is lost.

Overloading

Recall from Chapter 7 that PL/SQL allows two or more packaged subprograms to have the same name. This option is useful when you want a subprogram to accept parameters that have different datatypes. For example, the following package defines two procedures named *journalize*:

```
CREATE PACKAGE journal_entries AS
    PROCEDURE journalize (amount NUMBER, trans_date VARCHAR2);
    PROCEDURE journalize (amount NUMBER, trans_date NUMBER );
END journal_entries;

CREATE PACKAGE BODY journal_entries AS
    PROCEDURE journalize (amount NUMBER, trans_date VARCHAR2) IS
    BEGIN
        INSERT INTO journal
            VALUES (amount, TO_DATE(trans_date, 'DD-MON-YYYY'));
    END journalize;
    PROCEDURE journalize (amount NUMBER, trans_date NUMBER) 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). Yet, each procedure handles the data appropriately.

Package STANDARD

A package named `STANDARD` defines the PL/SQL environment. The package specification globally declares types, exceptions, and subprograms, which are available automatically to every PL/SQL program. For example, package `STANDARD` declares the following built-in function named `ABS`, which returns the absolute value of its argument:

```
FUNCTION ABS (n NUMBER) RETURN NUMBER;
```

The contents of package `STANDARD` are directly visible to applications. So, you can call `ABS` from a database trigger, a stored subprogram, an Oracle Precompiler application, an OCI application, and various Oracle tools including Oracle Forms, Oracle Reports, and SQL*Plus.

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 using dot notation, as follows:

```
... STANDARD.ABS(x) ...
```

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.

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 *Oracle8 Application Developer's Guide*.

DBMS_STANDARD

Package `DBMS_STANDARD` provides language facilities that help your application interact with Oracle. For instance, the procedure `raise_application_error` lets you issue user-defined error messages. That way, you can report errors to an application and avoid returning unhandled exceptions. For an example, see “Using `raise_application_error`” on page 6-9.

DBMS_OUTPUT

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 or Enterprise Manager.

For example, suppose you create the following stored procedure:

```
CREATE PROCEDURE calc_payroll (payroll IN OUT REAL) 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('payroll: ' || TO_CHAR(payroll));
END calc_payroll;
```

When you issue the following commands, SQL*Plus displays the value of payroll calculated by the procedure:

```
SQL> SET SERVEROUTPUT ON
SQL> VARIABLE num NUMBER
SQL> EXECUTE calc_payroll(:num)
```

DBMS_PIPE

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 servers to collect information, then send it through pipes to procedures stored in an Oracle database.

UTL_FILE

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. The procedure `get_line` reads a line of text from an open file into an output buffer.

PL/SQL file I/O is available on both the client and server sides. However, on the server side, file access is restricted to those directories explicitly listed in the *accessible directories list*, which is stored in the Oracle initialization file.

UTL_HTTP

Package `UTL_HTTP` allows your PL/SQL programs to make hypertext transfer protocol (HTTP) callouts. You can use it to retrieve data from the internet, or to call Oracle Web Server cartridges. The package has two entry points, each of which accepts a URL (universal resource locator) string, contacts the specified site, and returns the requested data, which is usually in hypertext markup language (HTML) format.

DBMS_SQL

Package `DBMS_SQL` allows PL/SQL to execute SQL data definition and data manipulation statements dynamically at run time. For an example, see “Using DDL and Dynamic SQL” on page 5-7.

DBMS_ALERT

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.

Guidelines

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 specifications reflect the design of your application. So, define them before the package bodies. Place in a specification 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 specification. Changes to a package body do not require Oracle to recompile dependent procedures. However, changes to a package specification require Oracle to recompile every stored subprogram that references the package.

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.

Major 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 and 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 allows you to 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.

Note: To use object types, you must have the Oracle8 Enterprise Edition and the Objects Option. For more information, see *Getting to Know Oracle8 and the Oracle8 Enterprise Edition*.

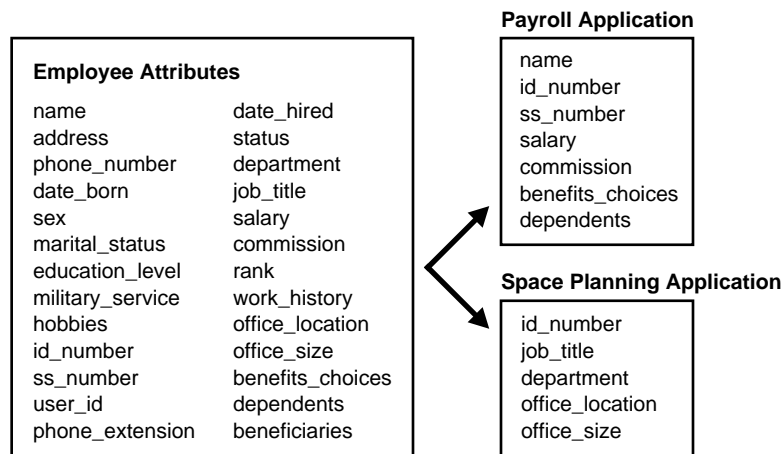
What Is an Object Type?

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 9-1).

Figure 9-1 Form Follows Function



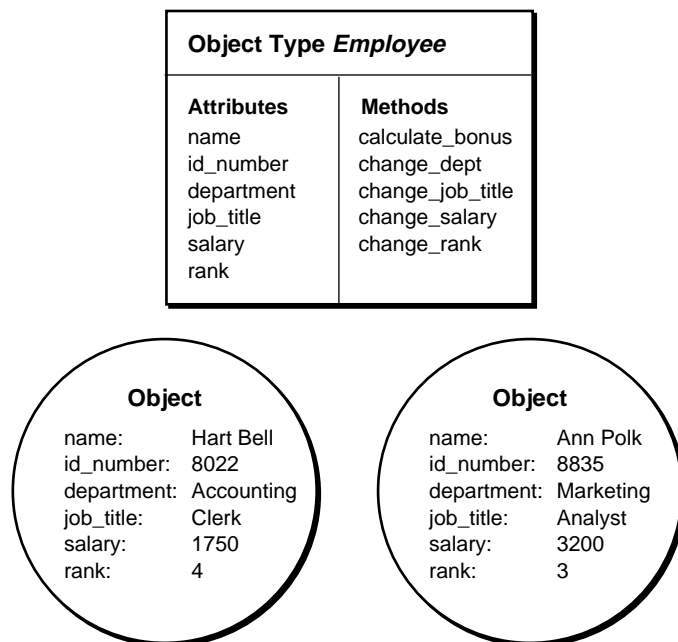
Suppose you must write a program to allocate employee bonuses. Not all employee attributes are needed to solve this problem. So, you design an abstract employee who has the following problem-specific attributes: name, id_number, department, job title, salary, and rank. Then, you identify the operations 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. (Future releases of Oracle will let you define private data structures, which can be manipulated only by the methods you provide.)

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 9-2). 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 9-2 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 allows you to create software components that are modular, maintainable, and reusable. It also allows different teams of programmers to develop software components concurrently.

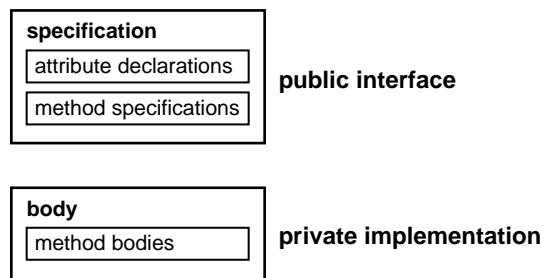
By encapsulating operations with data, object types let you move data-maintenance code out of SQL scripts and PL/SQL blocks into methods. Object types minimize side effects by allowing access to data only through approved operations. Also, object types hide implementation details, so that you can change 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 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 9–3). The *specification* 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 specification.

Figure 9–3 Object Type Structure



All the information a client program needs to use the methods is in the specification. Think of the specification as an operational interface and of the body as a black box. You can debug, enhance, or replace the body without changing the specification—and without affecting client programs.

In an object type specification, all attributes must be declared before any methods. Only subprograms have an underlying implementation. So, if an object type specification declares only attributes, the object type body is unnecessary. You cannot declare attributes in the body.

All declarations in the object type specification are public (visible outside the object type). However, the object type body can contain private declarations, which define methods necessary for the internal workings of the object type. The scope of private declarations is local to the object type body.

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,  
    ipart REAL,  
    MEMBER FUNCTION plus (x Complex) RETURN Complex,  
    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. So, you can declare attributes and methods in an object type specification, but *not* constants, exceptions, cursors, or types. At least one attribute is required (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
- MLSLABEL and ROWID
- 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

For example, the REAL variables *rpart* and *ipart* are attributes of object type *Complex* (defined in the previous section).

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 specification using the keyword `MEMBER`. The method cannot have the same name as the object type or any of its attributes.

Like packaged subprograms, most methods have two parts: a specification and a body. The *specification* 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 operation. For example, the functions *plus*, *less*, *times*, and *divby* are methods of object type *Complex*. These methods are always available to *Complex* objects.

For each method specification in an object type specification, there must be a corresponding method body in the object type body. To match method specifications and bodies, the PL/SQL compiler does a token-by-token comparison of their headers. So, the headers must match word for word.

In an object type, methods can reference attributes and other methods without a qualifier, as the example below 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;
```

Parameter SELF

All methods in an object type accept an instance of that type as their first parameter. The name of this built-in parameter is `SELF`. Whether declared implicitly or explicitly, `SELF` is always the first parameter passed to a method. For example, method *transform* declares `SELF` as an `IN OUT` parameter:

```
CREATE TYPE Complex AS OBJECT (  
    MEMBER FUNCTION transform (SELF IN OUT Complex) ...
```


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 a different datatype for `SELF`.

In a method body, `SELF` denotes the object whose method was called. 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
    -- the next two statements are equivalent
    g := gcd(SELF.num, SELF.den);
    g := gcd(num, den);
    num := num / g;
    den := den / g;
  END normalize;
  ...
END;
```

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.

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” on page 7-18.

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, 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  
    -- convert rational number to real number  
    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, which must be a parameterless function with one of the following scalar return types: `DATE`, `NUMBER`, `VARCHAR2`, an ANSI SQL type such as `CHARACTER` or `REAL`.

Alternatively, you can supply PL/SQL with an *order method*. In the example below, the keyword `ORDER` indicates that method `match` compares two objects. 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.

```
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;
```

An object type can contain only one order method, which must be a function that returns a numeric result.

Guidelines A map method, acting like a hash function, maps object values into scalar values (which are easier to compare), then compares the scalar values. 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. Constructor calls are allowed wherever function calls are allowed. For more information, see “Calling Constructors and Methods” on page 9-26.

Pragma RESTRICT_REFERENCES

To execute a SQL statement that calls a member function, Oracle must know the *purity level* of the function, that is, the extent to which the function is free of side effects. (In this context, *side effects* are references to database tables or packaged variables.)

Side effects can prevent the parallelization of a query, yield order-dependent (and therefore indeterminate) results, or require that package state be maintained across user sessions (which is not allowed). So, the following rules apply to a member function called from SQL statements:

- It cannot insert into, update, or delete from database tables.
- It cannot be executed remotely or in parallel if it reads or writes the values of packaged variables.
- It cannot write the values of packaged variables unless it is called from a `SELECT`, `VALUES`, or `SET` clause.
- It cannot call another method or subprogram that breaks one of the foregoing rules. Also, it cannot reference a view that breaks one of the rules. (Oracle replaces references to a view with a stored `SELECT` operation, which can include function calls.)

You use the pragma (compiler directive) `RESTRICT_REFERENCES` to enforce these rules. The pragma tells the PL/SQL compiler to deny the member function read/write access to database tables, packaged variables, or both.

In the object type specification, you code the pragma somewhere after the method to which it applies. The syntax follows:

```
PRAGMA RESTRICT_REFERENCES ({DEFAULT | method_name},
    {RNDS | WNDS | RNPS | WNPS}[, {RNDS | WNDS | RNPS | WNPS}]...);
```

For example, the following pragma constrains map method `convert` to read no database state (RNDS), write no database state (WNDS), read no package state (RNPS), and write no package state (WNPS):

```
CREATE TYPE Rational AS OBJECT (
    num INTEGER,
    den INTEGER,
    MAP MEMBER FUNCTION convert RETURN REAL,
    ...
    PRAGMA RESTRICT_REFERENCES (convert, RNDS, WNDS, RNPS, WNPS)
);
```

You can specify up to four constraints in any order. To call the method from parallel queries, you must specify all four constraints. No constraint implies another. For example, WNPS does not imply RNPS.

If you specify the keyword `DEFAULT` instead of a method name, the pragma applies to all member functions including the system-defined constructor. For example, the following pragma constrains all member functions to write no database or package state:

```
PRAGMA RESTRICT_REFERENCES (DEFAULT, WNDS, WNPS)
```

You can declare the pragma for any member function. Such pragmas override the default pragma. However, a non-default pragma can apply to only one method. So, among overloaded methods, the pragma always applies to the nearest preceding method.

For more information about pragma `RESTRICT_REFERENCES`, see *Oracle8 Application Developer's Guide*.

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 or Enterprise Manager using the following syntax:

```
CREATE TYPE type_name {IS | AS} OBJECT (  
    attribute_name datatype[, attribute_name datatype]...  
    [{MAP | ORDER} MEMBER function_specification,]  
    [ MEMBER {procedure_specification | function_specification}  
      | restrict_references pragma  
    [, MEMBER {procedure_specification | function_specification}  
      | restrict_references pragma]}...];  
  
[CREATE TYPE BODY type_name {IS | AS}  
    { {MAP | ORDER} MEMBER function_body;  
      | MEMBER {procedure_body | function_body};}  
    [MEMBER {procedure_body | function_body};]... END;]
```

Object Type *Stack*

A *stack* holds an ordered collection of data items. As the name implies, stacks have a top and a bottom. But, 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. Integers are stored in array elements, with one end of the array representing the top of the stack.

PL/SQL provides the datatype `VARRAY`, which allows you to declare variable-size arrays (varrays for short). To declare a varray attribute, we must first define its type. However, we cannot define types in an object type specification. So, we define a stand-alone varray type, specifying its maximum size, as follows:

```
CREATE TYPE IntArray AS VARRAY(25) OF INTEGER;
```

Now, we can write our object type specification, as follows:

```
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, we write the object type body, as follows:

```
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 (25)
        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;
```

Notice that in member procedures *push* and *pop*, we use the built-in procedure *raise_application_error* to issue user-defined error messages. That way, we 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, as follows:

```

DECLARE
    err_num NUMBER;
    err_msg VARCHAR2(100);
BEGIN
    ...
EXCEPTION
    ...
    WHEN OTHERS THEN
        err_num := SQLCODE;
        err_msg := SUBSTR(SQLERRM, 1, 100);
        DEMS_OUTPUT.PUT_LINE(TO_CHAR(err_num) || ': ' || err_msg);
```

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*.

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 ...
```


Object Type *Ticket_Booth*

Consider a chain of low-budget, triplex movie theatres. Each theatre has a ticket booth where tickets for three different movies are sold. All tickets are priced at \$2.50. Periodically, ticket receipts are collected and the stock of tickets is replenished.

Before defining an object type that represents a ticket booth, we 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, we 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, we must first define its type, as follows:

```
CREATE TYPE RealArray AS VARRAY(3) OF REAL;
```

Now, we can write our object type specification, as follows:

```
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, we write the object type body, as follows:

```
CREATE TYPE BODY Ticket_Booth AS
  MEMBER PROCEDURE initialize IS
  BEGIN
    price := 2.50;
    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 for that movie to zero  
END collect;  
END;
```

Object Type *Bank_Account*

Before defining an object type that represents a bank account, we 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, we write the object type specification, 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 (SELF IN OUT Bank_Account, num IN INTEGER)
    RETURN REAL
);
```

Then, we write the object type body, as follows:

```
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 (SELF IN OUT Bank_Account, num IN INTEGER)
RETURN REAL IS
BEGIN
    verify_acct(num);
    RETURN balance;
END curr_bal;
END;
```

Object Type *Rational*

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, we write the object type specification, 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. That is why we define methods named *plus*, *less* (the word *minus* is reserved), *times*, and *divby* instead of overloading the infix operators +, -, *, and /.

Next, we create the following stand-alone 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, we 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;

  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 are allowed, in which case `SELF` is bound to `NULL`. 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 allows you to access the attributes of a nested object type. For example, suppose we 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 and Methods

Calls to a constructor are allowed wherever function calls are allowed. Like all functions, a constructor is called as part of an expression, as 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;
```

Passing Parameters to a Constructor

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` clauses. 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
```

You can call a constructor using named notation instead of positional notation, as the following example shows:

```
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 example below, you call method `normalize`, which divides attributes `num` and `den` by their greatest common divisor.

```
DECLARE
    r Rational;
BEGIN
    r := Rational(6, 8);
    r.normalize;;
    DBMS_OUTPUT.PUT_LINE(r.num); -- prints 3
```

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
```

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 procedures are called as statements, not as part of an expression. For example, the following statement is illegal:

```
r.normalize().reciprocal; -- illegal
```

Also, if you chain two function calls, the first function must return an object that can be passed to the second function.

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, we 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*, we can model a community in which several people might share the same home. We 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 operator `DEREF` to access the object. For some examples, see “Using Operator `DEREF`” on page 9-34.

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*; that is, one depends on the other through a ref. 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 compiles with semantic (not syntactic) errors because it refers to an undefined type. For example, the following `CREATE TYPE` statement compiles with a semantic 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 allows you to 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.

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 E.)

```

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 WHERE ... -- returns 3
/
UPDATE numbers n SET n.rn = n.rn.reciprocal WHERE ... -- 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 operator `VALUE`, which is discussed in the next section.

Using Operator `VALUE`

As you might expect, the operator `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, you 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 Operator REF

You can retrieve refs using the operator `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:

```

BEGIN
  UPDATE department SET manager = NULL WHERE manager IS DANGLING;
```

Using Operator Deref

You cannot navigate through refs within PL/SQL procedural statements. Instead, you must use the operator `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 operator `DEREF` within procedural statements:

```
BEGIN
    ...
    p1 := Deref(p_ref); -- illegal
END
```

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 legal:

```
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 ('Jennifer', '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* is not referenceable 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 the following example shows:

```
BEGIN
  DELETE FROM persons p
    WHERE p.home_address = '108 Palm Dr';
  ...
END;
```

External Procedures

Well, if I called the wrong number, why did you answer the phone?

James Thurber

PL/SQL is a powerful development tool; you can use it for almost any purpose. But, it is specialized for SQL transaction processing. So, some tasks are more quickly or easily done in a lower-level language such as C, which is more efficient at machine-precision calculations. For example, a Fast Fourier Transform (FFT) routine written in C runs faster than one written in PL/SQL.

To support such special-purpose processing, PL/SQL provides an interface for calling routines written in other languages. This makes the strengths and capabilities of those languages available to you. No longer are you restricted to one language with its inherent limitations.

Major Topics

- What Is an External Procedure?
- Creating an External Procedure
- Registering an External Procedure
- Calling an External Procedure
- How PL/SQL Calls an External Procedure
- Passing Parameters to an External Procedure
- Using Service Routines
- Doing Callbacks
- Debugging External Procedures
- Guidelines for External Procedures
- Restrictions on External Procedures

What Is an External Procedure?

An *external procedure* is a third-generation-language routine stored in a dynamic link library (DLL), registered with PL/SQL, and called by you to do special-purpose processing. The routine must be callable from C but can be written in any language.

At run time, PL/SQL loads the library dynamically, then calls the routine as if it were a PL/SQL subprogram. To safeguard your database, the routine runs in a separate address space. But, it participates fully in the current transaction. Furthermore, the routine can call back to the database to do SQL operations.

External procedures promote reusability, efficiency, and modularity. DLLs already written and available in other languages can be called from PL/SQL programs. The DLLs are loaded only when needed, so memory is conserved. Moreover, the DLLs can be enhanced without affecting the calling programs.

Typically, external procedures are used to interface with embedded systems, solve scientific and engineering problems, analyze data, or control real-time devices and processes. For example, you might use external procedures to send instructions to a robot, solve partial differential equations, process signals, analyze time series, or create animation on a video display.

Moreover, external procedures enable you to

- move computation-bound programs from client to server, where they will execute faster thanks to more computing power and less across-network communication
- interface the database server with external systems and data sources
- extend the functionality of the database server itself

Note: This feature is available only on platforms that support DLLs or dynamically loadable shared libraries such as Solaris `.so` libraries.

Creating an External Procedure

To create an external procedure, you and your DBA take the following steps:

1. **Set Up the Environment** Your DBA sets up the environment for calling external procedures by adding entries to the files *tnsnames.ora* and *listener.ora* and by starting a Listener process exclusively for external procedures. For details, see *Oracle8 Administrator's Guide*.

2. Identify the DLL In this context, a *DLL* is any dynamically loadable operating-system file that stores external procedures. For safety, your DBA controls access to the DLL. Using the `CREATE LIBRARY` statement, the DBA creates a schema object called an *alias library*, which represents the DLL. Then, if you are an authorized user, the DBA grants you `EXECUTE` privileges on the alias library.

If the DBA grants you `CREATE ANY LIBRARY` privileges, you can create your own alias libraries using the following syntax:

```
CREATE LIBRARY library_name {IS | AS} 'file_path';
```

You must specify the full path to the DLL because the linker cannot resolve references to just the DLL name. In the following example, you create alias library `c_utils`, which represents DLL `utils.so`:

```
create library c_utils as '/DLLs/utils.so';
```

3. Designate the External Procedure You find or write a new routine, then add it to the DLL, or simply designate a routine already in the DLL.

4. Register the External Procedure Before you can call the external procedure, you must register it. That is, you must tell PL/SQL where to find the procedure, how to call it, and what to pass it. After registering the external procedure, you can call it from any PL/SQL program. It executes with the privileges granted to your userid.

Registering an External Procedure

You do that by writing a special kind of PL/SQL stand-alone or packaged subprogram, which acts like a proxy for the external procedure. (By default, they have the same name.)

You write the PL/SQL stored subprogram in the usual way except that, in its body, instead of declarations and a `BEGIN ... END` block, you code the `EXTERNAL` clause. This clause records information about the external procedure such as its location, its name, the programming language in which it was written, and the calling standard under which it was compiled. The syntax follows:

```
EXTERNAL LIBRARY library_name
  [NAME external_procedure_name]
  [LANGUAGE language_name]
  [CALLING STANDARD {C | PASCAL}]
  [WITH CONTEXT]
  [PARAMETERS (external_parameter[, external_parameter]...)];
```

where *external_parameter* stands for

```
{ CONTEXT  
  | {parameter_name | RETURN} [property] [BY REF] [external_datatype]}
```

and *property* stands for

```
{INDICATOR | LENGTH | MAXLEN | CHARSETID | CHARSETFORM}
```

Understanding the EXTERNAL Clause

The `EXTERNAL` clause is the interface between PL/SQL and an external procedure. The following subclauses tell PL/SQL where to find the procedure, how to call it, and what to pass it. (Only the `LIBRARY` subclause is required.)

LIBRARY

Specifies a local alias library. (You cannot use a database link to specify a remote library.) The library name is a PL/SQL identifier. So, if you enclose the name in double quotes, it becomes case sensitive. (By default, the name is stored in upper case.) You must have `EXECUTE` privileges on the alias library.

NAME

Specifies the external procedure to be called. If you enclose the procedure name in double quotes, it becomes case sensitive. (By default, the name is stored in upper case.) If you omit this subclause, the procedure name defaults to the upper-case name of the PL/SQL subprogram.

LANGUAGE

Specifies the third-generation language in which the external procedure was written. Currently, only the language name `C` is allowed. If you omit this subclause, the language name defaults to `C`.

CALLING STANDARD

Specifies the Windows NT calling standard (`C` or `Pascal`) under which the external procedure was compiled. (Under the `Pascal` Calling Standard, arguments are reversed on the stack and the called function must pop the stack.) If you omit this subclause, the calling standard defaults to `C`.

WITH CONTEXT

Specifies that a context pointer will be passed to the external procedure. The context data structure is opaque to the external procedure but is available to service routines called by the external procedure. For more information, see “Using the WITH CONTEXT Clause” on page 10-16.

PARAMETERS

Specifies the positions and datatypes of parameters passed to the external procedure. It can also specify parameter properties such as current length and maximum length, and the preferred parameter passing method (by value or by reference). For more information, see “Using the PARAMETERS Clause” on page 10-12.

An Example

Assume that C routine *c_gcd*, which finds the greatest common divisor of two numbers, is stored in DLL *utils.so* and that you have EXECUTE privileges on alias library *c_utils*. The C prototype for *c_gcd* follows:

```
int c_gcd(int x_val, int y_val);
```

In the following example, you write a PL/SQL stand-alone function named *gcd* that registers C routine *c_gcd* as an external function:

```
CREATE FUNCTION gcd (
-- find greatest common divisor of x and y
  x BINARY_INTEGER,
  y BINARY_INTEGER)
RETURN BINARY_INTEGER AS EXTERNAL
  LIBRARY c_utils
  NAME "c_gcd" -- quotes preserve lower case
  LANGUAGE C;
```

Calling an External Procedure

You do not call an external procedure directly. Instead, you call the PL/SQL subprogram that registered the external procedure. Such calls, which you code in the usual way, can appear in

- anonymous blocks
- stand-alone and packaged subprograms
- methods of an object type

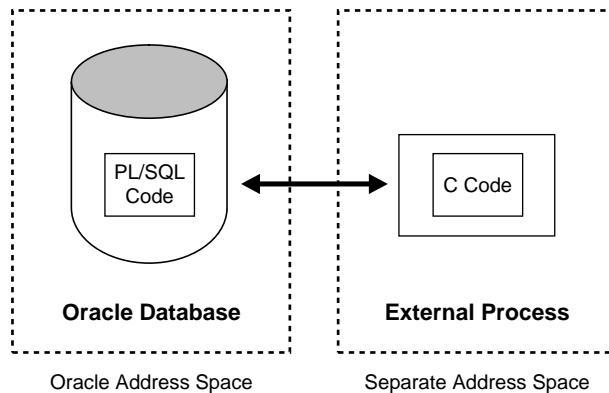
- database triggers
- SQL statements (calls to packaged functions only)

Note: To call a packaged function from SQL statements, you must use the pragma `RESTRICT_REFERENCES`, which asserts the purity level of the function (the extent to which the function is free of side effects). PL/SQL cannot check the purity level of the corresponding external routine. So, make sure the routine does not violate the pragma. Otherwise, you might get unexpected results. For more information about the pragma, see *Oracle8 Application Developer's Guide*.

Any PL/SQL block or subprogram executing on the server side or on the client side (for example, in a Developer/2000 tool such as Oracle Forms) can call an external procedure. The only requirement is that you call the external procedure from C code.

On the server side, the external procedure runs in a separate process address space, which safeguards your database. Figure 10-1 shows how Oracle8 and an external procedure interact.

Figure 10-1 Oracle8 Interacting with an External Procedure



An Example

In the last example, you wrote PL/SQL function *gcd*, which registered external procedure *c_gcd*, as follows:

```
CREATE FUNCTION gcd (
-- find greatest common divisor of x and y
  x BINARY_INTEGER,
  y BINARY_INTEGER)
RETURN BINARY_INTEGER AS EXTERNAL
  LIBRARY c_utils
  NAME "c_gcd" -- quotes preserve lower case
  LANGUAGE C;
```

In the example below, you call PL/SQL function *gcd* from an anonymous block. PL/SQL passes the two integer parameters to external function *c_gcd*, which returns their greatest common divisor.

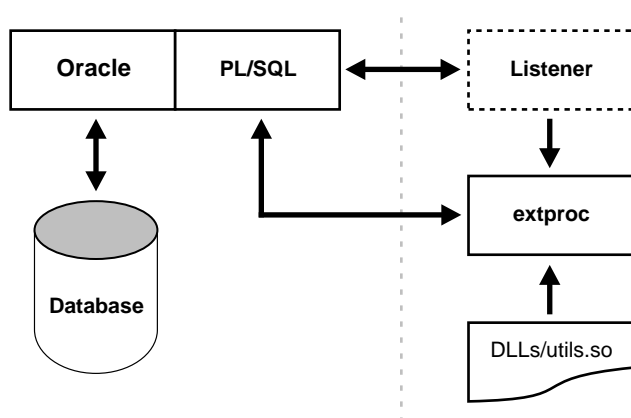
```
DECLARE
  g BINARY_INTEGER;
  a BINARY_INTEGER;
  b BINARY_INTEGER;
  ...
BEGIN
  ...
  g := gcd(a, b); -- call function
  IF g IN (2,4,8) THEN ...
```

How PL/SQL Calls an External Procedure

To call an external procedure, PL/SQL must know in which DLL it resides. So, PL/SQL looks up the alias library in the `EXTERNAL` clause of the subprogram that registered the external procedure, then has Oracle look up the DLL in the data dictionary.

Next, PL/SQL alerts a Listener process, which in turn spawns (launches) a session-specific agent named *extproc*. Then, the Listener hands over the connection to *extproc*. PL/SQL passes to *extproc* the name of the DLL, the name of the external procedure, and any parameters.

Then, *extproc* loads the DLL and runs the external procedure. Also, *extproc* handles service calls (such as raising an exception) and callbacks to the Oracle server. Finally, *extproc* passes to PL/SQL any values returned by the external procedure. Figure 10-2 shows the flow of control.

Figure 10–2 How an External Procedure Is Called

After the external procedure completes, *extproc* remains active throughout your Oracle session. (When you log off, *extproc* is killed.) So, you incur the cost of spawning *extproc* only once no matter how many calls you make. Still, you should call an external procedure only when the computational benefits outweigh the cost

Note: The Listener must start *extproc* on the machine that runs the Oracle server. Starting *extproc* on a different machine is not supported.

Environment Variables

The Listener sets a few required environment variables (such as `ORACLE_HOME`, `ORACLE_SID`, and `LD_LIBRARY_PATH`) for *extproc*. Otherwise, it provides *extproc* with a “clean” environment. The environment variables set for *extproc* are independent of those set for the client, server, and Listener. So, external procedures, which run in the *extproc* process, cannot read environment variables set for the client, server, or Listener process.

Passing Parameters to an External Procedure

Passing parameters to an external procedure is complicated by several circumstances:

- The set of PL/SQL datatypes does not correspond one-to-one with the set of C datatypes.
- PL/SQL parameters can be `NULL`, whereas C parameters cannot. (Unlike C, PL/SQL includes the RDBMS concept of nullity.)
- The external procedure might need the current length or maximum length of `CHAR`, `LONG RAW`, `RAW`, and `VARCHAR2` parameters.
- The external procedure might need character set information about `CHAR`, `VARCHAR2`, and `CLOB` parameters.
- PL/SQL might need the current length, maximum length, or null status of values returned by the external procedure.

In the following sections, you learn how to specify a parameter list that deals with these circumstances.

Specifying Datatypes

You do not pass parameters to an external procedure directly. Instead, you pass them to the PL/SQL subprogram that registered the external procedure. So, you must specify PL/SQL datatypes for the parameters. For guidance, see Table 10–1. Each PL/SQL datatype maps to a default external datatype. (In turn, each external datatype maps to a C datatype.) PL/SQL does all the datatype conversions for you.

Table 10–1 *Parameter Datatype Mappings*

PL/SQL Type	Supported External Types	Default External Type
<code>BINARY_INTEGER</code>	[UNSIGNED] <code>CHAR</code>	<code>INT</code>
<code>BOOLEAN</code>	[UNSIGNED] <code>SHORT</code>	
<code>PLS_INTEGER</code>	[UNSIGNED] <code>INT</code>	
	[UNSIGNED] <code>LONG</code>	
	<code>SB1</code> , <code>SB2</code> , <code>SB4</code>	
	<code>UB1</code> , <code>UB2</code> , <code>UB4</code>	
	<code>SIZE_T</code>	

Table 10–1 Parameter Datatype Mappings (Cont.)

PL/SQL Type	Supported External Types	Default External Type
NATURAL	[UNSIGNED] CHAR	UNSIGNED INT
NATURALN	[UNSIGNED] SHORT	
POSITIVE	[UNSIGNED] INT	
POSITIVEN	[UNSIGNED] LONG	
SIGNTYPE	SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T	
FLOAT	FLOAT	FLOAT
REAL		
DOUBLE PRECISION	DOUBLE	DOUBLE
CHAR	STRING	STRING
CHARACTER		
LONG		
NCHAR		
NVARCHAR2		
ROWID		
VARCHAR		
VARCHAR2		
LONG RAW	RAW	RAW
RAW		
BFILE	OCILOBLOCATOR	OCILOBLOCATOR
BLOB		
CLOB		
NCLOB		

In some cases, you can use the `PARAMETERS` clause to override the default datatype mappings. For example, you can re-map the PL/SQL datatype `BOOLEAN` from external datatype `INT` to external datatype `CHAR`.

To avoid errors when declaring C prototype parameters, refer to Table 10–2, which shows the C datatype to specify for a given external datatype and PL/SQL parameter mode. For example, if the external datatype of an OUT parameter is STRING, specify the datatype **char *** in your C prototype.

Table 10–2 External Datatype Mappings

External Datatype	IN, RETURN	IN by Ref, RETURN by Ref	IN OUT, OUT
CHAR	char	char *	char *
UNSIGNED CHAR	unsigned char	unsigned char *	unsigned char *
SHORT	short	short *	short *
UNSIGNED SHORT	unsigned short	unsigned short *	unsigned short *
INT	int	int *	int *
UNSIGNED INT	unsigned int	unsigned int *	unsigned int *
LONG	long	long *	long *
UNSIGNED LONG	unsigned long	unsigned long *	unsigned long *
SIZE_T	size_t	size_t *	size_t *
SB1	sb1	sb1 *	sb1 *
UB1	ub1	ub1 *	ub1 *
SB2	sb2	sb2 *	sb2 *
UB2	ub2	ub2 *	ub2 *
SB4	sb4	sb4 *	sb4 *
UB4	ub4	ub4 *	ub4 *
FLOAT	float	float *	float *
DOUBLE	double	double *	double *
STRING	char *	char *	char *
RAW	unsigned char *	unsigned char *	unsigned char *
OCILOBLOCATOR	OCILOBLocator *	OCILOBLocator *	OCILOBLocator **

Using the PARAMETERS Clause

Generally, the PL/SQL subprogram that registers an external procedure declares a list of formal parameters, as the following example shows:

```
CREATE FUNCTION interp (  
  -- find the value of y at x degrees using Lagrange interpolation  
  x IN FLOAT,  
  y IN FLOAT)  
RETURN FLOAT AS EXTERNAL  
  NAME "interp"  
  LIBRARY mathlib  
  LANGUAGE C;
```

Each formal parameter declaration specifies a name, parameter mode, and PL/SQL datatype (which maps to the default external datatype). That might be all the information the external procedure needs. If not, you can provide more information using the `PARAMETERS` clause, which lets you specify

- non-default external datatypes
- the current and/or maximum length of a parameter
- null/not null indicators for parameters
- character set IDs and forms
- the positions of parameters in the list
- how `IN` parameters are passed (by value or by reference)

For every formal parameter, there must be a corresponding parameter in the `PARAMETERS` clause. If you include the `WITH CONTEXT` clause, you must specify the parameter `CONTEXT`, which shows the position of the context pointer in the parameter list. Also, if the external routine is a function, you must specify the parameter `RETURN` in the last position.

Specifying Properties

You can also use the `PARAMETERS` clause to pass additional information about PL/SQL formal parameters and function results to an external procedure. You do that by specifying the following properties:

```
INDICATOR  
LENGTH  
MAXLEN  
CHARSETID  
CHARSETFORM
```

Table 10–3 shows the external datatypes, PL/SQL datatypes, and PL/SQL parameter modes allowed for a given property. Notice that `MAXLEN` cannot be applied to an `IN` parameter.

Table 10–3 Property Datatype Mappings

Property	C Parameter		PL/SQL Parameter	
	Allowed External Types	Default External Type	Allowed Types	Allowed Modes
INDICATOR	SHORT	SHORT	all scalars	IN
	INT			IN OUT
	LONG			OUT
				RETURN
LENGTH	[UNSIGNED] SHORT	INT	CHAR	IN
	[UNSIGNED] INT		LONG RAW	IN OUT
	[UNSIGNED] LONG		RAW	OUT
			VARCHAR2	RETURN
MAXLEN	[UNSIGNED] SHORT	INT	CHAR	IN OUT
	[UNSIGNED] INT		LONG RAW	OUT
	[UNSIGNED] LONG		RAW	RETURN
			VARCHAR2	
CHARSETID	UNSIGNED SHORT	UNSIGNED INT	CHAR	IN
CHARSETFORM	UNSIGNED INT		CLOB	IN OUT
	UNSIGNED LONG		VARCHAR2	OUT
				RETURN

In the following example, we use the `PARAMETERS` clause to specify properties for the PL/SQL formal parameters and function result:

```
CREATE FUNCTION parse (
    x IN BINARY_INTEGER,
    Y IN OUT CHAR)
RETURN CHAR AS EXTERNAL
    LIBRARY c_utils
    NAME "c_parse"
    LANGUAGE C
    CALLING STANDARD PASCAL
    PARAMETERS (
        x,           -- stores value of x
        x INDICATOR, -- stores null status of x
        y,           -- stores value of y
```

```
y LENGTH,      -- stores current length of y
y MAXLEN,      -- stores maximum length of y
RETURN INDICATOR,
RETURN);
```

With this `PARAMETERS` clause, the C prototype becomes

```
char * c_parse(int x, short x_ind, char *y, int *y_len,
               int *y_maxlen, short *retind);
```

The additional parameters in the C prototype correspond to the `INDICATOR`, `LENGTH`, and `MAXLEN` parameters in the `PARAMETERS` clause. The parameter `RETURN` corresponds to the C function identifier, which stores the result value.

Using `INDICATOR` An *indicator* is a parameter whose value “indicates” whether or not another parameter is null. PL/SQL does not need indicators because the RDBMS concept of nullity is built into the language. However, an external procedure might need to know if a parameter or function result is null. Also, an external procedure might need to signal the server that a returned “value” is actually a null, and should be treated accordingly.

In such cases, you can use the property `INDICATOR` to associate an indicator with a formal parameter. If the PL/SQL subprogram is a function, you can also associate an indicator with the function result.

To check the value of an indicator, you can use the constants `OCI_IND_NULL` and `OCI_IND_NOTNULL`. If the indicator equals `OCI_IND_NULL`, the associated parameter or function result is null. If the indicator equals `OCI_IND_NOTNULL`, the parameter or function result is not null.

For `IN` parameters, `INDICATOR` is passed by value (unless you specify `BY REF`) and is read-only (even if you specify `BY REF`). For `OUT`, `IN OUT`, and `RETURN` parameters, `INDICATOR` is passed by reference.

Using `LENGTH` and `MAXLEN` In PL/SQL, there is no standard way to indicate the length of a raw or string parameter. However, in many cases, you want to pass the length of a parameter to and from an external procedure. Using the properties `LENGTH` and `MAXLEN`, you can specify parameters that store the current length and maximum length of a formal parameter.

Note: With parameters of type `RAW` or `LONG RAW`, you must use the property `LENGTH`.

For IN parameters, LENGTH is passed by value (unless you specify BY REF) and is read-only (even if you specify BY REF). For OUT, IN OUT, and RETURN parameters, LENGTH is passed by reference.

MAXLEN does not apply to IN parameters. For OUT, IN OUT, and RETURN parameters, MAXLEN is passed by reference but is read-only.

Using CHARSETID and CHARSETFORM Oracle provides national language support, which lets you process single-byte and multi-byte character data and convert between character sets. It also lets your applications run in different language environments.

The properties CHARSETID and CHARSETFORM identify the nondefault character set from which the character data being passed was formed. With CHAR, CLOB, and VARCHAR2 parameters, you can use CHARSETID and CHARSETFORM to pass the character set ID and form to the external procedure.

For IN parameters, CHARSETID and CHARSETFORM are passed by value (unless you specify BY REF) and are read-only (even if you specify BY REF). For OUT, IN OUT, and RETURN parameters, CHARSETID and CHARSETFORM are passed by reference but are read-only.

The OCI attribute names for these properties are OCI_ATTR_CHARSET_ID and OCI_ATTR_CHARSET_FORM. For more information about using NLS data with the OCI, see *Oracle Call Interface Programmer's Guide*.

Repositioning Parameters

Remember, each formal parameter must have a corresponding parameter in the PARAMETERS clause. Their positions can differ because PL/SQL associates them by name, not by position. However, the PARAMETERS clause and the C prototype for the external procedure must have the same number of parameters in the same order.

Passing Parameters by Reference

In C, you can pass IN scalar parameters *by value* (the value of the parameter is passed) or *by reference* (a pointer to the value is passed). When an external procedure expects a pointer to a scalar, specify the BY REF phrase to pass the parameter by reference. An example follows:

```
CREATE PROCEDURE find_root (
    x IN REAL, ...)
AS EXTERNAL
    LIBRARY c_utils
```

```
NAME "c_find_root"  
PARAMETERS (  
    x BY REF, ...);
```

In this case, the C prototype would be

```
void c_find_root(float *x, ...);
```

rather than the default

```
void c_find_root(float x, ...);
```

Using the WITH CONTEXT Clause

By including the `WITH CONTEXT` clause, you can give an external procedure access to information about parameters, exceptions, memory allocation, and the user environment. The `WITH CONTEXT` clause specifies that a context pointer will be passed to the external procedure. For example, if you write the following PL/SQL function

```
CREATE FUNCTION get_num (  
    x IN REAL)  
RETURN BINARY_INTEGER AS EXTERNAL  
    LIBRARY c_utils  
    NAME "c_get_num"  
    LANGUAGE C  
    WITH CONTEXT  
    PARAMETERS (  
        CONTEXT,  
        x BY REF,  
        RETURN INDICATOR);
```

then the C prototype would be

```
int c_get_num(  
    OCIEExtProcContext *with_context,  
    float *x,  
    short *retind);
```

The context data structure is opaque to the external procedure but is available to service routines called by the external procedure.

If you also include the `PARAMETERS` clause, you must specify the parameter `CONTEXT`, which shows the position of the context pointer in the parameter list. If you omit the `PARAMETERS` clause, the context pointer is the first parameter passed to the external procedure.

Using Service Routines

When called from an external procedure, a service routine can raise exceptions, allocate memory, and get OCI (Oracle Call Interface) handles for callbacks to the server. To use the functions, you must specify the `WITH CONTEXT` clause, which lets you pass a context structure to the external procedure. The context structure is declared in header file `ociextp.h` as follows:

```
typedef struct OCIEExtProcContext OCIEExtProcContext;
```

Now, let us see how service routines use the context information.

OCIEExtProcAllocCallMemory

This service routine allocates *n* bytes of memory for the duration of the external procedure call. Any memory allocated by the function is freed automatically as soon as control returns to PL/SQL.

Note: The external procedure need not (and should not) call the C function `free()` to free memory allocated by this service routine.

The C prototype for this function follows:

```
dvoid *OCIEExtProcAllocCallMemory(
    OCIEExtProcContext *with_context,
    size_t amount);
```

The parameters *with_context* and *amount* are the context pointer and number of bytes to allocate, respectively. The function returns an untyped pointer to the allocated memory. A return value of zero indicates failure.

In SQL*Plus, suppose you register external function `concat`, as follows:

```
SQL> CREATE FUNCTION concat (
  2     str1 IN VARCHAR2,
  3     str2 IN VARCHAR2)
  4 RETURN VARCHAR2 AS EXTERNAL
  5     NAME "concat"
  6     LIBRARY stringlib
  7     WITH CONTEXT
  8     PARAMETERS (
  9         CONTEXT,
 10         str1  STRING,
 11         str1  INDICATOR short,
```

```
12     str2  STRING,  
13     str2  INDICATOR short,  
14     RETURN INDICATOR short,  
15     RETURN LENGTH short,  
16     RETURN STRING);
```

When called, *concat* concatenates two strings, then returns the result. If either string is null, the result is also null. As the following example shows, *concat* uses *OCIExtProcAllocCallMemory* to allocate memory for the result string:

```
char *concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l)  
OCIExtProcContext *ctx;  
char *str1;  
short str1_i;  
char *str2;  
short str2_i;  
short *ret_i;  
short *ret_l;  
{  
    char *tmp;  
    short len;  
    /* Check for null inputs. */  
    if ((str1_i == OCI_IND_NULL) || (str2_i == OCI_IND_NULL))  
    {  
        *ret_i = (short)OCI_IND_NULL;  
        /* PL/SQL has no notion of a null ptr, so  
         return a zero-byte string. */  
        tmp = OCIExtProcAllocCallMemory(ctx, 1);  
        tmp[0] = '\0';  
        return(tmp);  
    }  
    /* Allocate memory for result string, including null terminator. */  
    len = strlen(str1) + strlen(str2);  
    tmp = OCIExtProcAllocCallMemory(ctx, len + 1);  
  
    strcpy(tmp, str1);  
    strcat(tmp, str2);  
  
    /* Set null indicator and length. */  
    *ret_i = (short)OCI_IND_NOTNULL;  
    *ret_l = len;  
  
    /* Return pointer, which PL/SQL frees later. */  
    return(tmp);  
}
```


OCIExtProcRaiseExcp

This service routine raises a predefined exception, which must have a valid Oracle error number in the range 1 .. 32767. After doing any necessary cleanup, the external procedure must return immediately. (No values are assigned to OUT or IN OUT parameters.) The C prototype for this function follows:

```
int OCIExtProcRaiseExcp(
    OCIExtProcContext *with_context,
    size_t error_number);
```

The parameters *with_context* and *error_number* are the context pointer and Oracle error number. The return values OCIEXTPROC_SUCCESS and OCIEXTPROC_ERROR indicate success or failure.

In SQL*Plus, suppose you register external procedure *divide*, as follows:

```
SQL> CREATE PROCEDURE divide (
  2     dividend IN BINARY_INTEGER,
  3     divisor  IN BINARY_INTEGER,
  4     result   OUT FLOAT)
  5 AS EXTERNAL
  6     NAME "divide"
  7     LIBRARY mathlib
  8     WITH CONTEXT
  9     PARAMETERS (
10         CONTEXT,
11         dividend int,
12         divisor  int,
13         result   float);
```

When called, *divide* finds the quotient of two numbers. As the following example shows, if the divisor is zero, *divide* uses *OCIExtProcRaiseExcp* to raise the predefined exception ZERO_DIVIDE:

```
void divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int  dividend;
int  divisor;
float *result;
{
    /* Check for zero divisor. */
    if (divisor == (int)0)
    {
        /* Raise exception ZERO_DIVIDE, which is Oracle error 1476. */
        if (OCIExtProcRaiseExcp(ctx, (int)1476) == OCIEXTPROC_SUCCESS)
```

```
    {
        return;
    }
    else
    {
        /* Incorrect parameters were passed. */
        assert(0);
    }
}
*result = (float)dividend / (float)divisor;
}
```

OCIExtProcRaiseExcpWithMsg

This service routine raises a user-defined exception and returns a user-defined error message. The C prototype for this function follows:

```
int OCIExtProcRaiseExcpWithMsg(
    OCIExtProcContext *with_context,
    size_t error_number,
    text *error_message,
    size_t len);
```

The parameters *with_context*, *error_number*, and *error_message* are the context pointer, Oracle error number, and error message text. The parameter *len* stores the length of the error message. If the message is a null-terminated string, *len* is zero. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

In the previous example, you registered external procedure *divide*, as follows:

```
SQL> CREATE PROCEDURE divide (
2     dividend IN BINARY_INTEGER,
3     divisor  IN BINARY_INTEGER,
4     result   OUT FLOAT)
5 AS EXTERNAL
6     NAME "divide"
7     LIBRARY mathlib
8     WITH CONTEXT
9     PARAMETERS (
10        CONTEXT,
11        dividend int,
12        divisor  int,
13        result   float);
```

In the example below, you use a different version of *divide*. With this version, if the divisor is zero, *divide* uses *OCIExtProcRaiseExcpWithMsg* to raise a user-defined exception:

```
void divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int  dividend;
int  divisor;
float *result;
    /* Check for zero divisor. */
    if (divisor == (int)0)
    {
        /* Raise a user-defined exception, which is Oracle error 20100,
           and return a null-terminated error message. */
        if (OCIExtProcRaiseExcpWithMsg(ctx, (int)20100,
            "divisor is zero", 0) == OCIEXTPROC_SUCCESS)
        {
            return;
        }
        else
        {
            /* Incorrect parameters were passed. */
            assert(0);
        }
    }
    *result = dividend / divisor;
}
```

OCIExtProcGetEnv

This service routine enables OCI callbacks to the database during an external procedure call. Use the OCI handles obtained by this function only for callbacks. If you use them for standard OCI calls, the handles establish a new connection to the database and cannot be used for callbacks in the same transaction. In other words, during an external procedure call, you can use OCI handles for callbacks or a new connection but not for both.

The C prototype for this function follows:

```
sword OCIExtProcGetEnv(
    OCIExtProcContext *with_context,
    OCIEnv **envh,
    OCISvcCtx **svch,
    OCIError **errh);
```

The parameter *with_context* is the context pointer, and the parameters *envh*, *svch*, and *errh* are the OCI environment, service, and error handles, respectively. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

The next section shows how `OCIExtProcGetEnv` might be used in callbacks. For a working example, see “Demo Program” on page 10-24.

Doing Callbacks

An external procedure executing on the Oracle server can call a service routine to obtain OCI environment and service handles. With the OCI, you can use callbacks to execute SQL statements and PL/SQL subprograms, fetch data, and manipulate LOBs. Moreover, callbacks and external procedures operate in the same user session and transaction context. So, they have the same user privileges.

In SQL*Plus, suppose you run the following script:

```
CREATE TABLE emptab (empno NUMBER(10))
/
CREATE PROCEDURE insert_emptab (
    empno BINARY_INTEGER)
AS EXTERNAL
    NAME "insert_emptab"
    LIBRARY insert_lib
    WITH CONTEXT
    PARAMETERS (
        CONTEXT,
        empno LONG)
/
```

Later, you might call service routine `OCIExtProcGetEnv` from external procedure `insert_emptab`, as follows:

```
#include <stdio.h>
#include <stdlib.h>
#include <oratypes.h>
#include <oci.h>
...
void insert_emptab (ctx, empno)
OCIExtProcContext *ctx;
long empno;
{
    OCIEnv    *envhp;
    OCISvcCtx *svchp;
```

```

OCIError *errhp;
int      err;
...
err = OCIExtProcGetEnv(ctx, &envhp, &svchp, &errhp);
...
}

```

Restrictions on Callbacks

With callbacks, the following SQL commands and OCI routines are not supported:

- transaction control commands such as COMMIT
- data definition commands such as CREATE
- object-oriented OCI routines such as *OCIRefClear*
- polling-mode OCI routines such as *OCIGetPieceInfo*
- all these OCI routines:

```

OCIEnvInit
OCIInitialize
OCIPasswordChange
OCIserverAttach
OCIserverDetach
OCISessionBegin
OCISessionEnd
OCISvcCtxToLda
OCITransCommit
OCITransDetach
OCITransRollback
OCITransStart

```

Also, with OCI routine *OCIHandleAlloc*, the following handle types are not supported:

```

OCI_HTYPE_SERVER
OCI_HTYPE_SESSION
OCI_HTYPE_SVCCTX
OCI_HTYPE_TRANS

```

Debugging External Procedures

Usually, when an external procedure fails, its C prototype is faulty. That is, the prototype does not match the one generated internally by PL/SQL. This can happen if you specify an incompatible C datatype. For example, to pass an `OUT` parameter of type `REAL`, you must specify `float *`. Specifying `float`, `double *`, or any other C datatype will result in a mismatch.

In such cases, you might get a *lost RPC connection to external procedure agent* error, which means that agent `extproc` terminated abnormally because the external procedure caused a core dump. To avoid errors when declaring C prototype parameters, refer to Table 10–2.

Using Package `DEBUG_EXTPROC`

To help you debug external procedures, PL/SQL provides the utility package `DEBUG_EXTPROC`. To install the package, run the script `dbgextp.sql`, which you can find in the PL/SQL demo directory. (For the location of the directory, see your Oracle installation or user's guide.)

To use the package, follow the instructions in `dbgextp.sql`. Your Oracle account must have `EXECUTE` privileges on the package and `CREATE LIBRARY` privileges.

Note: `DEBUG_EXTPROC` works only on platforms with debuggers that can attach to a running process.

Demo Program

Also in the PL/SQL demo directory is the script `extproc.sql`, which demonstrates the calling of an external procedure. The companion file `extproc.c` contains the C source code for the external procedure.

To run the demo, follow the instructions in `extproc.sql`. You must use the `SCOTT/TIGER` account, which must have `CREATE LIBRARY` privileges.

Guidelines for External Procedures

In future releases, *extproc* might be a multi-threaded process. So, be sure to write thread-safe external procedures. That way, they will continue to run properly if *extproc* becomes multi-threaded. In particular, avoid using **static** variables, which can be shared by routines running in separate threads. Otherwise, you might get unexpected results.

For help in creating a dynamic link library, look in the RDBMS subdirectory */public*, where a template makefile can be found.

When calling external procedures, never write to **IN** parameters or overflow the capacity of **OUT** parameters. (PL/SQL does no runtime checks for these error conditions.) Likewise, never read an **OUT** parameter or a function result. Also, always assign a value to **IN** **OUT** and **OUT** parameters and to function results. Otherwise, your external procedure will not return successfully.

If you include the **WITH CONTEXT** and **PARAMETERS** clauses, you must specify the parameter **CONTEXT**, which shows the position of the context pointer in the parameter list. If you omit the **PARAMETERS** clause, the context pointer is the first parameter passed to the external procedure.

If you include the **PARAMETERS** clause and the external routine is a function, you must specify the parameter **RETURN** (not **RETURN** *property*) in the last position.

For every formal parameter, there must be a corresponding parameter in the **PARAMETERS** clause. Also, make sure that the datatypes of parameters in the **PARAMETERS** clause are compatible with those in the C prototype because no implicit conversions are done.

With a parameter of type **RAW** or **LONG RAW**, you must use the property **LENGTH**. Also, if that parameter is **IN** **OUT** or **OUT** and null, you must set the length of the corresponding C parameter to zero.

Restrictions on External Procedures

Currently, the following restrictions apply to external procedures:

- This feature is available only on platforms that support DLLs.
- Only routines callable from C code (not C++ code) are supported.
- You cannot pass PL/SQL cursor variables, records, collections, or instances of an object type to an external procedure.

- In the `LIBRARY` subclause, you cannot use a database link to specify a remote library.
- The Listener must start agent *extproc* on the machine that runs the Oracle server. Starting *extproc* on a different machine is not supported.
- The maximum number of parameters that you can pass to a C external procedure is 128. However, if you pass **float** or **double** parameters by value, the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each **float** or **double** passed by value as two parameters.

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.

Major Topics

- Assignment Statement
- Blocks
- CLOSE Statement
- Collection Methods
- Collections
- Comments
- COMMIT Statement
- Constants and Variables
- Cursor Attributes
- Cursor Variables
- Cursors
- DELETE Statement
- EXCEPTION_INIT Pragma
- Exceptions
- EXIT Statement
- Expressions
- External Procedures
- FETCH Statement
- Functions

GOTO Statement
IF Statement
INSERT Statement
Literals
LOCK TABLE Statement
LOOP Statements
NULL Statement
Object Types
OPEN Statement
OPEN-FOR Statement
Packages
Procedures
RAISE Statement
Records
RETURN Statement
ROLLBACK Statement
%ROWTYPE Attribute
SAVEPOINT Statement
SELECT INTO Statement
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.

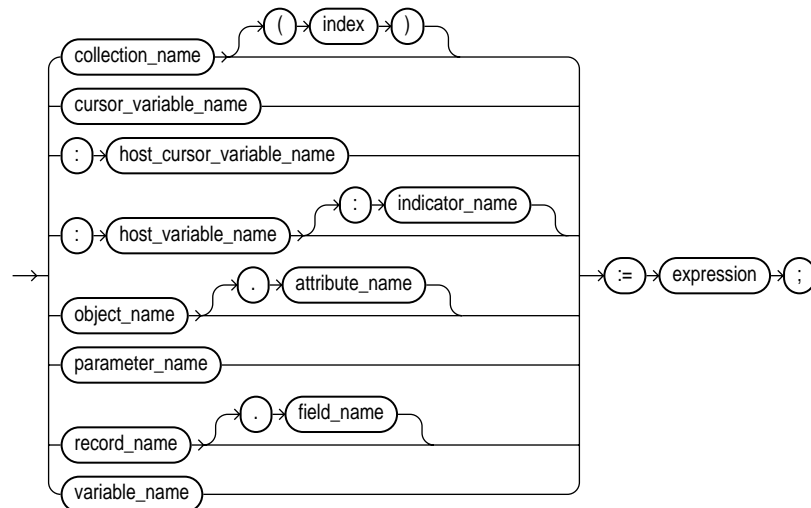
Each diagram defines a syntactic element. Every path through the diagram describes a possible form of that element. Follow in the direction of the arrows. If a line loops back on itself, you can repeat the element enclosed by the loop.

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 2-40.

Syntax

assignment_statement



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.

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.

object_name

This identifies an object (instance of an object type) previously declared within the current scope.

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.

parameter_name

This identifies a formal OUT or IN OUT parameter of the subprogram in which the assignment statement appears.

index

This is a numeric expression that must yield a value of type BINARY_INTEGER or a value implicitly convertible to that datatype.

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 PL/SQL variable previously declared within the current scope.

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 11-59. 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.

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` and `FALSE` and the non-value `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;
```

The next assignment is illegal because you cannot use the assignment operator to assign a list of values to a record:

```
dept_rec := (60, 'PUBLICITY', 'LOS ANGELES');
```

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

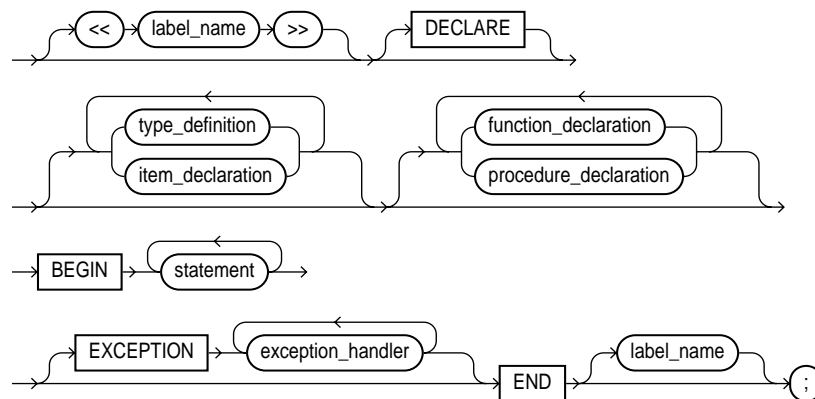
Constants and Variables, Expressions, SELECT INTO Statement

Blocks

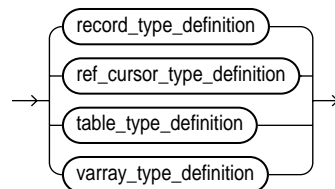
The basic program unit in PL/SQL is the block. A PL/SQL block is defined by the keywords `DECLARE`, `BEGIN`, `EXCEPTION`, and `END`. These keywords partition the PL/SQL block into a declarative part, an executable part, and an exception-handling part. Only the executable part is required. You can nest 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 2-37.

Syntax

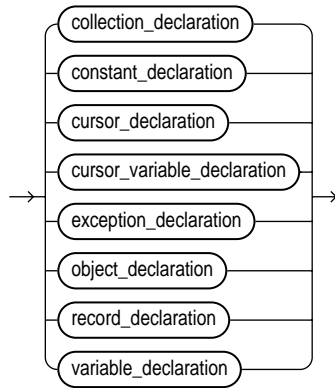
plsql_block



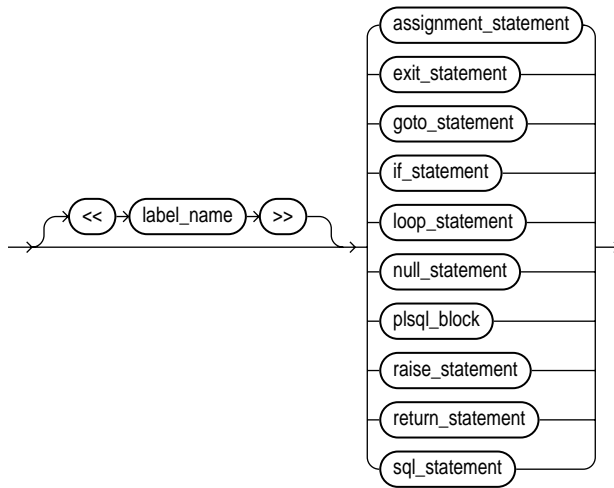
type_definition

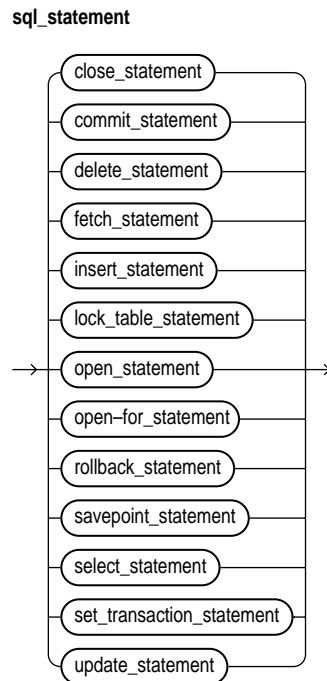


item_declaration



statement





Keyword and Parameter Description

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* 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. To reference the global identifier, you must 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;
```

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.

collection_declaration

This identifies a nested table, index-by table, or varray previously declared within the current scope. For the syntax of *collection_declaration*, see “Collections” on page 11-21.

constant_declaration

This construct declares a constant. For the syntax of *constant_declaration*, see “Constants and Variables” on page 11-29.

cursor_declaration

This construct declares an explicit cursor. For the syntax of *cursor_declaration*, see “Cursors” on page 11-45.

cursor_variable_declaration

This construct declares a cursor variable. For the syntax of *cursor_variable_declaration*, see “Cursor Variables” on page 11-38.

exception_declaration

This construct declares an exception. For the syntax of *exception_declaration*, see “Exceptions” on page 11-54.

object_declaration

This identifies an object (instance of an object type) previously declared within the current scope. For the syntax of *object_declaration*, see “Object Types” on page 11-103.

record_declaration

This construct declares a user-defined record. For the syntax of *record_declaration*, see “Records” on page 11-128.

variable_declaration

This construct declares a variable. For the syntax of *variable_declaration*, see “Constants and Variables” on page 11-29.

function_declaration

This construct declares a function. For the syntax of *function_declaration*, see “Functions” on page 11-79.

procedure_declaration

This construct declares a procedure. For the syntax of *procedure_declaration*, see “Procedures” on page 11-121.

BEGIN

This keyword signals the start of the executable part of a PL/SQL block, which contains executable statements. The executable part of a PL/SQL block is required. That is, a block must contain at least one executable statement. The `NULL` statement meets this requirement.

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.

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.

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 6.

exception_handler

This construct 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 11-54.

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.

END does *not* signal the end of a transaction. Just as a block can span multiple transactions, a transaction can span multiple blocks.

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;
```

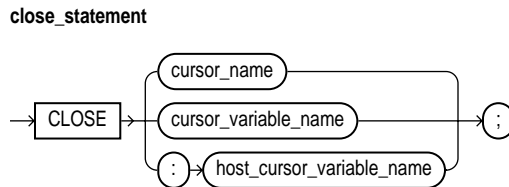
Related Topics

Constants and Variables, Exceptions, Functions, Procedures

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 5-9.

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](#)

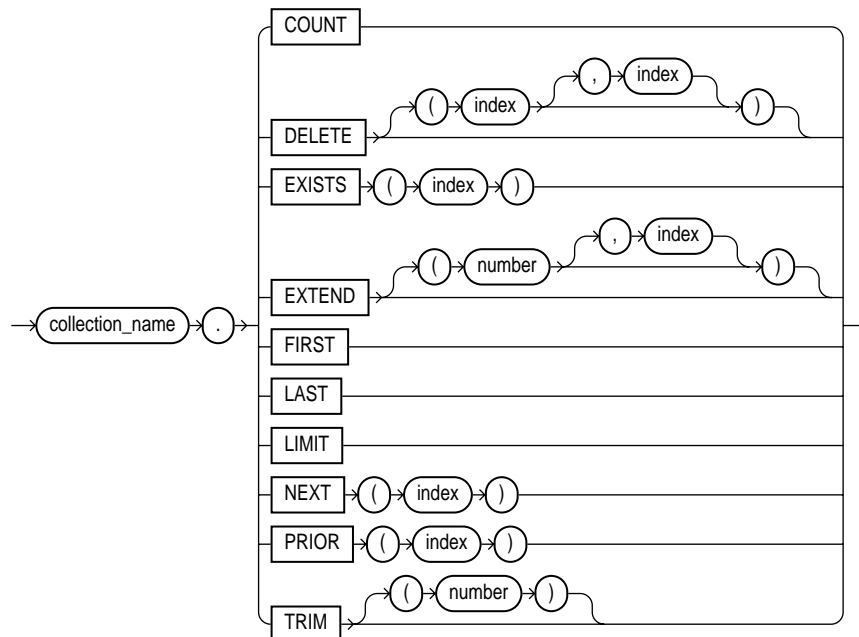
Collection Methods

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. For more information, see “Using Collection Methods” on page 4-21.

Syntax

collection_method_call



Keyword and Parameter Description

collection_name

This identifies a nested table, index-by 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 a nested table. If *n* is null, DELETE(*n*) does nothing. DELETE(*m*, *n*) removes all elements in the range *m* . . *n* from a nested table. If *m* is larger than *n* or if *m* or *n* is null, DELETE(*m*, *n*) does nothing.

index

This is an expression that must yield (or convert implicitly to) an integer. For more information, see “Datatype Conversion” on page 2-25.

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.

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`.

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 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`.

`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 next 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

Collections

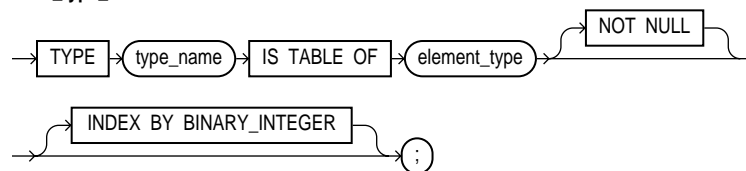
A collection is an ordered group of elements, all of the same type (for example, the grades for a class of students). Each element has a unique subscript that determines its position in the collection. PL/SQL offers two kinds of collections: nested tables and varrays (short for variable-size arrays).

Collections work like the arrays found in most third-generation programming languages. However, 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.)

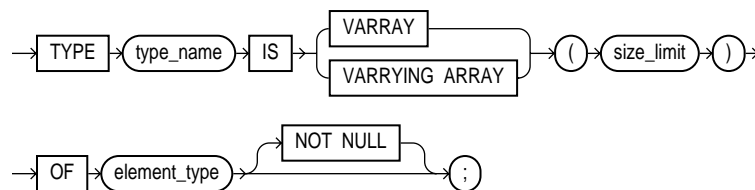
Collections can store instances of an object type and, conversely, can be attributes of an object type. Also, collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms. For more information, see “Defining and Declaring Collections” on page 4-5.

Syntax

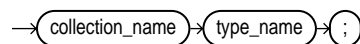
table_type_definition

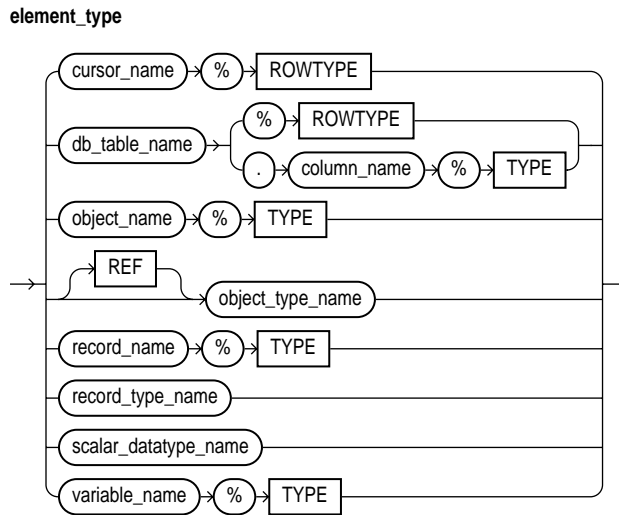


varray_type_definition



collection_declaration





Keyword and Parameter Description

type_name

This identifies a user-defined type specifier, which is used in subsequent declarations of collections.

element_type

This is any PL/SQL datatype except `BOOLEAN`, `NCHAR`, `NCLOB`, `NVARCHAR2`, `REF CURSOR`, `TABLE`, and `VARRAY`, or is any object type except those with `TABLE` or `VARRAY` attributes. If *element_type* is a record type, every field in the record must be a scalar type or an object type.

INDEX BY BINARY_INTEGER

This optional clause lets you define Version 2 PL/SQL tables, which are called index-by tables in Version 8.

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.

Usage Notes

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, collection subscripts have a fixed lower bound of 1.

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.

You can define collection types in the declarative part of any PL/SQL block, subprogram, or package. In SQL, collection types can be `CREATED` and stored in the database.

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 collection is atomically null (that is, the collection itself is null, not its elements). To initialize a collection, 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 collections can be atomically null, they can be tested for nullity. However, collections 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, nested tables and varrays can be passed as parameters. So, you can use them to move collections 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 collections declared as the formal parameters of a subprogram. That allows you to 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;
```

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 -- define 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 specification, 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 Statistics', 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

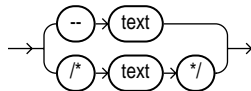
Collection Methods, Object Types, Records

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 2-9.

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

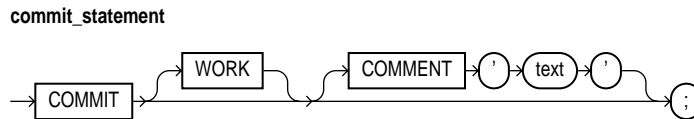
The following examples show various comment styles:

```
-- 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 “Processing Transactions” on page 5-44.

Syntax



Keyword and Parameter Description

WORK

This keyword is optional and has no effect except to improve readability.

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.

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 cursor that was declared using `FOR UPDATE` 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 5-51.

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 *Oracle8 Concepts*.

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
```

With embedded SQL, the optional `RELEASE` parameter is allowed after `COMMIT WORK`. The keyword `RELEASE` acts like a “disconnect” statement, which logs you off the database once your transaction is committed. PL/SQL does not support data control statements such as `CONNECT`, `GRANT`, or `REVOKE`. Therefore, it does not support the `RELEASE` parameter.

Related Topics

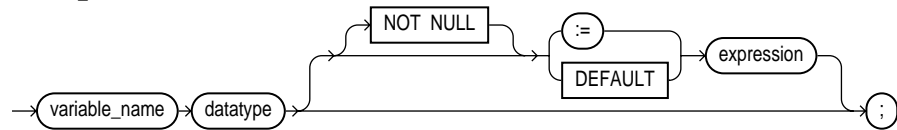
[ROLLBACK Statement](#), [SAVEPOINT Statement](#)

Constants and Variables

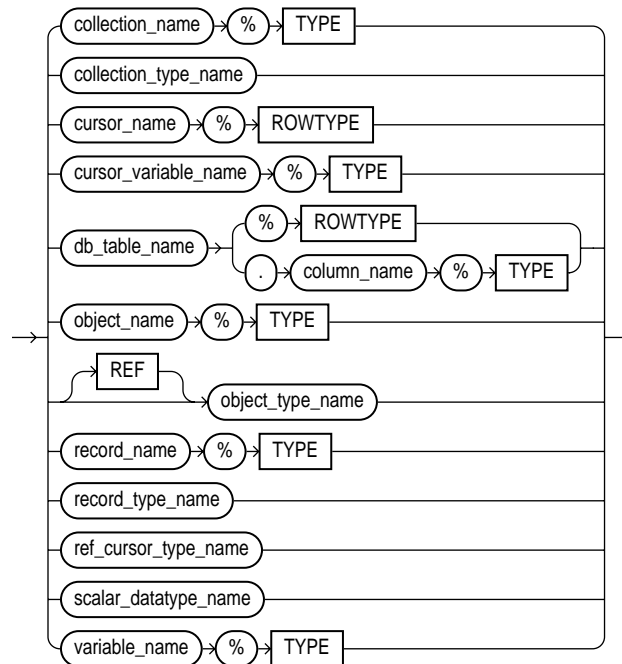
You can declare constants and variables in the declarative part of any PL/SQL block, subprogram, or package. Declarations allocate storage space for a value, specify its datatype, and name the storage location so that you can reference it. Declarations can also assign an initial value and impose the NOT NULL constraint. For more information, see “Declarations” on page 2-28.

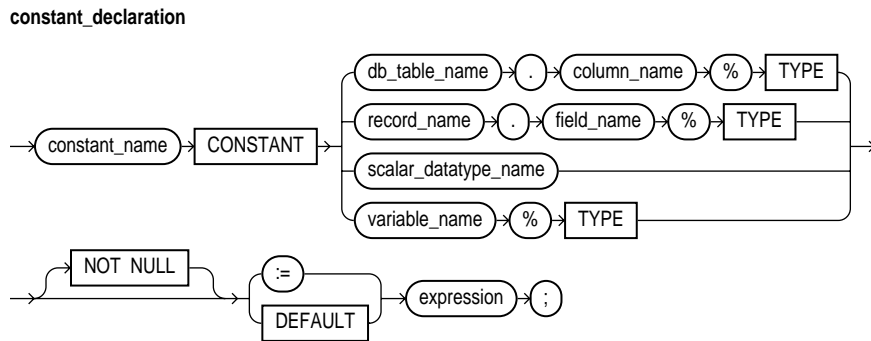
Syntax

variable_declaration



datatype





Keyword and Parameter Description

constant_name

This identifies a program constant. For naming conventions, see “Identifiers” on page 2-4.

CONSTANT

This keyword denotes the declaration of a constant. You must initialize a constant in its declaration. Once initialized, the value of a constant cannot be changed.

record_name.field_name

This identifies a field in a user-defined or %ROWTYPE record previously declared within the current scope.

scalar_type_name

This identifies a predefined scalar datatype such as BOOLEAN, NUMBER, or VARCHAR2. For more information, see “Datatypes” on page 2-10.

db_table_name.column_name

This identifies a database table and column that must be accessible when the declaration is elaborated.

variable_name

This identifies a program variable.

collection_name

This identifies a 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.

object_name

This identifies an object (instance of an object type) previously declared within the current scope.

record_name

This identifies a user-defined record 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.

%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.

%TYPE

This attribute provides the datatype of a previously declared collection, cursor variable, field, object, record, database column, or variable.

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.

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 constant or variable. The value and the constant or variable must have compatible datatypes.

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 specification are initialized only once per session.

An initialization clause is required when declaring `NOT NULL` variables and when declaring constants.

You cannot use the attribute `%ROWTYPE` to declare a constant. 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;
last_name    VARCHAR2(20);
my_ename     emp.ename%TYPE;
```

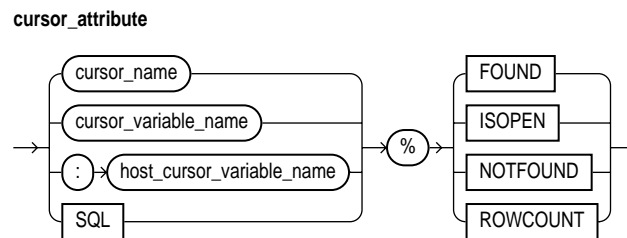
Related Topics

Assignment Statement, Expressions, `%ROWTYPE` Attribute, `%TYPE` Attribute

Cursor Attributes

Cursors and cursor variables have four attributes that give you useful information about the execution of a data manipulation statement. For more information, see “Using Cursor Attributes” on page 5-38.

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 cursor variable (or parameter) previously declared within the current scope.

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.

SQL

This is the name of the implicit SQL cursor. For more information, see “SQL Cursor” on page 11-144.

%FOUND

This is a cursor attribute, which 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.

Until a SQL statement is executed, *SQL*%FOUND yields NULL. Thereafter, it yields TRUE if the statement affected any rows, or FALSE if it affected no rows.

%ISOPEN

This is a cursor attribute, which 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.

Oracle automatically closes the implicit SQL cursor after executing its associated SQL statement, so *SQL*%ISOPEN always yields FALSE.

%NOTFOUND

This is a cursor attribute, which 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.

Until a SQL statement is executed, *SQL*%NOTFOUND yields NULL. Thereafter, it yields FALSE if the statement affected any rows, or TRUE if it affected no rows.

%ROWCOUNT

This is a cursor attribute, which 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.

Until a SQL statement is executed, *SQL*%ROWCOUNT yields NULL. Thereafter, it yields the number of rows affected by the statement. *SQL*%ROWCOUNT yields 0 if the statement affected no rows.

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 ci%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

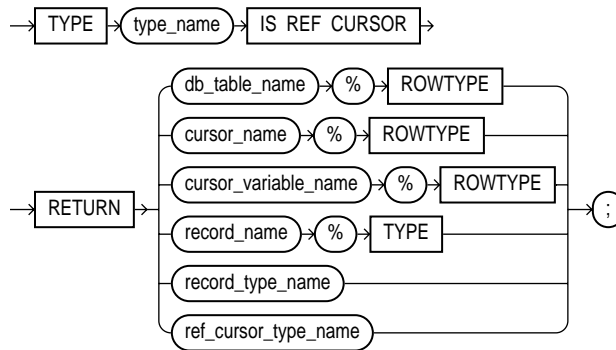
Cursor Variables

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.

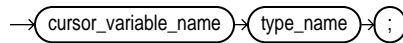
Cursor variables are like C or Pascal pointers, which hold the memory location (address) of some item instead of the item itself. So, declaring a cursor variable creates a pointer, *not* an item. For more information, see “Using Cursor Variables” on page 5-18.

Syntax

`ref_cursor_type_definition`



`cursor_variable_declaration`



Keyword and Parameter Description

type_name

This is a user-defined type specifier, which is used in subsequent declarations of PL/SQL cursor variables.

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 result 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.

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.

record_name

This identifies a user-defined record previously declared within the current scope.

record_type_name

This identifies a `RECORD` type previously defined within the current scope.

db_table_name

This identifies a database table (or view) that must be accessible when the declaration is elaborated.

%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.

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 server also has a PL/SQL engine. So, you can pass cursor variables back and forth between an application and server via 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.

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 one at a time. 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. For more information, see “Using Cursor Attributes” on page 5-38.

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.

Currently, cursor variables are subject to the following restrictions, some of which future releases of PL/SQL will remove:

- You cannot declare cursor variables in a package because they do not have persistent state.

- 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 (bind variable) to PL/SQL, you cannot fetch from it on the server side unless you also open it there on the same server call.
- The query associated with a cursor variable in an `OPEN-FOR` statement cannot be `FOR UPDATE`.
- 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.
- Cursors and cursor variables are not interoperable; that is, you cannot use one where the other is expected.
- You cannot use a `REF CURSOR` type to specify the element type of a collection, which means that elements in a collection cannot store the values of cursor variables.
- You cannot use cursor variables with dynamic SQL.

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 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;

```

```
        END IF;
    END open_emp_cv;
END emp_data;
```

Alternatively, you can use a stand-alone procedure to open the cursor variable. Simply define the `REF CURSOR` type in a separate package, then reference that type in the stand-alone procedure. For instance, if you create the following (bodiless) package, you can create stand-alone 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

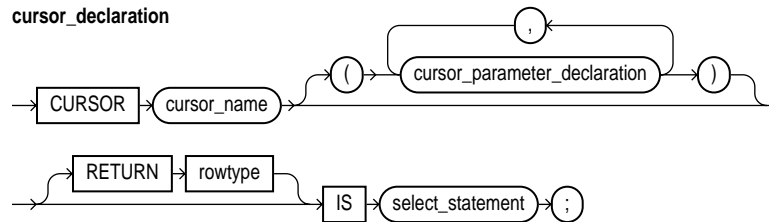
[CLOSE Statement](#), [Cursor Attributes](#), [Cursors](#), [FETCH Statement](#), [OPEN-FOR Statement](#)

Cursors

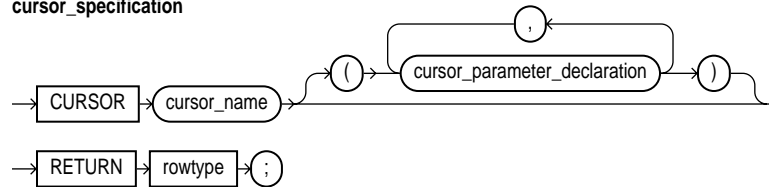
To execute a multi-row query, Oracle opens an unnamed work area that stores processing information. A cursor lets you name the work area, access the information, and process the rows individually. For more information, see “Managing Cursors” on page 5-9.

Syntax

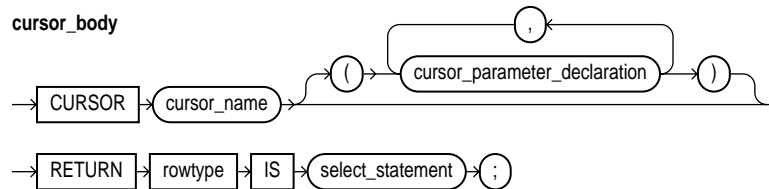
cursor_declaration



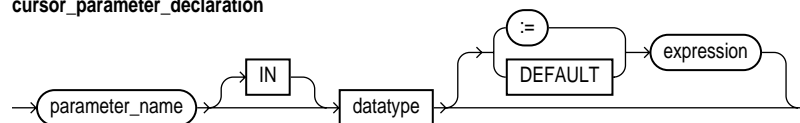
cursor_specification



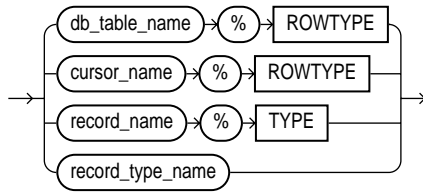
cursor_body



cursor_parameter_declaration



rowtype



Keyword and Parameter Description

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 11-139. If the cursor declaration declares parameters, each parameter must be used in the query.

RETURN

This keyword introduces the `RETURN` clause, which specifies the datatype of a cursor result 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 specification. Also, the number, order, and datatypes of select items in the `SELECT` clause must match the `RETURN` clause.

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.

db_table_name

This identifies a database table (or view) that must be accessible when the declaration is elaborated.

cursor_name

This identifies an explicit cursor previously declared within the current scope.

record_name

This identifies a user-defined record previously declared within the current scope.

record_type_name

This identifies a `RECORD` type previously defined within the current scope.

%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.

%TYPE

This attribute provides the datatype of a previously declared collection, cursor variable, field, object, record, database column, or variable.

datatype

This is a type specifier. For the syntax of *datatype*, see “Constants and Variables” on page 11-29.

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.

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 2-37.

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

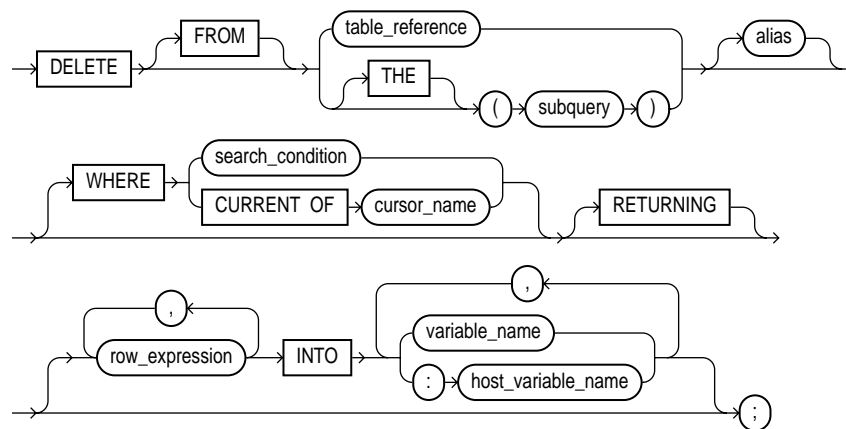
[CLOSE Statement](#), [FETCH Statement](#), [OPEN Statement](#), [SELECT INTO Statement](#)

DELETE Statement

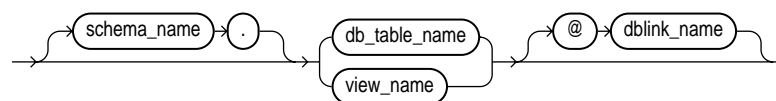
The **DELETE** statement removes entire rows of data from a specified table or view. For a full description of the **DELETE** statement, see *Oracle8 SQL Reference*.

Syntax

delete_statement



table_reference



Keyword and Parameter Description

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.

THE

The operand of **THE** is a subquery that returns a single column value to the **DELETE** statement. The column value must be a nested table. Operator **THE** informs Oracle that the value is a nested table, not a scalar value.

subquery

This is a select statement that provides a value or set of values to the **DELETE** statement. Its syntax is like that of *select_into_statement* without the **INTO** clause. See “SELECT INTO Statement” on page 11-139.

alias

This is another (usually short) name for the referenced table or view and is typically used in the **WHERE** clause.

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.

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**.

RETURNING

This clause lets you return values from the deleted row, thereby eliminating the need to **SELECT** the row beforehand. You can retrieve the column values into variables and/or host variables.

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 SQL cursor and the cursor attributes `%NOTFOUND`, `%FOUND`, and `%ROWCOUNT` let you access useful information about the execution of a `DELETE` statement.

A `DELETE` statement might delete one or more rows or no rows. If one or more rows are deleted, you get the following results:

- `SQL%NOTFOUND` yields `FALSE`
- `SQL%FOUND` yields `TRUE`
- `SQL%ROWCOUNT` yields the number of rows deleted

If no rows are deleted, you get these results:

- `SQL%NOTFOUND` yields `TRUE`
- `SQL%FOUND` yields `FALSE`
- `SQL%ROWCOUNT` yields `0`

Example

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 column `sal` from deleted rows and stores the column values in the elements of a host array:

```
DELETE FROM emp WHERE job = 'CLERK' AND sal > 3000  
RETURNING sal INTO :clerk_sals;
```

Related Topics

FETCH Statement, SELECT Statement

EXCEPTION_INIT Pragma

The pragma `EXCEPTION_INIT` associates an exception name with an Oracle error number. That allows you to 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 “Using `EXCEPTION_INIT`” on page 6-8.

Syntax

exception_init_pragma

```
→ PRAGMA EXCEPTION_INIT ( ( exception_name , error_number ) ) ;
```

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.

exception_name

This identifies a user-defined exception previously declared within the current scope.

error_number

This is any valid Oracle error number. These are the same error numbers returned by the function `SQLCODE`.

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

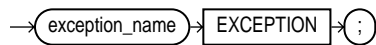
Exceptions, SQLCODE Function

Exceptions

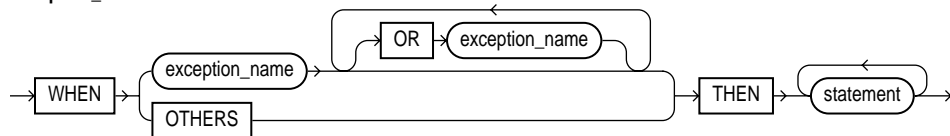
An exception is a runtime error or warning condition, which can be predefined or user-defined. Predefined exceptions are raised implicitly (automatically) by the runtime system. User-defined exceptions must be raised explicitly by `RAISE` statements. To handle raised exceptions, you write separate routines called exception handlers. For more information, see Chapter 6.

Syntax

exception_declaration



exception_handler



Keyword and Parameter Description

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.

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 11-7.

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 Exceptions” on page 6-4. 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 should be raised only when an error occurs that makes it impossible or undesirable 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.

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 “Using `raise_application_error`” on page 6-9.

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.

An exception handler can reference only those variables that the current block can reference.

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;
```

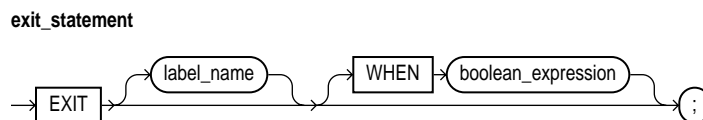
Related Topics

Blocks, EXCEPTION_INIT Pragma, RAISE Statement

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 3-6.

Syntax



Keyword and Parameter Description

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.

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 11-59.

Usage Notes

The `EXIT` statement can be used only inside a loop. PL/SQL allows you to 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
        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
    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

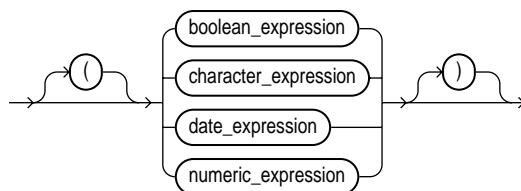
Expressions

An expression is an arbitrarily complex combination of variables, constants, literals, operators, and function calls. The simplest expression is a single variable.

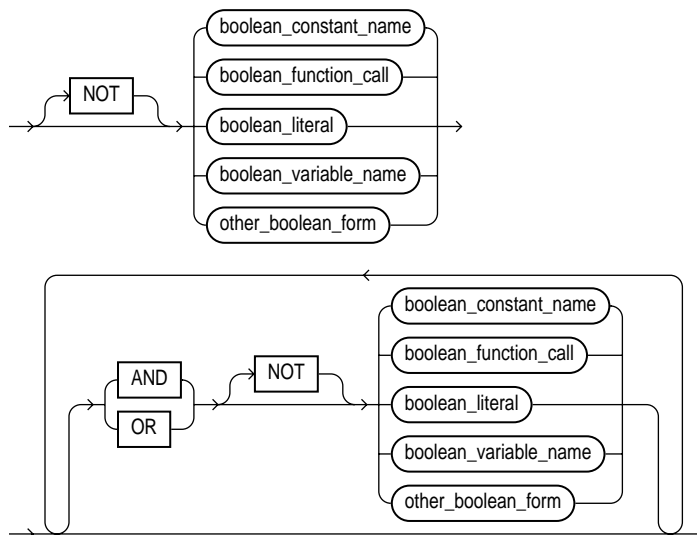
The PL/SQL compiler determines the datatype of an expression from the types of the variables, constants, literals, and operators that comprise the expression. Every time the expression is evaluated, a single value of that type results. For more information, see “Expressions and Comparisons” on page 2-41.

Syntax

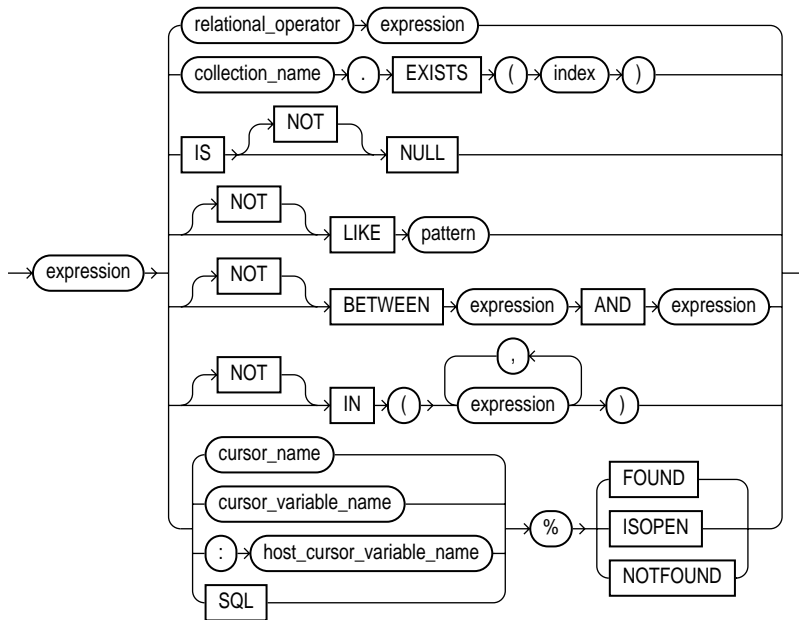
expression



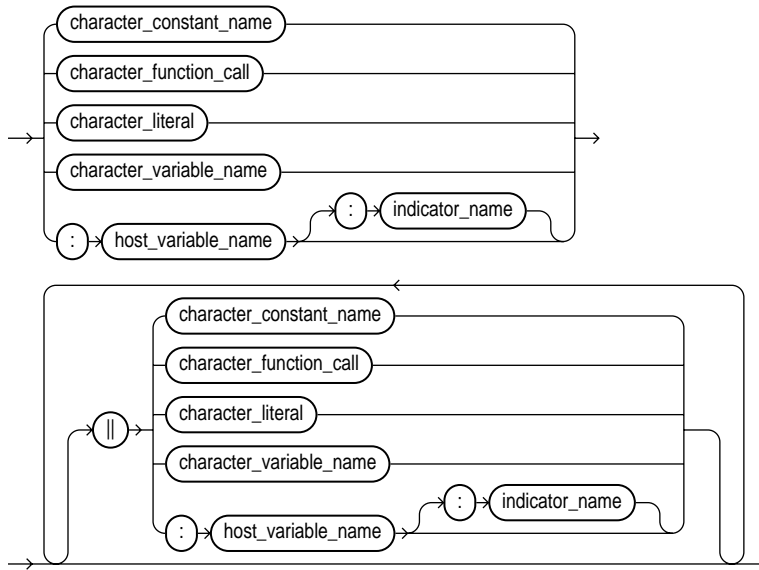
boolean_expression



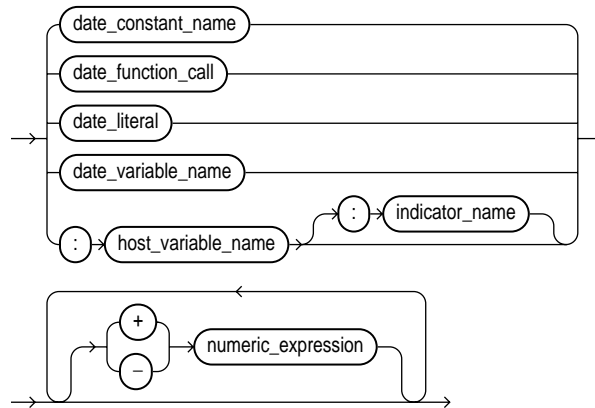
other_boolean_form



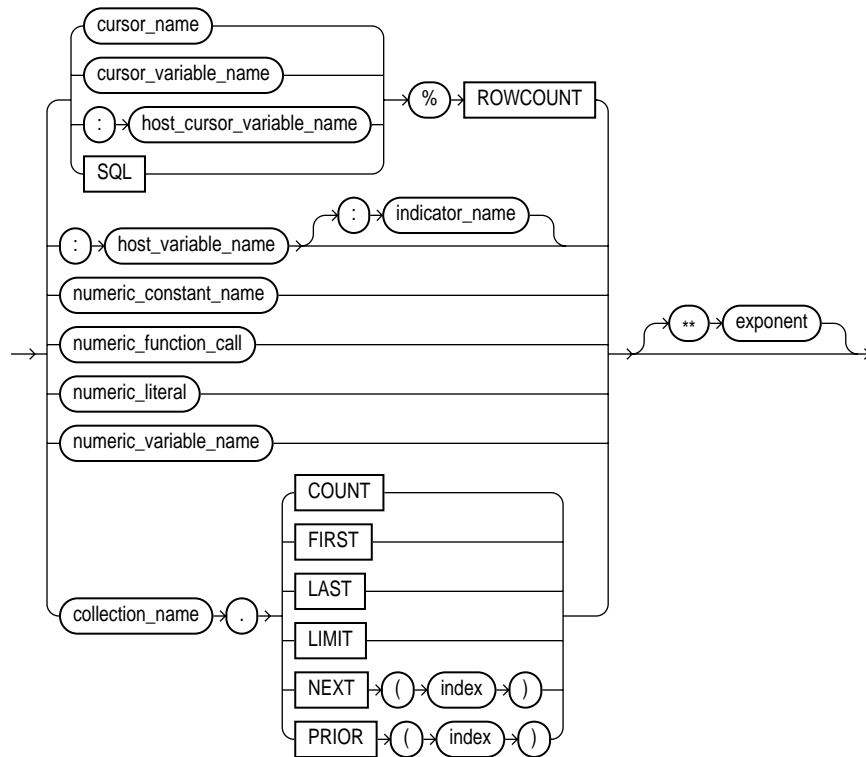
character_expression

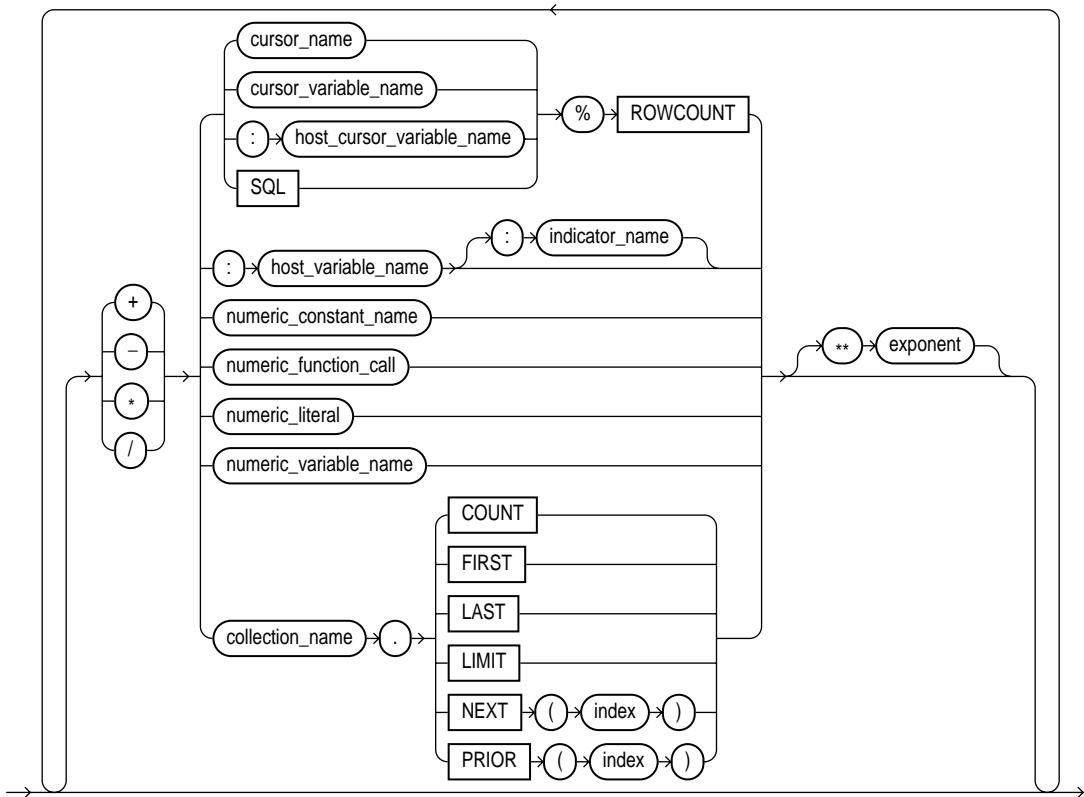


date_expression



numeric_expression





Keyword and Parameter Description

boolean_expression

This is an expression that yields the Boolean value `TRUE`, `FALSE`, or `NULL`.

character_expression

This is an expression that yields a character or character string.

date_expression

This is an expression that yields a date/time value.

numeric_expression

This is an expression that yields an integer or real value.

NOT, AND, OR

These are logical operators, which follow the tri-state logic of Table 2-3 on page 2-43. **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. **NOT NULL** returns **NULL** because nulls are indeterminate. For more information, see “Logical Operators” on page 2-43.

boolean_constant_name

This identifies a constant of type **BOOLEAN**, which must be initialized to the value **TRUE** or **FALSE** or the non-value **NULL**. Arithmetic operations on Boolean constants are illegal.

boolean_function_call

This is any function call that returns a Boolean value.

boolean_literal

This is the predefined value **TRUE** or **FALSE** or the non-value **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** and **FALSE** and the non-value **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.

relational_operator

This operator allows you to compare expressions. For the meaning of each operator, see “Comparison Operators” on page 2-44.

IS [NOT] NULL

This comparison operator returns the Boolean value **TRUE** if its operand is null, or **FALSE** if its operand is not null.

[NOT] 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.

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.

[NOT] 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*.”

[NOT] 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.

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.

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.

SQL

This identifies a cursor opened implicitly by Oracle to process a SQL data manipulation statement. The implicit `SQL` cursor always refers to the most recently executed SQL statement.

%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 SQL cursor. For more information, see “Using Cursor Attributes” on page 5-38.

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 11-16.

index

This is a numeric expression that must yield a value of type `BINARY_INTEGER` or a value implicitly convertible to that datatype.

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.

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.

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_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 numeric value or a value implicitly convertible to a numeric value.

collection_name

This identifies a nested table, index-by table, or varray previously declared within the current scope.

numeric_variable_name

This identifies a previously declared variable that stores a numeric value.

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.

exponent

This is an expression that must yield a numeric value.

+, -, /, *, **

These symbols are the addition, subtraction, division, multiplication, and exponentiation operators, respectively.

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_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.

||

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 string zero characters in length (' ') is called a null string and is treated like a null.

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_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.

Usage Notes

In a Boolean expression, you can only compare values that have compatible datatypes. For more information, see “Datatype Conversion” on page 2-25.

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 value 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

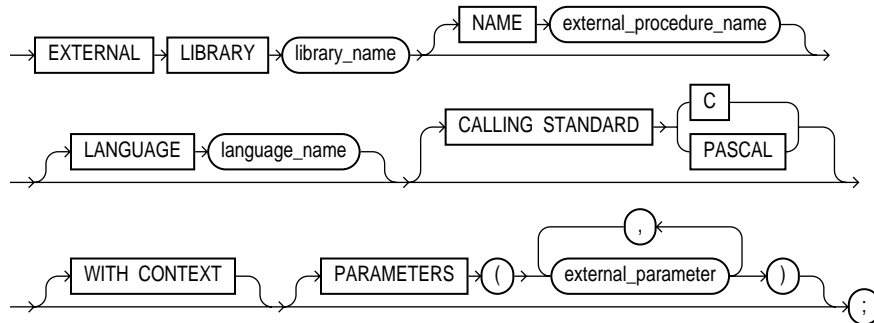
External Procedures

An external procedure is a third-generation-language routine stored in a dynamic link library (or shared library that loads dynamically), registered with PL/SQL, and called by you to do special-purpose processing. At run time, PL/SQL loads the library dynamically, then calls the routine as if it were a PL/SQL subprogram. To safeguard your database, the routine runs in a separate address space.

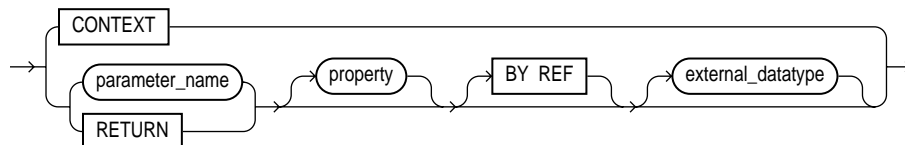
A dynamic link library (DLL) is an operating-system file that stores external procedures. For safety, your DBA controls access to the DLL. Using the `CREATE LIBRARY` statement, the DBA creates a schema object called an alias library, which represents the DLL. Then, if you are an authorized user, the DBA grants you `EXECUTE` privileges on the alias library. After registering an external procedure, you can call it from any PL/SQL program. It executes with the privileges granted to your userid. For more information, see Chapter 10.

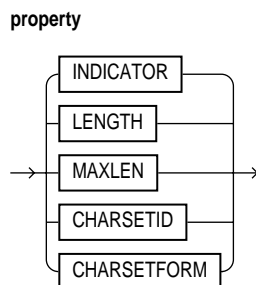
Syntax

external_clause



external_parameter





Keyword and Parameter Description

LIBRARY

This clause specifies the name of the alias library. The name is a PL/SQL identifier. So, if you enclose the name in double quotes, it becomes case sensitive. You must have EXECUTE privileges on the alias library.

NAME

This clause specifies the external procedure to be called. If you enclose the procedure name in double quotes, it becomes case sensitive. If you omit this clause, the procedure name defaults to the upper case name of the PL/SQL subprogram.

LANGUAGE

This clause specifies the third-generation language in which the external procedure was written. Currently, the only language name allowed is C. If you omit this clause, the language name defaults to C.

CALLING STANDARD

This clause specifies the Windows NT calling standard (C or Pascal) under which the external procedure was compiled. (Under the Pascal Calling Standard, arguments are reversed on the stack and the called function must pop the stack.) If you omit this clause, the calling standard defaults to C.

WITH CONTEXT

This clause specifies that a context pointer will be passed to the external procedure. The context data structure is opaque to the external procedure but is available to service routines called by the external procedure.

By including the `WITH CONTEXT` clause, you can give an external procedure access to information about parameters, exceptions, memory allocation, and the user environment.

PARAMETERS

This clause specifies the positions and datatypes of parameters passed to the external procedure. It can also specify parameter properties such as current length and maximum length, and the preferred parameter passing method (by value or by reference).

You do not pass parameters to an external procedure directly. Instead, you pass them to the PL/SQL subprogram that registered the external procedure. So, you must specify PL/SQL datatypes for the parameters. For guidance, see Table 10-1 on page 10-9. Each PL/SQL datatype maps to a default external datatype. (In turn, each external datatype maps to a C datatype.)

To avoid errors when declaring C prototype parameters, refer to Table 10-2 on page 10-11, which shows the C datatype to specify for a given external datatype and PL/SQL parameter mode.

You can also use the `PARAMETERS` clause to pass additional information about PL/SQL formal parameters and function results to an external procedure. You do that by specifying the following properties: `INDICATOR`, `LENGTH`, `MAXLEN`, `CHARSETID`, `CHARSETFORM`.

CONTEXT

This parameter *cannot* be repeated. If you include the `WITH CONTEXT` and `PARAMETERS` clauses, you must specify this parameter, which shows the position of the context pointer in the parameter list. If you omit the `PARAMETERS` clause, the context pointer is the first parameter passed to the external procedure.

INDICATOR

This property lets you associate a null/not null indicator with a formal parameter. If the PL/SQL subprogram is a function, you can also associate an indicator with the return value.

LENGTH, MAXLEN

These properties let you specify parameters that store the current length and maximum length of a formal parameter. With parameters of type `RAW` or `LONG RAW`, you must use the property `LENGTH`.

CHARSETID, CHARSETFORM

The properties `CHARSETID` and `CHARSETFORM` identify the nondefault character set from which the character data being passed was formed. With `CHAR`, `CLOB`, and `VARCHAR2` parameters, you can use `CHARSETID` and `CHARSETFORM` to pass the character set ID and form to the external procedure. The OCI attribute names for these properties are `OCI_ATTR_CHARSET_ID` and `OCI_ATTR_CHARSET_FORM`.

BY REF

In C, you can pass `IN` parameters by value (the value of the parameter is passed) or by reference (a pointer to the value is passed). When an external procedure expects a pointer, `BY REF` lets you pass the parameter by reference.

Usage Notes

When calling external procedures, never write to `IN` parameters or overflow the capacity of `OUT` parameters. (PL/SQL does no runtime checks for these error conditions.) Likewise, never read an `OUT` parameter or a function result. Also, always assign a value to `IN` `OUT` and `OUT` parameters and to function results. Otherwise, your external procedure will not return successfully.

If you include the `WITH CONTEXT` and `PARAMETERS` clauses, you must specify the parameter `CONTEXT`, which shows the position of the context pointer in the parameter list. If you omit the `PARAMETERS` clause, the context pointer is the first parameter passed to the external procedure.

If you include the `PARAMETERS` clause and the external routine is a function, you must specify the parameter `RETURN` (not `RETURN property`) in the last position.

For every formal parameter, there must be a corresponding parameter in the `PARAMETERS` clause. Also, make sure that the datatypes of parameters in the `PARAMETERS` clause are compatible with those in the C prototype because no implicit conversions are done.

To check the value of an indicator, you can use the constants `OCI_IND_NULL` and `OCI_IND_NOTNULL`. If the indicator equals `OCI_IND_NULL`, the associated parameter or function result is null. If the indicator equals `OCI_IND_NOTNULL`, the parameter or function result is not null.

With a parameter of type `RAW` or `LONG RAW`, you must use the property `LENGTH`. Also, if that parameter is `IN` `OUT` or `OUT` and null, you must set the length of the corresponding C parameter to zero.

Currently, the following restrictions apply to external procedures:

- This feature is available only on platforms that support DLLs.
- Only routines callable from C code (not C++ code) are supported.
- You cannot pass PL/SQL cursor variables, records, collections, or instances of an object type to an external procedure.
- In the `LIBRARY` clause, you cannot use a database link to specify a remote library.
- The Listener must start agent *extproc* on the machine that runs the Oracle server. Starting *extproc* on a different machine is not supported.
- The maximum number of parameters that you can pass to a C external procedure is 128. However, if you pass **float** or **double** parameters by value, the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each **float** or **double** passed by value as two parameters.

Examples

Assume that C routine *c_gcd*, which finds the greatest common divisor of two numbers, is stored in DLL *utils.dll* and that you have EXECUTE privileges on alias library *c_utils*. The C prototype for *c_gcd* follows:

```
int c_gcd(int x_val, int y_val);
```

In the following example, you write a PL/SQL stand-alone function named *gcd* that registers the C routine *c_gcd* as an external function:

```
CREATE FUNCTION gcd (  
  -- find greatest common divisor of x and y  
  x BINARY_INTEGER,  
  y BINARY_INTEGER)  
RETURN BINARY_INTEGER AS EXTERNAL  
  LIBRARY c_utils  
  NAME "c_gcd" -- quotes preserve lower case  
  LANGUAGE C;
```

In the example below, you call PL/SQL function *gcd* from an anonymous block. PL/SQL passes the two integer parameters to external function *c_gcd*, which returns their greatest common divisor.

```
DECLARE  
  g INTEGER;  
  a INTEGER;  
  b INTEGER;
```

```

...
BEGIN
  ...
  g := gcd(a, b); -- call function
  IF g IN (2,4,8) THEN ...

```

The following example uses the `PARAMETERS` clause to specify properties for the PL/SQL formal parameters and function result:

```

CREATE FUNCTION parse (
  x IN BINARY_INTEGER,
  y IN OUT CHAR)
RETURN CHAR AS EXTERNAL
  LIBRARY c_utils
  NAME "c_parse"
  LANGUAGE C
  CALLING STANDARD PASCAL
  PARAMETERS (
    x,          -- stores value of x
    x INDICATOR, -- stores null status of x
    y,          -- stores value of y
    y LENGTH,   -- stores current length of y
    y MAXLEN,   -- stores maximum length of y
    RETURN INDICATOR,
    RETURN);

```

The corresponding C prototype follows:

```

char * c_parse(int x, short x_ind, char *y, int *y_len,
               int *y_maxlen, short *retind);

```

Related Topics

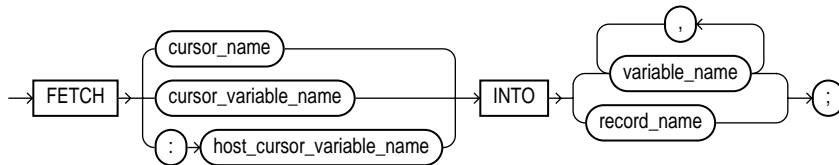
Functions, Procedures

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 5-9.

Syntax

`fetch_statement`



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.

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.

variable_name[, variable_name]...

This identifies a list of previously declared scalar variables into which column 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 variable in the list.

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.

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. For more information, see “Using Cursor Attributes” on page 5-38.

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 Pro*C example, you fetch rows from a host cursor variable into a host record (struct) named *emp_rec*:

```

/* Exit loop when done fetching. */
EXEC SQL WHENEVER NOTFOUND DO break;
for (;;)
{
  /* Fetch row into record. */
  EXEC SQL FETCH :emp_cur INTO :emp_rec;
}

```

The next example shows that 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.

```

for (;;)
{
  /* Fetch row from result set. */
  EXEC SQL FETCH :emp_cur INTO :emp_rec1;
  /* Fetch next row from same result set. */
  EXEC SQL FETCH :emp_cur INTO :emp_rec2;
}

```

Related Topics

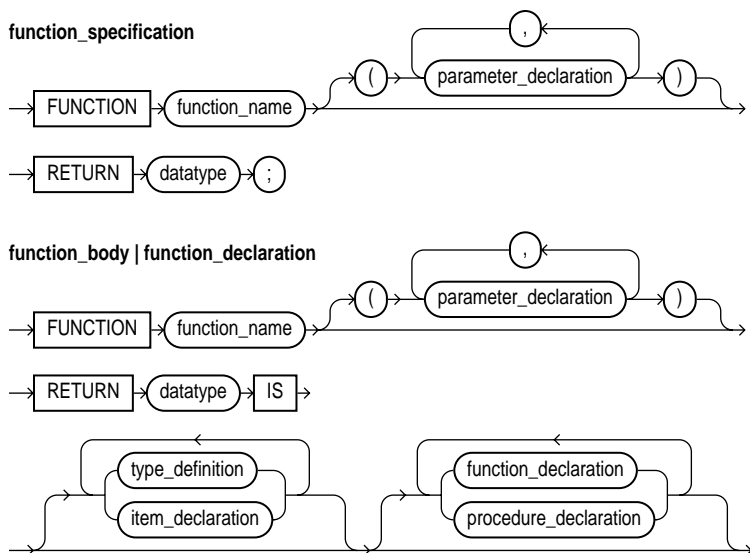
CLOSE Statement, Cursors, Cursor Variables, LOOP Statements, OPEN Statement, OPEN-FOR Statement

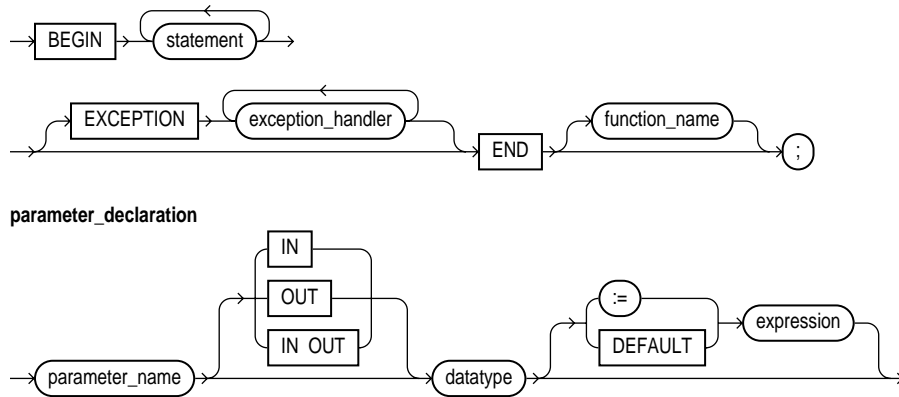
Functions

A function is a subprogram, which 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 function specification begins with the keyword `FUNCTION` and ends with the `RETURN` clause, which specifies the datatype of the result value. Parameter declarations are optional. Functions that take no parameters are written without parentheses. The function body begins with the keyword `IS` 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 exception handlers, which deal with exceptions raised during execution. For more information, see “Functions” on page 7-5.

Syntax





Keyword and Parameter Description

function_name

This identifies a user-defined function.

parameter_name

This identifies a formal parameter, which is a variable declared in a function specification and referenced in the function body.

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.

datatype

This is a type specifier. For the syntax of *datatype*, see “Constants and Variables” on page 11-29.

:= | DEFAULT

This operator or keyword allows you to initialize **IN** parameters to default values.

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.

RETURN

This keyword introduces the RETURN clause, which specifies the datatype of the result value.

type_definition

This specifies a user-defined datatype. For the syntax of *type_definition*, see “Blocks” on page 11-7.

item_declaration

This declares a program object. For the syntax of *item_declaration*, see “Blocks” on page 11-7.

function_declaration

This construct declares a function. For the syntax of *function_declaration*, see “Functions” on page 11-79.

procedure_declaration

This construct declares a procedure. For the syntax of *procedure_declaration*, see “Procedures” on page 11-121.

exception_handler

This construct 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 11-54.

Usage Notes

A function is called as part of an expression. For example, the function *sal_ok* might be called as follows:

```
promotable := sal_ok(new_sal, new_title) AND (rating > 3);
```

Every function must contain at least one RETURN statement. Otherwise, PL/SQL raises the predefined exception PROGRAM_ERROR at run time.

To be callable from SQL expressions, a stored function must obey certain rules meant to control side effects. For packaged functions, you must use the pragma `RESTRICT_REFERENCES` to enforce the rules. For more information, see *Oracle8 Application Developer's Guide*.

You can write the function specification and body as a unit. Or, you can separate the function specification 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 specifications in the package specification. However, such functions can be called only from inside the package.

Inside a function, an `IN` parameter acts like a constant. Therefore, it cannot be assigned a value. An `OUT` parameter acts like an uninitialized variable. So, its value cannot be assigned to another variable or reassigned to itself. 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. For summary information about the parameter modes, see Table 7-1 on page 7-15.

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.

Functions can be defined using any Oracle tool that supports PL/SQL. However, to become available for general use, functions must be `CREATED` and stored in an Oracle database. You can issue the `CREATE FUNCTION` statement interactively from SQL*Plus or Enterprise Manager. For the full syntax of the `CREATE FUNCTION` statement, see *Oracle8 SQL Reference*.

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

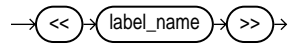
Collections, Packages, Procedures, Records

GOTO Statement

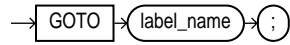
The `GOTO` statement branches unconditionally to a statement label or block label. The label must be unique within its scope and must precede an executable statement or a PL/SQL block. The `GOTO` statement transfers control to the labelled statement or block. For more information, see “GOTO Statement” on page 3-15.

Syntax

`label_declaration`



`goto_statement`



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;
```

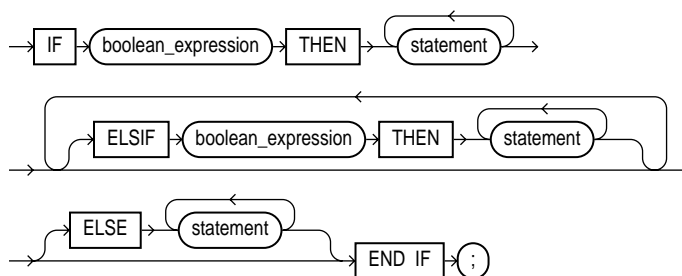
For more examples of legal and illegal `GOTO` statements, see “`GOTO` Statement” on page 3-15.

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 Statements” on page 3-2.

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`.

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.

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`.

ELSE

If control reaches this keyword, the sequence of statements that follows it 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;
```

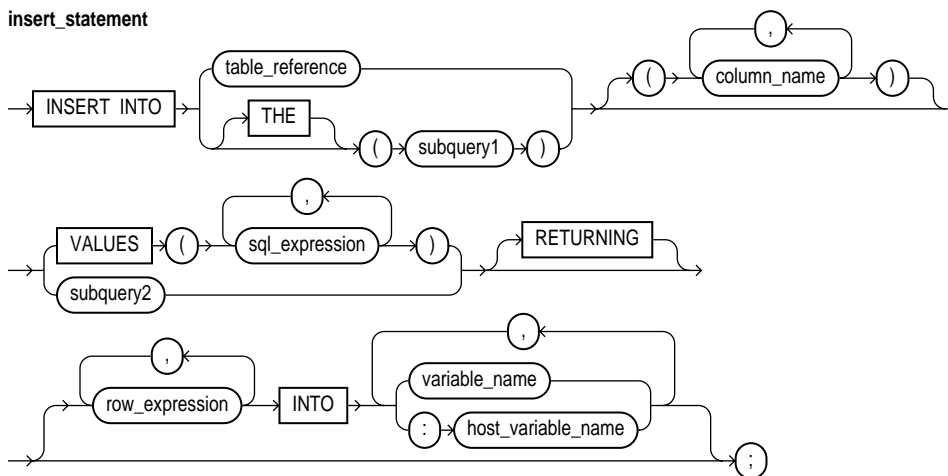
Related Topics

Expressions

INSERT Statement

The `INSERT` statement adds new rows of data to a specified database table or view. For a full description of the `INSERT` statement, see *Oracle8 SQL Reference*.

Syntax



Keyword and Parameter Description

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 11-49.

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.

sql_expression

This is any expression valid in SQL. For more information, see *Oracle8 SQL Reference*.

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. The first value is associated with the first column, the second value is associated with the second column, and so on. If there is no column list, you must supply a value for each column in the table.

The datatypes of the values being inserted must be compatible with the datatypes of corresponding columns in the column list.

THE

The operand of `THE` is a subquery that returns a single column value to the `INSERT` statement. The column value must be a nested table. Operator `THE` informs Oracle that the value is a nested table, not a scalar value.

subquery1

This is a select statement that provides a value or set of values to the `INSERT` statement. Its syntax is like that of *select_into_statement* without the `INTO` clause. See “SELECT INTO Statement” on page 11-139.

As many rows are added to the table as are returned by the subquery in the `VALUES` clause. The subquery must return a value for every column in the column list or for every column in the table if there is no column list.

subquery2

This is a select statement that provides a value or set of values to the `VALUES` clause. The subquery must return only one row containing a value for every column in the column list or for every column in the table if there is no column list.

RETURNING

This clause lets you return values from the inserted row, thereby eliminating the need to `SELECT` the row afterward. You can retrieve the column values into variables and/or host variables.

Usage Notes

All character and date literals in the `VALUES` list must be enclosed by single quotes (`'`). Numeric literals are not enclosed by quotes.

The implicit SQL cursor and cursor attributes `%NOTFOUND`, `%FOUND`, `%ROWCOUNT`, and `%ISOPEN` let you access useful information about the execution of an `INSERT` statement.

An `INSERT` statement might insert one or more rows or no rows. If one or more rows are inserted, you get the following results:

- `SQL%NOTFOUND` yields `FALSE`
- `SQL%FOUND` yields `TRUE`
- `SQL%ROWCOUNT` yields the number of rows inserted

If no rows are inserted, you get these results:

- `SQL%NOTFOUND` yields `TRUE`
- `SQL%FOUND` yields `FALSE`
- `SQL%ROWCOUNT` yields `0`

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

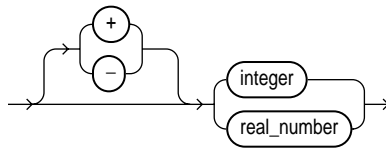
[SELECT Statement](#)

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

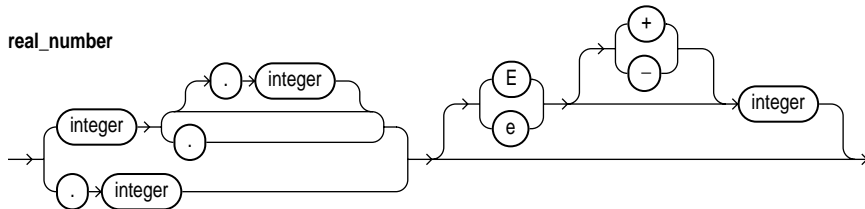
numeric_literal



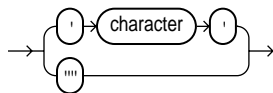
integer



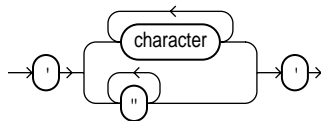
real_number

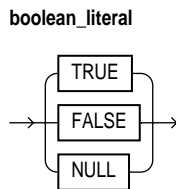


character_literal



string_literal





Keyword and Parameter Description

integer

This is an optionally signed whole number without a decimal point.

real_number

This is an optionally signed whole or fractional number with a decimal point.

digit

This is one of the numerals 0 .. 9.

char

This is a member of the PL/SQL character set. For more information, see “Character Set” on page 2-2.

TRUE, FALSE

This is a predefined Boolean value.

NULL

This is a predefined non-value, which stands for a missing, unknown, or inapplicable value.

Usage Notes

Two kinds of numeric literals can be used in arithmetic expressions: integers and reals. Numeric literals must be separated by punctuation. Space characters 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 'White' and 'White ' are different. How a string literal compares to a variable does *not* depend on the variable; trailing blanks in a literal are never trimmed.

Unlike the non-value NULL, 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 so that you can share or deny access to tables while maintaining their integrity. For more information, see “Using `LOCK TABLE`” on page 5-52.

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 11-49.

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](#), [UPDATE 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 the following types of loop statements:

- basic loop
- WHILE loop
- FOR loop
- cursor FOR loop

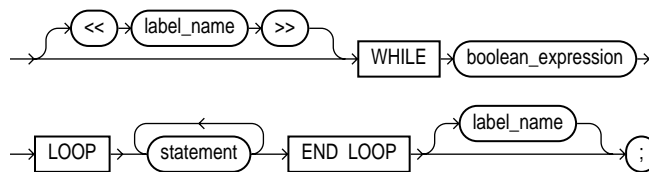
For more information, see “Iterative Control: LOOP and EXIT Statements” on page 3-6.

Syntax

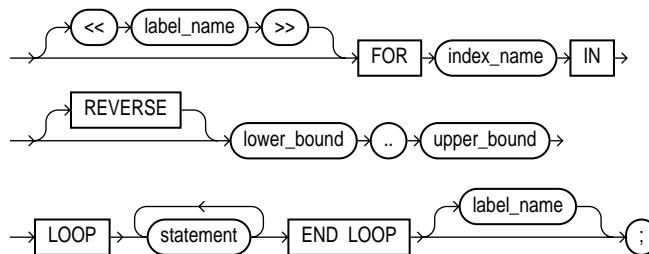
basic_loop_statement

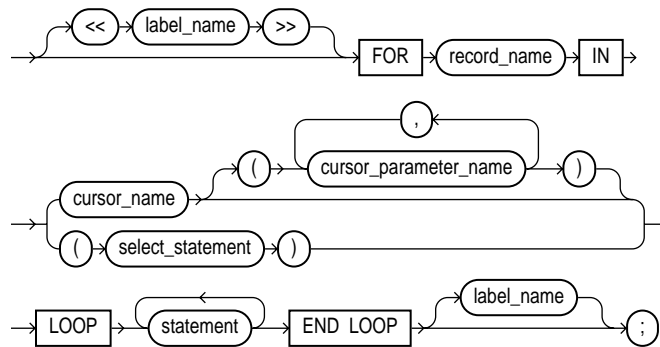


while_loop_statement



for_loop_statement



cursor_for_loop_statement**Keyword and Parameter Description****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* 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 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;
  
```

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.

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.

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 11-59.

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. (Cursor FOR loops, which iterate over the result set of a cursor, are discussed later.) 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.

lower_bound, upper_bound

These are expressions that must yield integer values. The expressions are evaluated only when the loop is first entered.

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.

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.

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. Thus, the sequence of statements in the loop is executed once for each row that satisfies the query associated with *cursor_name*.

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.

record_name

This identifies an implicitly declared record. The record has the same structure as a row retrieved by *cursor_name* and is equivalent to a record declared as follows:

```
record_name cursor_name%ROWTYPE;
```

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+NVL(comm,0) wages, job ...
```

cursor_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. For the syntax of *cursor_parameter_declaration*, see “Cursors” on page 11-45.

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 11-139. PL/SQL automatically declares, opens, fetches from, and closes the internal cursor. Because *select_statement* is not an independent statement, the implicit SQL cursor does not apply to it.

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

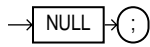
Cursors, `EXIT` Statement, `FETCH` Statement, `OPEN` Statement, `%ROWTYPE` Attribute

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 3-19.

Syntax

`null_statement`



Usage Notes

The `NULL` statement improves readability by making the meaning and action of conditional statements clear. It tells readers that the associated alternative has not been overlooked, 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 non-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;
```

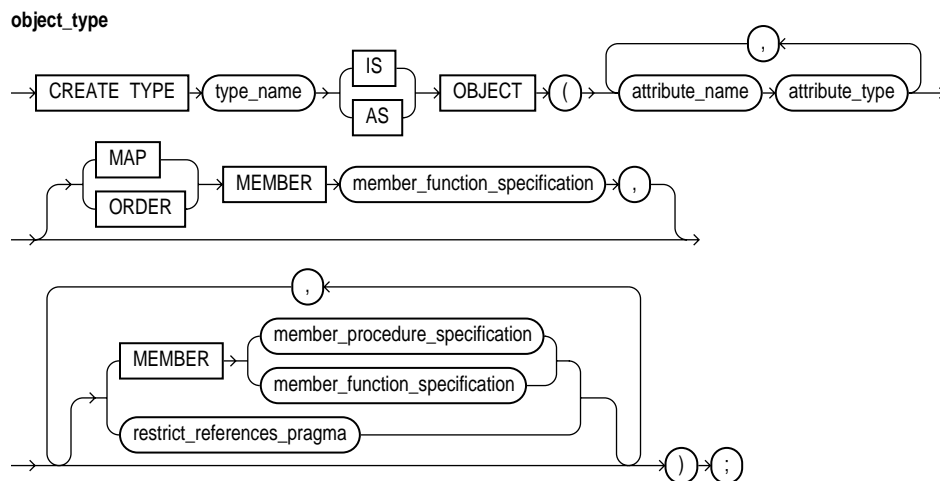
Object Types

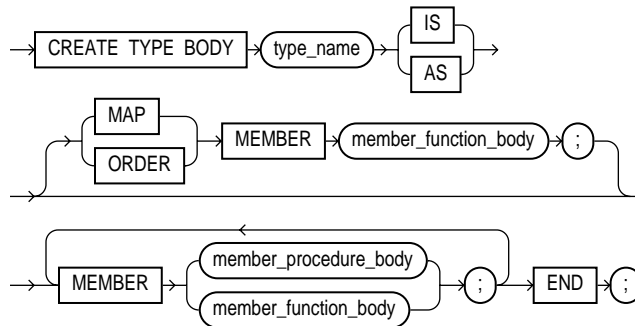
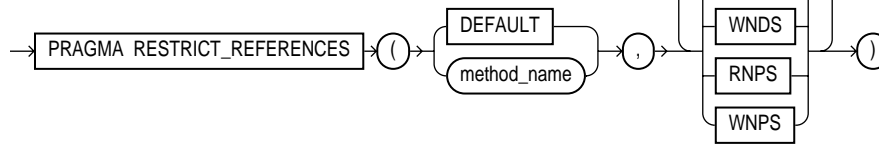
An object type is a user-defined composite datatype that encapsulates a data structure along with the functions and procedures needed to manipulate the data. The variables that form the data structure are called *attributes*. The functions and procedures that characterize the behavior of the object type 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 9.

Syntax



object_type_body**restrict_references pragma****Keyword and Parameter Description****type_name**

This identifies a user-defined type specifier, which is used in subsequent declarations of objects.

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.

attribute_datatype

This is any Oracle datatype except `LONG`, `LONG RAW`, `MLSLABEL`, `NCHAR`, `NCLOB`, `NVARCHAR2`, `ROWID`, 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.

MEMBER

This keyword allows you to declare a function or procedure in an object type specification. The method cannot have the same name as the object type or any of its attributes.

Like packaged subprograms, methods have two parts: a specification and a body. The specification 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 operation.

For each method specification in an object type specification, there must be a corresponding method body in the object type body. To match method specifications and bodies, the compiler does a token-by-token comparison of their headers. So, the headers must match word for word.

All methods in an object type accept an instance of that type as their first parameter. The name of this built-in parameter is `SELF`. Whether declared implicitly or explicitly, `SELF` is always the first parameter passed to a method. In a method body, `SELF` denotes the object whose method was called.

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 a different datatype for `SELF`.

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`.

ORDER

This keyword indicates that a method compares two objects. Every order method takes just two parameters: the built-in parameter `SELF` and another object of the same type. If `o1` and `o2` are objects, a comparison such as $o1 > o2$ automatically calls the order method with parameters `o1` and `o2`. The method returns a negative number, zero, or a positive number signifying that `SELF` is less than, equal to, or greater than the other parameter, respectively.

An object type can contain only one order method, which must be a function that returns a numeric result.

member_function_specification

This construct declares the interface to a member function. Its syntax is like that of *function_specification* without the terminator. See “Functions” on page 11-79.

member_procedure_specification

This construct declares the interface to a member procedure. Its syntax is like that of *procedure_specification* without the terminator. See “Procedures” on page 11-121.

member_function_body

This construct defines the underlying implementation of a member function. Its syntax is like that of *function_body* without the terminator. See “Functions” on page 11-79.

member_procedure_body

This construct defines the underlying implementation of a member procedure. Its syntax is like that of *procedure_body* without the terminator. See “Procedures” on page 11-121.

restrict_references_pragma

You use this pragma (compiler directive) to enforce rules that control side effects. The pragma tells the PL/SQL compiler to deny the member function read/write access to database tables, packaged variables, or both.

In the object type specification, you code the pragma somewhere after the method to which it applies. You can specify up to four constraints in any order, but you must specify WNDS. To call the method from parallel queries, you must also specify WNPS, RNDS, and RNPS. No constraint implies another.

If you specify the keyword `DEFAULT` instead of a method name, the pragma applies to all member functions including the system-defined constructor. You can declare the pragma for any member function. Such pragmas override the default pragma. However, a non-default pragma can apply to only one method. So, among overloaded methods, the pragma always applies to the nearest preceding method.

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* 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 specification.

All the information a client program needs to use the methods is in the specification. Think of the specification as an operational interface and of the body as a black box. You can debug, enhance, or replace the body without changing the specification.

An object type encapsulates data and operations. So, you can declare attributes and methods in an object type specification, but *not* constants, exceptions, cursors, or types. At least one attribute is required; methods are optional.

In an object type specification, all attributes must be declared before any methods. Only subprograms have an underlying implementation. So, if an object type specification declares only attributes, the object type body is unnecessary. You cannot declare attributes in the body.

All declarations in the object type specification are public (visible outside the object type). However, the object type body can contain private declarations, which define methods necessary for the internal workings of the object type. The scope of private declarations is local to the object type body.

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 allows you to 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.

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 varray size constraint (25)
        position.EXTEND(max_size - 1, 1); -- copy element 1 into 2..25
    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;
```

Notice that in member procedures *push* and *pop*, we use the built-in procedure *raise_application_error* to issue user-defined error messages. That way, we can report errors to the client program and avoid returning unhandled exceptions to the host environment.

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,  
);
```

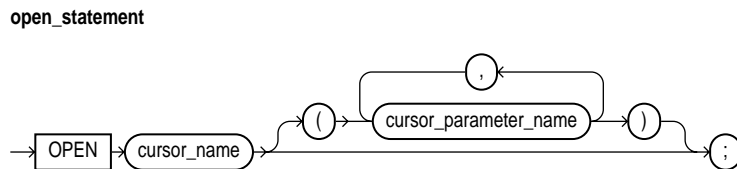
Related Topics

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 5-9.

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. A cursor parameter can appear in a query wherever a constant can appear. For the syntax of *cursor_parameter_declaration*, see “Cursors” on page 11-45.

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 bumped 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. 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. For more information, see “Positional and Named Notation” on page 7-12.

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 CHAR, 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

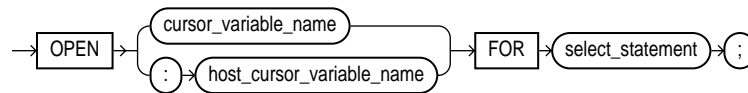
[CLOSE Statement](#), [Cursors](#), [FETCH Statement](#), [LOOP Statements](#)

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 5-18.

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 but cannot be `FOR UPDATE`. The syntax of *select_statement* is similar to the syntax for *select_into_statement* defined in “SELECT INTO Statement” on page 11-139, 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

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;

```

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 GenericCurTyp IS REF CURSOR;
  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;

```

For more flexibility, you can pass a cursor variable to a stored procedure that executes queries with different return types, as follows:

```
CREATE PACKAGE BODY emp_data AS
  PROCEDURE open_cv (generic_cv IN OUT GenericCurTyp,
                    choice      IN 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 open_cv;
END emp_data;
```

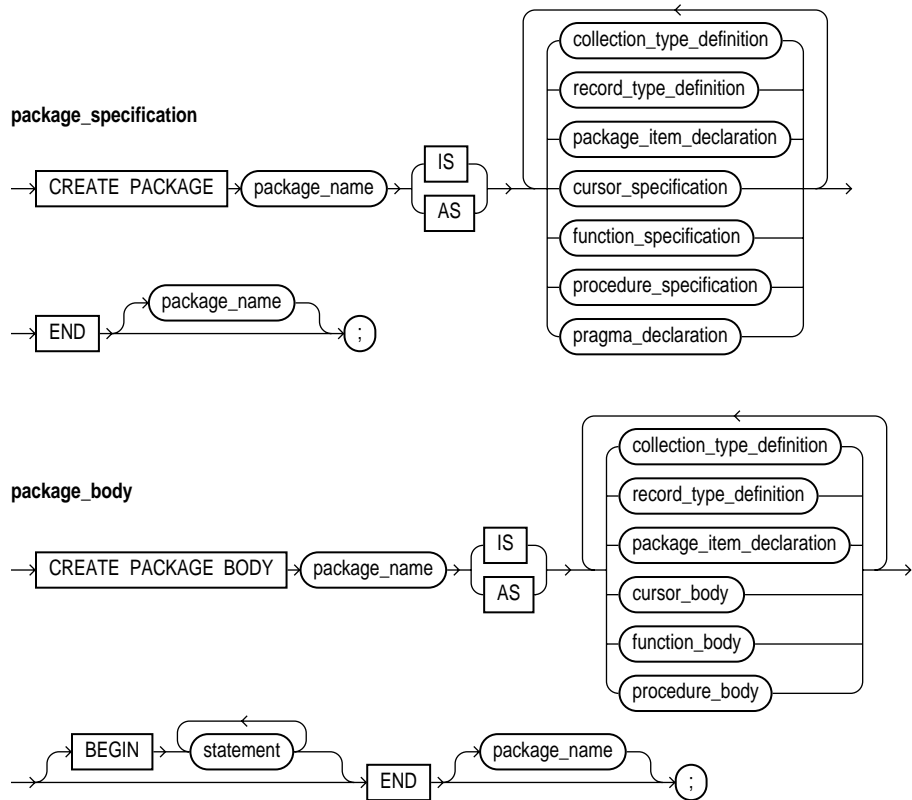
Related Topics

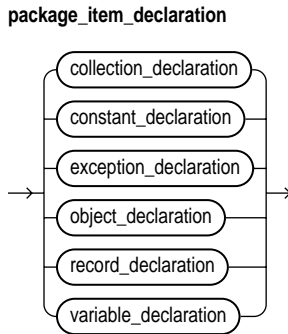
CLOSE Statement, Cursor Variables, FETCH Statement, LOOP Statements

Packages

A package is a schema object that groups logically related PL/SQL types, items, and subprograms. Packages have two parts: a specification and a body. For more information, see Chapter 8.

Syntax





Keyword and Parameter Description

package_name

This identifies a package. For naming conventions, see “Identifiers” on page 2-4.

collection_declaration

This identifies a nested table, index-by table, or varray previously declared within the current scope. For the syntax of *collection_declaration*, see “Collections” on page 11-21.

constant_declaration

This construct declares a constant. For the syntax of *constant_declaration*, see “Constants and Variables” on page 11-29.

exception_declaration

This construct declares an exception. For the syntax of *exception_declaration*, see “Exceptions” on page 11-54.

object_declaration

This identifies an object (instance of an object type) previously declared within the current scope. For the syntax of *object_declaration*, see “Object Types” on page 11-103.

record_declaration

This construct declares a user-defined record. For the syntax of *record_declaration*, see “Records” on page 11-128.

variable_declaration

This construct declares a variable. For the syntax of *variable_declaration*, see “Constants and Variables” on page 11-29.

cursor_specification

This construct declares the interface to an explicit cursor. For the syntax of *cursor_specification*, see “Cursors” on page 11-45.

function_specification

This construct declares the interface to a function. For the syntax of *function_specification*, see “Functions” on page 11-79.

procedure_specification

This construct declares the interface to a procedure. For the syntax of *procedure_specification*, see “Procedures” on page 11-121.

cursor_body

This construct defines the underlying implementation of an explicit cursor. For the syntax of *cursor_body*, see “Cursors” on page 11-45.

function_body

This construct defines the underlying implementation of a function. For the syntax of *function_body*, see “Functions” on page 11-79.

procedure_body

This construct defines the underlying implementation of a procedure. For the syntax of *procedure_body*, see “Procedures” on page 11-121.

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 interactively from SQL*Plus or Enterprise Manager and from an Oracle Precompiler or OCI host program. For the full syntax of the `CREATE PACKAGE` statement, see *Oracle8 SQL Reference*.

Most packages have a specification and a body. The specification is the interface to your applications; it declares the types, variables, constants, exceptions, cursors, and subprograms available for use. The body fully defines cursors and subprograms, and so implements the specification.

Only subprograms and cursors have an underlying implementation (definition). So, if a specification declares only types, constants, variables, and exceptions, the package body is unnecessary. However, the body can still be used to initialize items declared in the specification, 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 specification without its body. Once the specification 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 specification) to the package body. That means you need not recompile calling programs.

Cursors and subprograms declared in a package specification must be defined in the package body. Other program items declared in the package specification cannot be redeclared in the package body.

To match subprogram specifications 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

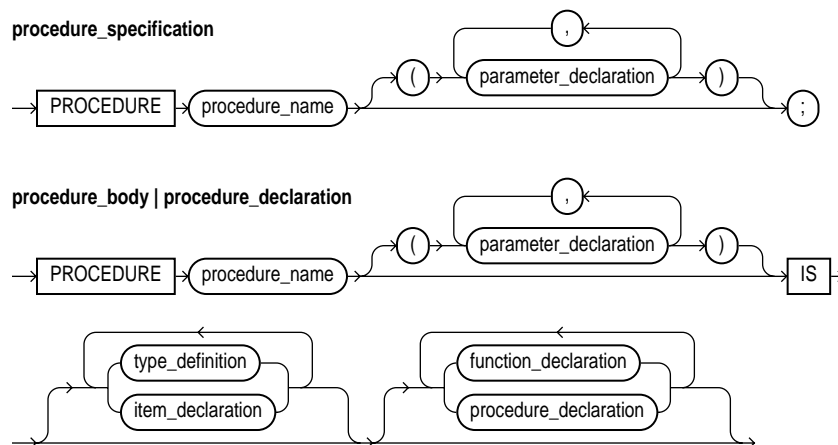
Collections, Cursors, Exceptions, Functions, Procedures, Records

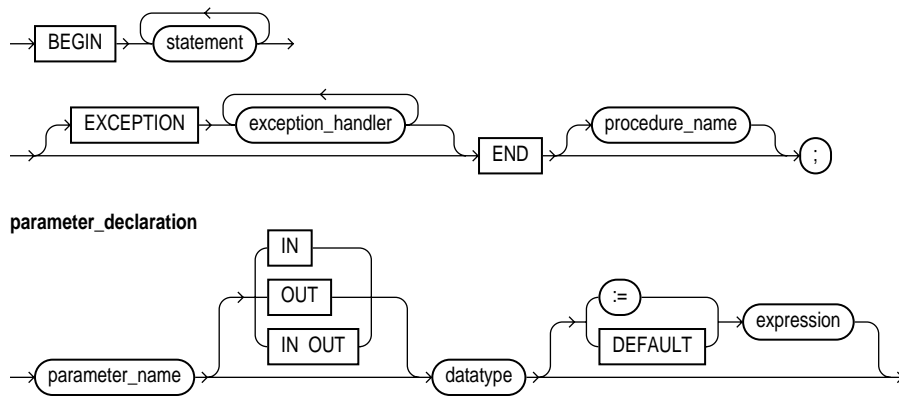
Procedures

A procedure is a subprogram, which 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 procedure specification 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` 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 exception handlers, which deal with exceptions raised during execution. For more information, see “Procedures” on page 7-3.

Syntax





Keyword and Parameter Description

procedure_name

This identifies a user-defined procedure.

parameter_name

This identifies a formal parameter, which is a variable declared in a procedure specification and referenced in the procedure body.

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.

datatype

This is a type specifier. For the syntax of *datatype*, see “Constants and Variables” on page 11-29.

:= | DEFAULT

This operator or keyword allows you to initialize **IN** parameters to default values.

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.

type_definition

This specifies a user-defined datatype. For the syntax of *type_definition*, see “Blocks” on page 11-7.

item_declaration

This declares a program object. For the syntax of *item_declaration*, see “Blocks” on page 11-7.

function_declaration

This construct declares a function. For the syntax of *function_declaration*, see “Functions” on page 11-79.

procedure_declaration

This construct declares a procedure. For the syntax of *procedure_declaration*, see “Procedures” on page 11-121.

exception_handler

This construct 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 11-54.

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. Therefore, it cannot be assigned a value. An `OUT` parameter acts like an uninitialized variable. So, its value cannot be assigned to another variable or reassigned to itself. 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. For summary information about the parameter modes, see Table 7-1 on page 7-15.

Unlike `OUT` and `IN OUT` parameters, `IN` parameters can be initialized to default values. For more information, see “Parameter Default Values” on page 7-15.

Before exiting a procedure, explicitly assign values to all `OUT` formal parameters. Otherwise, the values of corresponding actual parameters are indeterminate. 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.

You can write the procedure specification and body as a unit. Or, you can separate the procedure specification 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 specifications in the package specification. However, such procedures can be called only from inside the package.

Procedures can be defined using any Oracle tool that supports PL/SQL. To become available for general use, however, procedures must be `CREATED` and stored in an Oracle database. You can issue the `CREATE PROCEDURE` statement interactively from SQL*Plus or Enterprise Manager. For the full syntax of the `CREATE PROCEDURE` statement, see *Oracle8 SQL Reference*.

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

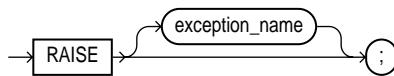
Collections, Functions, Packages, Records

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 “User-Defined Exceptions” on page 6-6.

Syntax

`raise_statement`



Keyword and Parameter Description

exception_name

This identifies a predefined or user-defined exception. For a list of the predefined exceptions, see “Predefined Exceptions” on page 6-4.

Usage Notes

PL/SQL blocks and subprograms should `RAISE` an exception only when an error makes it impractical 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;
```

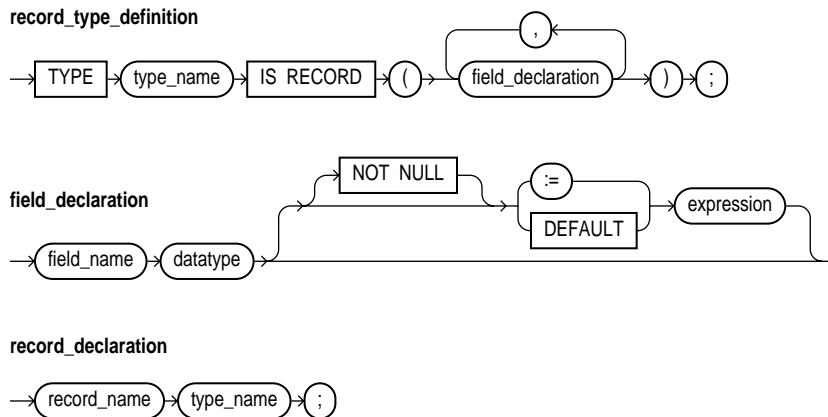
Related Topics

[Exceptions](#)

Records

Records are items of type `RECORD`. Records have uniquely named fields that can store data values of different types. For more information, see “What Is a Record?” on page 4-28.

Syntax



Keyword and Parameter Description

record_type_name

This identifies a user-defined type specifier, which is used in subsequent declarations of records.

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.

datatype

This is a type specifier. For the syntax of *datatype*, see “Constants and Variables” on page 11-29.

:= | DEFAULT

This operator or keyword allows you to initialize fields to default values.

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 11-59. When the declaration is elaborated, the value of *expression* is assigned to the field. The value and the field must have compatible datatypes.

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(
    second SMALLINT := 0,
    minute SMALLINT := 0,
    hour   SMALLINT := 0);
```

The next example shows that you can use the `%TYPE` attribute to specify a field datatype. It also shows that you can add the `NOT NULL` constraint to any field declaration and so prevent the assigning of nulls to that field.

```
DECLARE
  TYPE DeptRecTyp IS RECORD(
    deptno NUMBER(2) NOT NULL,
    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 *dname* field in the *dept_rec* record 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(
    minute SMALLINT,
    hour   SMALLINT);
  TYPE MeetingTyp IS RECORD(
    day     DATE,
    time   TimeTyp,      -- nested record
    place  CHAR(20),
    purpose CHAR(50));
  TYPE PartyTyp IS RECORD(
    day DATE,
    time TimeTyp,      -- nested record
    loc CHAR(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 := meeting.time;
```

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 exit the application or 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 specification. That allows the function to return a user-defined record of the same type. When calling a function that returns a user-defined record, you use the following syntax to reference fields in the record:

```
function_name(parameters).field_name
```

To reference nested fields in a record returned by a function, you use the following syntax:

```
function_name(parameters).field_name.nested_field_name
```

Currently, you cannot use the syntax above to call a parameterless function because PL/SQL does not allow empty parameter lists. That is, the following syntax is illegal:

```
function_name().field_name -- illegal; empty parameter list
```

You cannot just drop the empty parameter list because the following syntax is also illegal:

```
function_name.field_name -- illegal; no parameter list
```

Instead, declare a local user-defined record to which you can assign the function result, then reference its fields directly.

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  CHAR(14),
        loc    CHAR(13));
    dept_rec DeptRecTyp;
    ...
BEGIN
    SELECT deptno, dname, loc INTO dept_rec FROM dept
    WHERE deptno = 20;
```

Related Topics

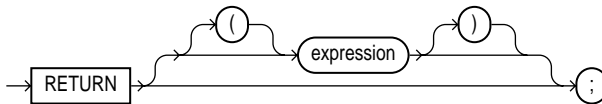
Assignment Statement, Collections, Functions, Procedures

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 result value. For more information, see “RETURN Statement” on page 7-7.

Syntax

`return_statement`



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, which specifies the datatype of the result value in a function specification.

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, a function must contain at least one RETURN statement. Otherwise, PL/SQL raises the predefined exception PROGRAM_ERROR 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

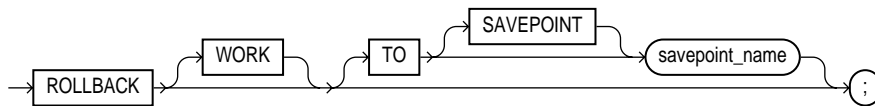
Functions, Procedures

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 “Processing Transactions” on page 5-44.

Syntax

`rollback_statement`



Keyword and Parameter Description

ROLLBACK

When a parameterless `ROLLBACK` statement is executed, all database changes made during the current transaction are undone.

WORK

This keyword is optional and has no effect except to improve readability.

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.

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.

Related Topics

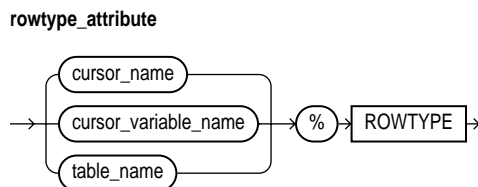
[COMMIT Statement](#), [SAVEPOINT Statement](#)

%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 2-31.

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, 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 the following example shows:

```
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 defined by the `CREATE TABLE` or `CREATE VIEW` statement. 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

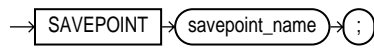
Constants and Variables, Cursors, Cursor Variables, `FETCH` Statement

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 “Processing Transactions” on page 5-44.

Syntax

`savepoint_statement`



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

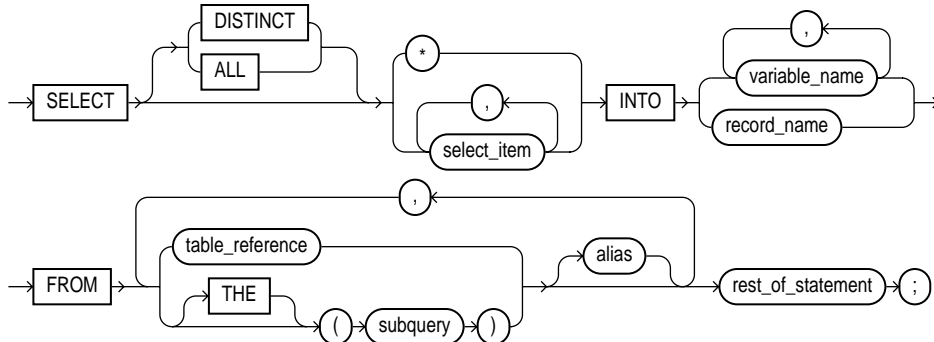
[COMMIT Statement](#), [ROLLBACK Statement](#)

SELECT INTO Statement

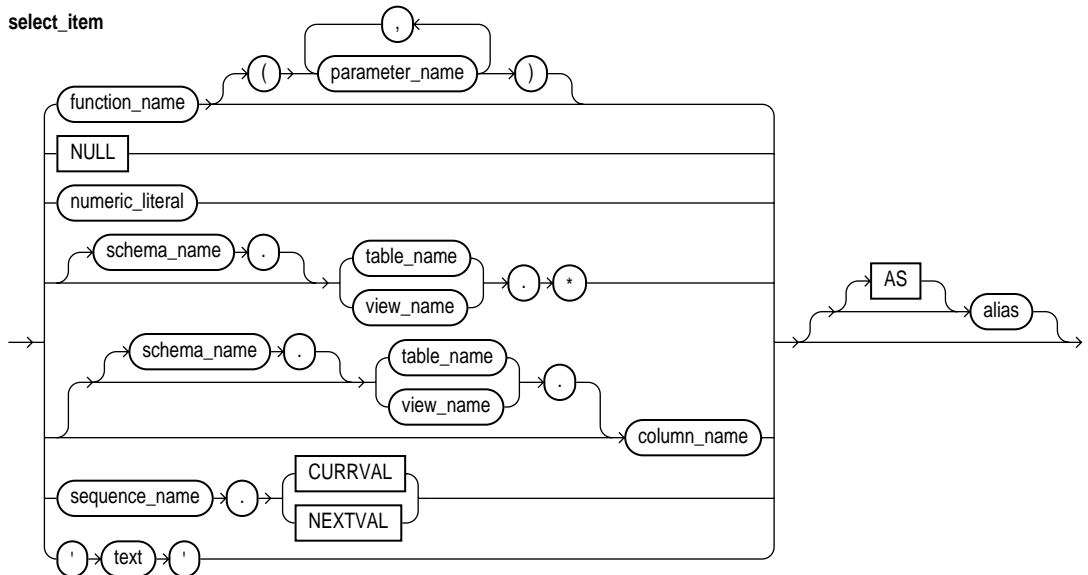
The **SELECT INTO** statement retrieves data from one or more database tables, then assigns the selected values to variables or fields. For a full description of the **SELECT** statement, see *Oracle8 SQL Reference*.

Syntax

select_into_statement



select_item



Keyword and Parameter Description

select_item

This is a value returned by the `SELECT` statement, then assigned to the corresponding variable or field in the `INTO` clause.

variable_name[, variable_name]...

This identifies a list of previously declared scalar variables into which *select_item* values are fetched. For each *select_item* value returned by the query, there must be a corresponding, type-compatible variable in the list.

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.

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 11-49.

THE

The operand of `THE` is a subquery that returns a single column value to the `SELECT` statement. The column value must be a nested table. Operator `THE` informs Oracle that the value is a nested table, not a scalar value.

subquery

This is query that provides a value or set of values to the `SELECT` statement. Its syntax is like that of *select_into_statement* without the `INTO` clause. See “`SELECT INTO` Statement” on page 11-139.

alias

This is another (usually short) name for the referenced column, table, or view.

rest_of_statement

This is anything that can legally follow the `FROM` clause in a `SELECT` statement.

Usage Notes

The implicit SQL cursor and the cursor attributes `%NOTFOUND`, `%FOUND`, `%ROWCOUNT`, and `%ISOPEN` let you access useful information about the execution of a `SELECT INTO` statement.

When you use a `SELECT INTO` statement to assign values to variables, it should return only one row. If it returns more than one row, you get the following results:

- PL/SQL raises the predefined exception `TOO_MANY_ROWS`
- `SQLCODE` returns -1422 (Oracle error code ORA-01422)
- `SQLERRM` returns the Oracle error message *single-row query returns more than one row*
- `SQL%NOTFOUND` yields `FALSE`
- `SQL%FOUND` yields `TRUE`
- `SQL%ROWCOUNT` yields 1

If no rows are returned, you get these results:

- PL/SQL raises the predefined exception `NO_DATA_FOUND` unless the `SELECT` statement called a SQL group function such as `AVG` or `SUM`. (SQL group functions always return a value or a null. So, a `SELECT INTO` statement that calls a group function never raises `NO_DATA_FOUND`.)
- `SQLCODE` returns +100 (Oracle error code ORA-01403)
- `SQLERRM` returns the Oracle error message *no data found*
- `SQL%NOTFOUND` yields `TRUE`
- `SQL%FOUND` yields `FALSE`
- `SQL%ROWCOUNT` yields 0

Example

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;
```

Related Topics

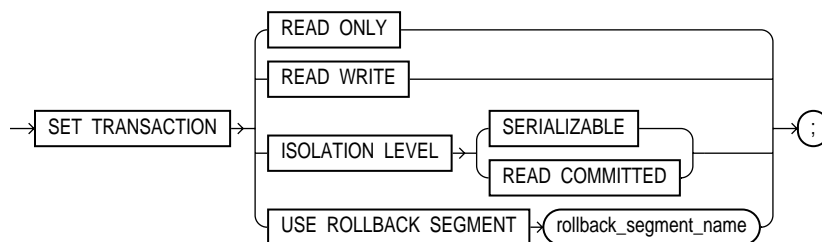
Assignment Statement, `FETCH` Statement, `%ROWTYPE` Attribute

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 “Using `SET TRANSACTION`” on page 5-50.

Syntax

`set_transaction_statement`



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.

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
```

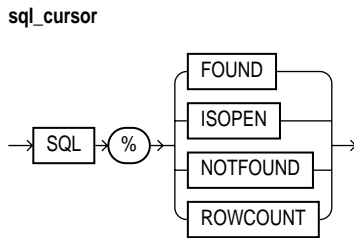
Related Topics

[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 has four attributes: `%FOUND`, `%ISOPEN`, `%NOTFOUND`, and `%ROWCOUNT`. They give you information about the execution of data manipulation statements. For more information, see “Managing Cursors” on page 5-9.

Syntax



Keyword and Parameter Description

SQL

This is the name of the implicit SQL cursor.

%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.

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 group function never raises `NO_DATA_FOUND`. That is because group functions such as `AVG` and `SUM` always return a value or a null. In such cases, `SQL%NOTFOUND` yields `FALSE`.

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;
```

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 zero.

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 “Using `SQLCODE` and `SQLERRM`” on page 6-18.

Syntax

`sqlcode_function`

→ SQLCODE →

Usage Notes

You cannot use `SQLCODE` directly in a SQL statement. First, you must assign the value of `SQLCODE` to a local variable. An example follows:

```
DECLARE
    my_sqlcode NUMBER;
BEGIN
    ...
EXCEPTION
    WHEN OTHERS THEN
        my_sqlcode := SQLCODE;
        INSERT INTO errors VALUES (my_sqlcode, ...);
END;
```

`SQLCODE` is especially useful in the `OTHERS` exception handler because it lets you identify which internal exception was raised.

Related Topics

Exceptions, `SQLERRM` Function

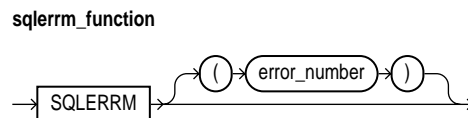
SQLERRM Function

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 “Using `SQLCODE` and `SQLERRM`” on page 6-18.

Syntax



Keyword and Parameter Description

error_number

This must be a valid Oracle error number. For a list of Oracle errors, see *Oracle8 Error Messages*.

Usage Notes

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. An example follows:

```
DECLARE
    my_sqlerrm CHAR(150);
    ...
BEGIN
    ...
EXCEPTION
    ...
    WHEN OTHERS THEN
        my_sqlerrm := SUBSTR(SQLERRM, 1, 150);
        INSERT INTO errors VALUES (my_sqlerrm, ...);
END;
```

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`. `SQLERRM` is especially useful in the `OTHERS` exception handler because it lets you identify which internal exception was raised.

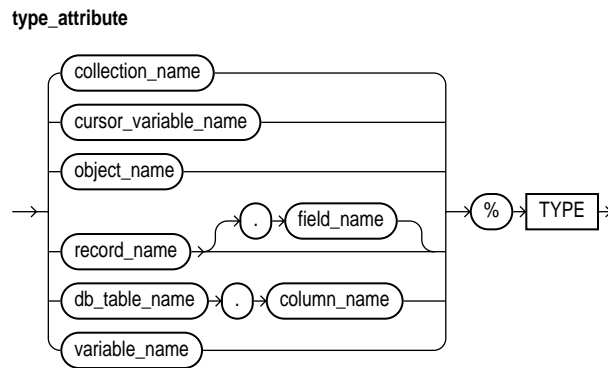
Related Topics

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 2-30.

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.

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.

table_name.column_name

This refers to a table and column that must be accessible when the declaration is elaborated.

variable_name

This is the name of 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 does *not* apply to items declared using %TYPE.

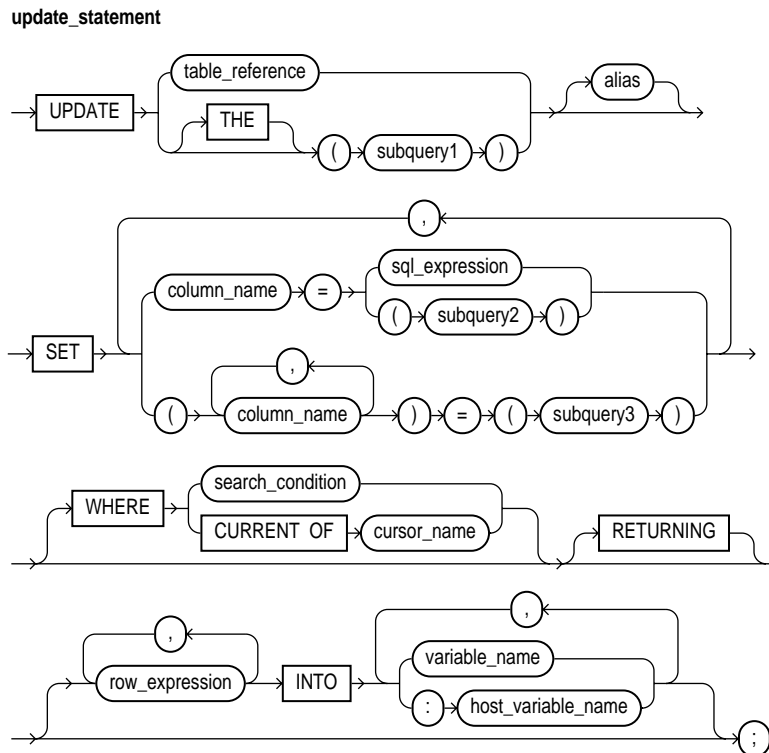
Related Topics

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 *Oracle8 SQL Reference*.

Syntax



Keyword and Parameter Description

`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 11-49.

THE

The operand of **THE** is a subquery that returns a single column value to the **UPDATE** statement. The column value must be a nested table. Operator **THE** informs Oracle that the value is a nested table, not a scalar value.

subquery1

This is a select statement that provides a value or set of values to the **UPDATE** statement. Its syntax is like that of *select_into_statement* without the **INTO** clause. See “SELECT INTO Statement” on page 11-139.

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.

sql_expression

This is any valid SQL expression. For more information, see *Oracle8 SQL Reference*.

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 1.1, then the result is assigned to the *sal* column.

```
UPDATE emp SET sal = sal * 1.1;
```

SET column_name = (subquery2)

This clause assigns the value retrieved from the database by *subquery2* to the column identified by *column_name*. The subquery must return exactly one row and one column.

SET (column_name, column_name, ...) = (subquery3)

This clause assigns the values retrieved from the database by *subquery3* 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. Thus, 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);
```

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.

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`.

RETURNING

This clause lets you return values from the updated row, thereby eliminating the need to `SELECT` the row afterward. You can retrieve the column values into variables and/or host variables.

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 SQL cursor and the cursor attributes `%NOTFOUND`, `%FOUND`, `%ROWCOUNT`, and `%ISOPEN` let you access useful information about the execution of an UPDATE statement.

An UPDATE statement might update one or more rows or no rows. If one or more rows are updated, you get the following results:

- `SQL%NOTFOUND` yields FALSE
- `SQL%FOUND` yields TRUE
- `SQL%ROWCOUNT` yields the number of rows updated

If no rows are updated, you get these results:

- `SQL%NOTFOUND` yields TRUE
- `SQL%FOUND` yields FALSE
- `SQL%ROWCOUNT` yields 0

Examples

In the following example, a 10% raise is given to all analysts and clerks in department 20:

```
UPDATE emp SET sal = sal * 1.10
  WHERE (job = 'ANALYST' OR job = 'CLERK') 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, you return values from an updated row and store them 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](#)

New Features

This appendix surveys the new features in release 8.0 of PL/SQL. Designed to meet your practical needs, these features will help you build effective, reliable applications.

Major Topics

External Procedures

Object Types

Collections

LOB Types

NLS Types

External Procedures

To support special-purpose processing and promote reuse of code, PL/SQL provides an interface for calling routines written in other languages. This makes the strengths and capabilities of those languages available to you.

An external procedure is a third-generation-language routine stored in a dynamic link library (DLL), registered with PL/SQL, and called by you to do special-purpose processing. At run time, PL/SQL loads the library dynamically, then calls the routine as if it were a PL/SQL subprogram. Typically, external procedures are used to interface with embedded systems, solve scientific and engineering problems, analyze data, or control real-time devices and processes.

For more information, see Chapter 10.

Object Types

Object-oriented programming is based on the concept of interacting objects. In, PL/SQL, objects are instances of object types. 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.

An *object type* encapsulates a data structure along with the functions and procedures needed to manipulate the data. At run time, when the data structure is filled with values, you have created an object. You can create as many objects as you need. Each object stores different real-world values.

Object types, which map directly into classes defined in object-oriented languages such as C++, reduce complexity by breaking down a large system into logical entities. This allows you to create software components that are modular, maintainable, and reusable.

For more information, see Chapter 9.

Collections

The collection types `TABLE` and `VARRAY` allow you to declare 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.

Collections work like the arrays found in most third-generation programming languages. They 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 Chapter 4.

LOB Types

The LOB (large object) datatypes `BFILE`, `BLOB`, `CLOB`, and `NCLOB` let you store blocks of unstructured data up to four gigabytes in size. And, they allow efficient, random, piece-wise access to the data.

LOB types store values, called locators, that specify the location of large objects stored out-of-line or in an external file. PL/SQL operates on LOBs through the locators. To manipulate LOBs, you use the supplied package `DBMS_LOB`, which is discussed in *Oracle8 Application Developer's Guide*.

For more information, see “Datatypes” on page 2-10.

NLS Types

Oracle8 offers extended NLS (National Language Support) including national character sets and the datatypes `NCHAR` and `NVARCHAR2`, which store NLS data. With NLS, number and date formats adapt automatically to the language conventions specified for a user session. So, users around the world can interact with Oracle in their native languages. NLS is discussed in *Oracle8 Reference*.

Besides the *database character set*, which is used for identifiers and source code, PL/SQL now supports a second character set called the *national character set*, which is used for NLS data. The PL/SQL datatypes `NCHAR` and `NVARCHAR2` allow you to store character strings formed from the national character set.

For more information, see “Datatypes” on page 2-10.

Sample 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.

Major 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. The following list shows the names of the files and their locations in this guide:

Filename	Location in Guide
examp1	on page 1-2
examp2	on page 1-9
examp3	on page 1-10
examp4	on page 2-33
examp5	on page 5-40
examp6	on page 5-41
examp7	on page 5-16
examp8	on page 5-18
examp11	on page 11-12
examp12	on page 11-35
examp13	on page 11-36
examp14	on page 11-36
sample1	on page B-11
sample2	on page B-12
sample3	on page B-13
sample4	on page B-15
sample5	on page B-19
sample6	on page B-23

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, *examp1d* and *examp1od*, supplied with PL/SQL. You can find these scripts in the PL/SQL demo directory.

Creating the Tables

Below is a listing of the SQL*Plus script *exampbld*. The CREATE statements in this script build the database tables processed by the sample programs. To run the script, invoke SQL*Plus, then issue the following command:

```
SQL> START exampbld
```

exampbld Script

```
set compatibility V7
/
drop table accounts
/
create table accounts(
    account_id number(4) not null,
    bal        number(11,2))
/
create unique index accounts_index on accounts (account_id)
/
drop table action
/
create table action(
    account_id number(4) not null,
    oper_type  char(1) not null,
    new_value  number(11,2),
    status     char(45),
    time_tag   date not null)
/
drop table bins
/
create table bins(
    bin_num    number(2) not null,
    part_num   number(4),
    amt_in_bin number(4))
/
drop table data_table
/
create table data_table(
    exper_num number(2),
    n1        number(5),
    n2        number(5),
    n3        number(5))
/
```

```
drop table emp
/
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))
/
drop table inventory
/
create table inventory(
    prod_id   number(5) not null,
    product   char(15),
    quantity  number(5))
/
drop table journal
/
create table journal(
    account_id number(4) not null,
    action     char(45) not null,
    amount     number(11,2),
    date_tag   date not null)
/
drop table num1_tab
/
create table num1_tab(
    sequence  number(3) not null,
    num       number(4))
/
drop table num2_tab
/
create table num2_tab(
    sequence  number(3) not null,
    num       number(4))
/
drop table purchase_record
/
```

```
create table purchase_record(
    mesg      char(45),
    purch_date date)
/
drop table ratio
/
create table ratio(
    sample_id number(3) not null,
    ratio      number)
/
drop table result_table
/
create table result_table(
    sample_id number(3) not null,
    x          number,
    y          number)
/
drop table sum_tab
/
create table sum_tab(
    sequence number(3) not null,
    sum       number(5))
/
drop table temp
/
create table temp(
    num_col1 number(9,4),
    num_col2 number(9,4),
    char_col  char(55))
/
create or replace package personnel as
    type charArrayType is table of varchar2(10)
        index by binary_integer;
    type numArrayType is table of float
        index by binary_integer;
    procedure get_employees(
        dept_number in    integer,
        batch_size  in    integer,
        found       in out integer,
        done_fetch  out   integer,
        emp_name    out   charArrayType,
        job-title   out   charArrayType,
        salary      out   numArrayType);
end personnel;
/
```

```
create or replace package body personnel as
  cursor get_emp (dept_number integer) is
    select ename, job, sal from emp
       where deptno = dept_number;
  procedure get_employees(
    dept_number in    integer,
    batch_size  in    integer,
    found       in out integer,
    done_fetch  out   integer,
    emp_name    out   charArrayType,
    job_title   out   charArrayType,
    salary      out   numArrayType) is
  begin
    if not get_emp%isopen then
      open get_emp(dept_number);
    end if;
    done_fetch := 0;
    found := 0;
    for i in 1..batch_size loop
      fetch get_emp into emp_name(i),
        job_title(i), salary(i);
      if get_emp%notfound then
        close get_emp;
        done_fetch := 1;
        exit;
      else
        found := found + 1;
      end if;
    end loop;
  end get_employees;
end personnel;
/
```

Loading the Data

Below is a listing of the SQL*Plus script *exemplod*. The INSERT statements in this script load (or reload) the database tables processed by the sample programs. To run the script, invoke SQL*Plus in the same Oracle account from which you ran *exampbld*, then issue the following command:

```
SQL> START exemplod
```

exemplod Script

```
delete from accounts
/
insert into accounts values (1,1000.00)
/
insert into accounts values (2,2000.00)
/
insert into accounts values (3,1500.00)
/
insert into accounts values (4,6500.00)
/
insert into accounts values (5,500.00)
/
delete from action
/
insert into action values (3,'u',599,null,sysdate)
/
insert into action values (6,'i',20099,null,sysdate)
/
insert into action values (5,'d',null,null,sysdate)
/
insert into action values (7,'u',1599,null,sysdate)
/
insert into action values (1,'i',399,null,sysdate)
/
insert into action values (9,'d',null,null,sysdate)
/
insert into action values (10,'x',null,null,sysdate)
/
delete from bins
/
insert into bins values (1, 5469, 650)
/
```

```

insert into bins values (2, 7243, 450)
/
insert into bins values (3, 5469, 120)
/
insert into bins values (4, 5469, 300)
/
insert into bins values (5, 6085, 415)
/
insert into bins values (6, 5469, 280)
/
insert into bins values (7, 8159, 619)
/
delete from data_table
/
insert into data_table values (1, 10, 167, 17)
/
insert into data_table values (1, 16, 223, 35)
/
insert into data_table values (2, 34, 547, 2)
/
insert into data_table values (3, 23, 318, 11)
/
insert into data_table values (1, 17, 266, 15)
/
insert into data_table values (1, 20, 117, 9)
/
delete from emp
/
insert into emp values
    (7369,'SMITH','CLERK',7902,TO_DATE('12-17-80','MM-DD-YY'),800,NULL,20)
/
insert into emp values
    (7499,'ALLEN','SALESMAN',7698,TO_DATE('02-20-81','MM-DD-YY'),1600,300,30)
/
insert into emp values
    (7521,'WARD','SALESMAN',7698,TO_DATE('02-22-81','MM-DD-YY'),1250,500,30)
/
insert into emp values
    (7566,'JONES','MANAGER',7839,TO_DATE('04-02-81','MM-DD-YY'),2975,NULL,20)
/
insert into emp values
    (7654,'MARTIN','SALESMAN',7698,TO_DATE('09-28-81','MM-DD-YY'),1250,1400,30)
/

```

```
insert into emp values
  (7698,'BLAKE','MANAGER',7839,TO_DATE('05-1-81','MM-DD-YY'),2850,NULL,30)
/
insert into emp values
  (7782,'CLARK','MANAGER',7839,TO_DATE('06-9-81','MM-DD-YY'),2450,NULL,10)
/
insert into emp values (7788,'SCOTT','ANALYST',7566,SYSDATE-85,3000,NULL,20)
/
insert into emp values
  (7839,'KING','PRESIDENT',NULL,TO_DATE('11-17-81','MM-DD-YY'),5000,NULL,10)
/
insert into emp values
  (7844,'TURNER','SALESMAN',7698,TO_DATE('09-8-81','MM-DD-YY'),1500,0,30)
/
insert into emp values (7876,'ADAMS','CLERK',7788,SYSDATE-51,1100,NULL,20)
/
insert into emp values
  (7900,'JAMES','CLERK',7698,TO_DATE('12-3-81','MM-DD-YY'),950,NULL,30)
/
insert into emp values
  (7902,'FORD','ANALYST',7566,TO_DATE('12-3-81','MM-DD-YY'),3000,NULL,20)
/
insert into emp values
  (7934,'MILLER','CLERK',7782,TO_DATE('01-23-82','MM-DD-YY'),1300,NULL,10)
/
delete from inventory
/
insert into inventory values ('TENNIS RACKET', 3)
/
insert into inventory values ('GOLF CLUB', 4)
/
insert into inventory values ('SOCCER BALL', 2)
/
delete from journal
/
delete from num1_tab
/
insert into num1_tab values (1, 5)
/
insert into num1_tab values (2, 7)
/
insert into num1_tab values (3, 4)
```

```
/
insert into num1_tab values (4, 9)
/
delete from num2_tab
/
insert into num2_tab values (1, 15)
/
insert into num2_tab values (2, 19)
/
insert into num2_tab values (3, 27)
/
delete from purchase_record
/
delete from ratio
/
delete from result_table
/
insert into result_table values (130, 70, 87)
/
insert into result_table values (131, 77, 194)
/
insert into result_table values (132, 73, 0)
/
insert into result_table values (133, 81, 98)
/
delete from sum_tab
/
delete from temp
/
commit
```


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 col1;
```

COL1	COL2	MESSAGE
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

10 records selected.

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

14 records selected.

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 CHAR(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      */
  END LOOP;
END;
```

```

        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;
```

COL1	COL2	MESSAGE
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, '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;
```

COL1	COL2	MESSAGE
1000	1	OUTER loop
1	2	inner loop
2	3	inner loop
3	4	inner loop
4	5	inner loop
2000	6	OUTER loop
1	7	inner loop
2	8	inner loop
3	9	inner loop
4	10	inner loop
3000	11	OUTER loop
1	12	inner loop
2	13	inner loop
3	14	inner loop
4	15	inner loop
4000	16	OUTER loop
1	17	inner loop
2	18	inner loop
3	19	inner loop
4	20	inner loop

20 records selected.

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

7 records selected.

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;
      END IF;
    END LOOP;
END;
```

```
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

6 records selected.

```
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

7 records selected.

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               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

14 records selected.

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];
    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%s\n", "Employee", "Job", "Salary");
    printf("%-10.10s%-10.10s%s\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.

Major 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. For example, given the following declaration, the value of `name` includes six trailing blanks, not just one:

```
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

```
name1 VARCHAR2(10) := 'COLES';  
name2 VARCHAR2(10) := 'COLEMAN';
```

the following IF condition is true:

```
IF name1 > 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

```
name1 CHAR(5) := 'BELLO';
name2 CHAR(10) := 'BELLO  '; -- note trailing blanks
```

the following `IF` condition is true:

```
IF name1 = 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

```
name1 VARCHAR2(10) := 'DOW';
name2 VARCHAR2(10) := 'DOW  '; -- note trailing blanks
```

the following `IF` condition is false:

```
IF name1 = 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

```
name1 VARCHAR2(10) := 'STAUB';
name2 CHAR(10)      := 'STAUB'; -- PL/SQL blank-pads value
```

the following `IF` condition is false because the value of `name2` includes five trailing blanks:

```
IF name1 = 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.

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'
```

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 the exception `VALUE_ERROR`.

When you select a column value into a `VARCHAR2` variable, if the value is shorter than the declared length of the variable, PL/SQL neither blank-pads the value nor strips trailing blanks. Character values are stored intact, so no information is lost.

For example, when you select a blank-padded `CHAR` column value into a `VARCHAR2` variable, the trailing blanks are not stripped. If the character value is longer than the declared length of the `VARCHAR2` variable, PL/SQL aborts the assignment and raises `VALUE_ERROR`.

The same rules apply when fetching.

D

PL/SQL Wrapper

This appendix shows you how to run the PL/SQL Wrapper, a stand-alone utility that converts PL/SQL source code into portable object code. You can use the Wrapper to deliver PL/SQL applications without exposing your source code.

Major Topics

Advantages of Wrapping

Running the PL/SQL Wrapper

Advantages of Wrapping

The PL/SQL Wrapper converts PL/SQL source code into an intermediate form of object code. By hiding application internals, the Wrapper 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 relink 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 PL/SQL Wrapper

To run the PL/SQL Wrapper, enter the `WRAP` command at your system prompt using the following syntax:

```
WRAP INAME=input_file [ONAME=output_file]
```

You can use uppercase or lowercase. 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 path and name of the Wrapper 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 path and name of the Wrapper 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

The input file can contain any combination of SQL statements. However, the PL/SQL Wrapper wraps only the following `CREATE` statements, which define PL/SQL packages and stand-alone subprograms:

- `CREATE [OR REPLACE] PACKAGE`
- `CREATE [OR REPLACE] PACKAGE BODY`
- `CREATE [OR REPLACE] FUNCTION`
- `CREATE [OR REPLACE] PROCEDURE`

All other SQL statements are passed intact to the output file. Comment lines (beginning with `REM` or `--`) are deleted unless they appear in a package or subprogram definition.

A wrapped package or subprogram definition has the form

```
<header> WRAPPED <body>
```

where *header* begins with the reserved word `CREATE` and ends with the name of the package or subprogram, and *body* is an intermediate form of object code that looks like a random sequence of characters. The keyword `WRAPPED` tells the PL/SQL compiler that the package or subprogram is wrapped.

The header can contain comments. For example, the Wrapper converts

```
CREATE OR REPLACE PACKAGE
-- Author: J Smith
-- Date: 11/15/94
mypkg AS ...
```

into

```
CREATE OR REPLACE PACKAGE
-- Author: J Smith
-- Date: 11/15/94
mypkg WRAPPED 8c724af33 ...
```

Generally, the output file is much larger than the input file.

Error Detection

If your input file contains syntactic errors, the PL/SQL Wrapper detects and reports them. However, the Wrapper cannot detect semantic errors because it does not resolve external references. That is done at compile time. So, only the PL/SQL compiler can detect semantic errors.

Name Resolution

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

Major Topics

What Is Name Resolution?

Various Forms of References

Name-Resolution Algorithm

Understanding Capture

Avoiding Capture

Accessing Attributes and Methods

Calling Subprograms and Methods

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 pack1 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
/
CREATE PACKAGE BODY pack1 AS
  FUNCTION f1 (p1 NUMBER) RETURN t1 IS
    n NUMBER;
  BEGIN
    ...
    n := m;           -- (1) unqualified name
    n := pack1.m;    -- (2) dot-separated chain of identifiers
                    -- (package name used as scope qualifier
                    -- followed by variable name)
    n := pack1.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 := pack1.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.pack1.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.

END;
FUNCTION f2 (q1 NUMBER) RETURN t2 IS
BEGIN
    NULL;
END;
END;
/
CREATE OR REPLACE PACKAGE BODY pack1 AS
    FUNCTION f1 (p1 NUMBER) RETURN t1 IS
        n NUMBER;
    BEGIN
        n := scott.pack1.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;
    FUNCTION f2 (q1 NUMBER) RETURN t2 IS
    BEGIN
        NULL;
    END;
END;
/

```

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) `pack1.f1.p1` is `PACK1`, the basis for (4) `scott.pack1.f1.n` is `SCOTT.PACK1`, 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 tries 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 SQL data manipulation statement except items in the `INTO` clause and schema-level table names) it first tries to find the basis in that scope. If it fails, it tries 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 tries 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 chain of two identifiers, the compiler tries 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 tries 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 tries 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 tries to resolve the complete reference by finding a component of the basis and so on depending upon the type of the 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 tries 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 tries 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 tries to find the basis by searching for schema objects using the following rules:

- First, the compiler tries 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.
- If the previous search fails, the compiler tries 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.
- If the previous search fails and there are at least two identifiers in the chain, the compiler tries 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.
- 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.
- If the compiler fails to find a basis by searching for schema objects, it generates a *not declared* error.
- If the compiler finds a basis, it tries 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 unbeknown to you. Consider, the following example:

```
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 this 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*. 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. Consider the following example:

```
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 -- note lack of alias
                  WHERE x = s.tab2.a)
/
```

In this example, the reference to *s.tab2.a* resolves to attribute *a* of column *tab2* in table *tab1* via table alias *s* which is visible in the outer scope of the query. 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 will occur because the reference to *s.tab2.a* will resolve to column *a* of table *tab2* in schema *s*.

You can avoid inner captures by following the rules given in “Avoiding Capture” on page E-10. According to those rules, you should recode the above 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 the last 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 following new rules were added to the name-resolution algorithm:

- 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 (or schema and 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

You can call a parameterless subprogram with or without an empty parameter list. Likewise, within PL/SQL scopes, the empty parameter list is optional. However, within SQL scopes, it is required.

Example 1

```
CREATE FUNCTION func1 RETURN NUMBER AS
BEGIN
    RETURN 10;
END;

CREATE PACKAGE pkg1 AS
    FUNCTION func1 RETURN NUMBER;
    PRAGMA RESTRICT_REFERENCES(func1,WNDS,RNDS,WNPS,RNPS);
END;

CREATE PACKAGE BODY pkg1 AS
    FUNCTION func1 RETURN NUMBER IS BEGIN RETURN 20; END;
END;

SELECT func1 FROM dual;
SELECT func1() FROM dual;
```

```

SELECT pkg1.func1 FROM dual;
SELECT pkg1.func1() FROM dual;

DECLARE
    x NUMBER;
BEGIN
    x := func1;
    x := func1();
    SELECT func1 INTO x FROM dual;
    SELECT func1() INTO x FROM dual;
    SELECT pkg1.func1 INTO x FROM dual;
    SELECT pkg1.func1() INTO x FROM dual;
END;
```

Example 2

```

CREATE OR REPLACE TYPE typ1 AS OBJECT (
    a NUMBER,
    MEMBER FUNCTION f RETURN number,
    PRAGMA RESTRICT_REFERENCES (f,WNDS,RNDS,WNPS,RNPS)
);

CREATE TYPE BODY typ1 AS
    MEMBER FUNCTION f RETURN number IS BEGIN RETURN 1; END;
END;

CREATE TABLE tabl (coll typ1);
INSERT INTO tabl VALUES (typ1(10));

SELECT x.coll.f FROM tabl x; -- illegal
SELECT x.coll.f() FROM tabl x;

DECLARE
    n NUMBER;
    y typ1;
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 tabl x; -- illegal
    SELECT y.f() INTO n FROM tabl x;1
END;
```

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, allow for more legal situations. Also, the SQL rules recognize as legal more DML statements than the PL/SQL rules recognize.

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. Also, some of these words (marked by an asterisk) are reserved by SQL. So, you should not use them to name schema objects such as columns, tables, or indexes.

ABORT	DATABASE	INCREMENT*	OUT	SQL
ACCEPT	DATA_BASE	INDEX*	PACKAGE	SQLCODE
ACCESS*	DATE*	INDEXES	PARTITION	SQLERRM
ADD*	DBA	INDICATOR	PCTFREE*	START*
ALL*	DEBUGOFF	INITIAL*	PLS_INTEGER	STATEMENT
ALTER*	DEBUGON	INSERT*	POSITIVE	STDDEV
AND*	DECLARE	INTEGER*	POSITIVEN	SUBTYPE
ANY*	DECIMAL*	INTERFACE	PRAGMA	SUCCESSFUL*
ARRAY	DEFAULT*	INTERSECT*	PRIOR*	SUM
ARRAYLEN	DEFINITION	INTO*	PRIVATE	SYNONYM*
AS*	DELAY	IS*	PRIVILEGES*	SYSDATE*
ASC*	DELETE*	LEVEL*	PROCEDURE	TABAUTH
ASSERT	DESC*	LIKE*	PUBLIC*	TABLE*
ASSIGN	DIGITS	LIMITED	RAISE	TABLES
AT	DISPOSE	LOCK*	RANGE	TASK
AUDIT*	DISTINCT*	LONG*	RAW*	TERMINATE
AUTHORIZATION	DO	LOOP	REAL	THEN*
AVG	DROP*	MAX	RECORD	TO*
BASE_TABLE	ELSE*	MAXEXTENTS*	REF	TRIGGER*
BEGIN	ELSF	MIN	RELEASE	TRUE
BETWEEN*	END	MINUS*	REMR	TYPE
BINARY_INTEGER	ENTRY	MLSLABEL*	RENAME*	UID*
BODY	EXCEPTION	MOD	RESOURCE*	UNION*
BOOLEAN	EXCEPTION_INIT	MODE*	RETURN	UNIQUE*
BY*	EXCLUSIVE*	NATURAL	REVERSE	UPDATE*
CASE	EXISTS*	NATURALN	REVOKE*	USE
CHAR*	EXIT	NEW	ROLLBACK	USER*
CHAR_BASE	FALSE	NEXTVAL	ROW*	VALIDATE*
CHECK*	FETCH	NOAUDIT*	ROWID*	VALUES*
CLOSE	FILE*	NOCOMPRESS*	ROWLABEL*	VARCHAR*
CLUSTER*	FLOAT*	NOT*	ROWNUM*	VARCHAR2*
CLUSTERS	FOR*	NOWAIT*	ROWS*	VARIANCE
COLAUTH	FORM	NULL*	ROWTYPE	VIEW*
COLUMN*	FROM*	NUMBER*	RUN	VIEWS
COMMENT*	FUNCTION	NUMBER_BASE	SAVEPOINT	WHEN
COMMIT	GENERIC	OF*	SCHEMA	WHENEVER*
COMPRESS*	GOTO	OFFLINE*	SELECT*	WHERE*
CONNECT*	GRANT*	ON*	SEPERATE	WHILE
CONSTANT	GROUP*	ONLINE*	SESSION*	WITH*
CRASH	HAVING*	OPEN	SET*	WORK
CREATE*	IDENTIFIED*	OPTION*	SHARE*	WRITE
CURRENT*	IF	OR*	SIGNTYPE	XOR
CURRVAL	IMMEDIATE*	ORDER*	SMALLINT*	
CURSOR	IN*	OTHERS	SPACE	

Symbols

+ addition/identity operator, 2-3
:= assignment operator, 1-4, 2-4
=> association operator, 2-4, 7-12
% attribute indicator, 1-7, 2-3
' character string delimiter, 2-3
. component selector, 1-6, 2-3
|| concatenation operator, 2-4, 2-46
/ division operator, 2-3
** exponentiation operator, 2-4
(expression or list delimiter, 2-3
) expression or list delimiter, 2-3
: host variable indicator, 2-3
. item separator, 2-3
<< label delimiter, 2-4
>> label delimiter, 2-4
/* multi-line comment delimiter, 2-4
*/ multi-line comment delimiter, 2-4
* multiplication operator, 2-3
" quoted identifier delimiter, 2-3
.. range operator, 2-4, 3-10
= relational operator, 2-3, 2-45
< relational operator, 2-3, 2-45
> relational operator, 2-3, 2-45
<> relational operator, 2-4, 2-45
!= relational operator, 2-4, 2-45
~= relational operator, 2-4, 2-45
<= relational operator, 2-4, 2-45
>= relational operator, 2-4, 2-45
@ remote access indicator, 2-3, 2-34
-- single-line comment delimiter, 2-4
; statement terminator, 2-3, 11-12
- subtraction/negation operator, 2-3

A

abstraction, 7-3, 9-2
ACCESS_INTO_NULL exception, 6-5
actual parameter, 5-11
address, 5-19
aggregate assignment, 2-32
alias library, 10-3
aliasing, 5-36
ALL comparison operator, 5-6
ALL option, 5-3
ALL row operator, 5-7
anonymous PL/SQL block, 7-2
ANY comparison operator, 5-6
apostrophe, 2-8
architecture, 1-18
assignment
 aggregate, 2-32
 character string, C-2
 collection, 4-12
 cursor variable, 5-34
 field, 4-33
 record, 4-33
 semantics, C-2
assignment operator, 1-4
assignment statement
 syntax, 11-3
association operator, 7-12
asterisk (*) option, 5-3
asynchronous operation, 8-18
atomically null, 9-24

- attribute, 1-7
 - %ROWTYPE, 2-31
 - %TYPE, 2-30
 - cursor, 5-38
 - object, 9-3, 9-7
- attribute indicator, 1-7
- AVG group function, 5-3

B

- base type, 2-12, 2-22
- basic loop, 3-6
- BETWEEN comparison operator, 2-45, 5-6
- BFILE datatype, 2-20
- binary operator, 2-41
- BINARY_INTEGER datatype, 2-11
- bind variable, 5-19
- binding, 5-7
- blank-padding semantics, C-3
- BLOB datatype, 2-20
- block
 - anonymous, 7-2
 - label, 2-39
 - maximum size, 5-60
 - PL/SQL, 11-7
 - structure, 1-2
- body
 - cursor, 5-15
 - function, 7-5
 - method, 9-8
 - object, 9-5
 - package, 8-7
 - procedure, 7-4
- Boolean
 - expression, 2-46
 - literal, 2-8
 - value, 2-46
- BOOLEAN datatype, 2-21
- built-in function, 2-51
- BY REF phrase, 10-15
- by-reference parameter passing, 7-17
- by-value parameter passing, 7-17

C

- call, subprogram, 7-12
- callback, 10-22
 - example, 10-22
 - restrictions, 10-23
- CALLING STANDARD clause, 10-4
- carriage return, 2-3
- case sensitivity
 - identifier, 2-5
 - string literal, 2-8
- case, lower, xix
- case, upper, xix
- CHAR column
 - maximum width, 2-14
- CHAR datatype, 2-14
- CHAR semantics, C-1
- CHAR_CS value, 2-28
- character literal, 2-7
- character set, 2-2
- CHARACTER subtype, 2-14
- character value
 - assigning, C-2
 - comparing, C-2
 - inserting, C-4
 - selecting, C-4
- CHARSETFORM property, 10-15
- CHARSETID property, 10-15
- client program, 9-2
- CLOB datatype, 2-20
- CLOSE statement, 5-13, 5-27
 - syntax, 11-14
- collating sequence, 2-47
- collection, 4-2
 - assigning, 4-12
 - comparing, 4-13
 - constructor, 4-9
 - declaring, 4-7
 - defining, 4-5
 - element type, 4-5
 - initializing, 4-9
 - referencing, 4-11
 - scope, 4-9
 - syntax, 11-21

- collection exceptions
 - when raised, 4-28
- collection method
 - applying to parameters, 4-27
 - COUNT, 4-22
 - DELETE, 4-26
 - EXISTS, 4-22
 - EXTEND, 4-24
 - FIRST, 4-23
 - LAST, 4-23
 - LIMIT, 4-22
 - NEXT, 4-23
 - PRIOR, 4-23
 - syntax, 11-16
 - TRIM, 4-25
- collection types, 4-1
- COLLECTION_IS_NULL exception, 6-5
- column alias, 5-17
 - when needed, 2-33
- comment, 2-9
 - restrictions, 2-10
 - syntax, 11-26
- COMMENT clause, 5-46
- COMMIT statement, 5-46
 - syntax, 11-27
- comparison
 - of character values, C-2
 - of collections, 4-13
 - of expressions, 2-46
 - operators, 2-44, 5-6
- compilation
 - using the PL/SQL Wrapper, D-1
- compiler, 5-7
- component selector, 1-6
- composite type, 2-10
- compound symbol, 2-4
- concatenation operator, 2-46
 - treatment of nulls, 2-50
- concurrency, 5-44
- conditional control, 3-2
- constant
 - declaring, 2-29
 - syntax, 11-29
- constraint
 - NOT NULL, 2-30
 - where not allowed, 2-23, 7-4
- constructor
 - collection, 4-9
 - object, 9-12
- control structure, 3-2
 - conditional, 3-2
 - iterative, 3-6
 - sequential, 3-15
- conventions
 - naming, 2-34
- conversion function
 - when needed, 2-26
- conversion, datatype, 2-25
- correlated subquery, 5-14
- COUNT collection method, 4-22
- COUNT group function, 5-3
- CREATE LIBRARY statement, 10-3
- CURRENT OF clause, 5-52
- current row, 1-5
- CURRVAL pseudocolumn, 5-4
- cursor, 1-5, 5-9
 - analogy, 1-5
 - closing, 5-13
 - declaring, 5-10
 - explicit, 5-9
 - fetching from, 5-12
 - implicit, 5-14
 - opening, 5-11
 - packaged, 5-15
 - parameterized, 5-11
 - RETURN clause, 5-15
 - scope rules, 5-10
 - syntax, 11-45
- cursor attribute
 - %FOUND, 5-38, 5-42
 - %ISOPEN, 5-38, 5-42
 - %NOTFOUND, 5-39
 - %ROWCOUNT, 5-39, 5-43
 - implicit, 5-42
 - syntax, 11-33
 - values, 5-40
- cursor FOR loop, 5-16
 - passing parameters to, 5-18

- cursor variable, 5-18
 - assignment, 5-34
 - closing, 5-27
 - declaring, 5-20
 - fetching from, 5-26
 - opening, 5-22
 - restrictions, 5-37
 - syntax, 11-38
 - using to reduce network traffic, 5-33
- CURSOR_ALREADY_OPEN exception, 6-5

D

- dangling ref, 9-34
- data abstraction, 9-2
- data encapsulation, 1-16
- data integrity, 5-44
- data lock, 5-45
- database changes
 - making permanent, 5-46
 - undoing, 5-47
- database character set, 2-18
- datatype, 2-10
 - BFILE, 2-20
 - BINARY_INTEGER, 2-11
 - BLOB, 2-20
 - BOOLEAN, 2-21
 - CHAR, 2-14
 - CLOB, 2-20
 - constraint, 7-4
 - DATE, 2-21
 - families, 2-10
 - implicit conversion, 2-26
 - LONG, 2-15
 - LONG RAW, 2-15
 - MLSLABEL, 2-22
 - NCHAR, 2-18
 - NCLOB, 2-21
 - NLS, 2-17
 - NUMBER, 2-12
 - NVARCHAR2, 2-19
 - PLS_INTEGER, 2-13
 - RAW, 2-15
 - RECORD, 4-28
 - REF CURSOR, 5-19
 - ROWID, 2-16
 - scalar versus composite, 2-10
 - TABLE, 4-2
 - VARCHAR2, 2-16
 - VARRAY, 4-4
- date
 - converting, 2-27
 - TO_CHAR default format, 2-27
- DATE datatype, 2-21
- DBMS_ALERT package, 8-18
- DBMS_OUTPUT package, 8-16
- DBMS_PIPE package, 8-17
- DBMS_SQL package, 5-8, 8-17
 - array interface, 5-57
- DBMS_STANDARD package, 8-16
- DDL support, 5-7
- deadlock, 5-45
 - effect on transactions, 5-47
 - how broken, 5-47
- DEBUG_EXTPROC package, 10-24
- DEC subtype, 2-13
- DECIMAL subtype, 2-13
- declaration
 - collection, 4-7
 - constant, 2-29
 - cursor, 5-10
 - cursor variable, 5-20
 - exception, 6-6
 - forward, 7-8
 - object, 9-23
 - record, 4-30
 - subprogram, 7-8
 - variable, 2-28
- declarative part
 - function, 7-6
 - PL/SQL block, 1-3
 - procedure, 7-4
- DECODE function
 - treatment of nulls, 2-50
- DEFAULT keyword, 2-29
- default parameter value, 7-15
- default pragma, 9-13
- DELETE collection method, 4-26

DELETE statement
 RETURNING clause, 5-55
 syntax, 11-49
 delimiter, 2-3
 demo, external procedure, 10-24
 dense collection, 4-3
 DEPT table, xx
 Deref operator, 9-34
 dereference, 9-34
 digits of precision, 2-12
 DISTINCT option, 5-3
 DISTINCT row operator, 5-7
 distributed transaction, 5-45
 DLL (dynamic link library), 10-3
 dot notation, 1-6, 1-7
 for collection methods, 4-21
 for global variables, 3-13
 for object attributes, 9-25
 for object methods, 9-27
 for package contents, 8-6
 for record fields, 2-32
 DOUBLE PRECISION subtype, 2-13
 DUP_VAL_ON_INDEX exception, 6-5
 dynamic FOR-loop range, 3-12
 dynamic link library (DLL), 10-3
 dynamic SQL support, 5-7

E

elaboration, 2-29
 element type
 collection, 4-5
 ellipsis, xix
 ELSE clause, 3-3
 ELSIF clause, 3-4
 EMP table, xx
 encapsulation, data, 1-16
 END IF reserved words, 3-3
 END LOOP reserved words, 3-9
 Entry SQL support, 5-7
 error message
 maximum length, 6-18
 evaluation, 2-41
 short-circuit, 2-44
 EXAMPBLD script, B-3

EXAMPLDOD script, B-7
 exception, 6-2
 declaring, 6-6
 predefined, 6-4
 propagation, 6-12
 raised in declaration, 6-16
 raised in handler, 6-17
 raising with RAISE statement, 6-11
 reraising, 6-14
 scope rules, 6-7
 syntax, 11-54
 user-defined, 6-6
 WHEN clause, 6-15
 exception handler, 6-15
 branching from, 6-17
 OTHERS handler, 6-2
 using RAISE statement in, 6-15
 using SQLCODE function in, 6-18
 using SQLERRM function in, 6-18
 EXCEPTION_INIT pragma, 6-8
 syntax, 11-52
 using with raise_application_error, 6-10
 exception-handling part
 function, 7-6
 PL/SQL block, 1-3
 procedure, 7-4
 executable part
 function, 7-6
 PL/SQL block, 1-3
 procedure, 7-4
 execution environment, 1-18
 EXISTS collection method, 4-22
 EXISTS comparison operator, 5-6
 EXIT statement, 3-6, 3-14
 syntax, 11-57
 WHEN clause, 3-7
 where allowed, 3-6
 explicit cursor, 5-9
 expression
 Boolean, 2-46
 how evaluated, 2-41
 parentheses in, 2-42
 syntax, 11-59
 EXTEND collection method, 4-24
 extensibility, 7-3

- EXTERNAL clause, 10-3
 - components, 10-4
 - syntax, 11-70
- external procedure, 10-2
 - calling, 10-5
 - DEBUG_EXTPROC package, 10-24
 - debugging, 10-24
 - demo program, 10-24
 - environment variables, 10-8
 - guidelines, 10-25
 - how PL/SQL calls, 10-7
 - maximum number of parameters, 10-26
 - passing parameters to, 10-9
 - registering, 10-3
 - restrictions, 10-25
 - specifying datatypes, 10-9
 - specifying properties, 10-12
- extproc process, 10-7

F

- FALSE value, 2-8
- features, new, A-1
- FETCH statement, 5-12, 5-26
 - syntax, 11-76
- fetching across commits, 5-53
- Fibonacci sequence, 7-23
- field, 4-28
- field type, 4-29
- file I/O, 8-17
- FIRST collection method, 4-23
- flag, PLSQL_V2_COMPATIBILITY, 5-62
- FLOAT subtype, 2-13
- FOR loop, 3-10
 - dynamic range, 3-12
 - iteration scheme, 3-10
 - loop counter, 3-10
 - nested, 3-14
- FOR loop, cursor, 5-16
- FOR UPDATE clause, 5-11
 - restriction on, 5-22
 - when to use, 5-51
- formal parameter, 5-11

- format
 - function, 7-5
 - package, 8-2
 - packaged procedure, 7-9
 - procedure, 7-3
- format mask
 - when needed, 2-27
- forward declaration, 7-8
 - when needed, 7-8, 7-26
- forward reference, 2-34
- forward type definition, 9-30
- %FOUND cursor attribute, 5-38, 5-42
- function, 7-1, 7-5
 - body, 7-5
 - built-in, 2-51
 - call, 7-6
 - parameter, 7-5
 - parts, 7-5
 - RETURN clause, 7-5
 - specification, 7-5
 - syntax, 11-79

G

- gigabyte, 2-20
- GLB group function, 5-3
- GOTO statement, 3-15
 - label, 3-15
 - misuse, 3-17
 - restriction, 6-17
 - syntax, 11-83
- GROUP BY clause, 5-3
- group function
 - AVG, 5-3
 - COUNT, 5-3
 - GLB, 5-3
 - LUB, 5-3
 - MAX, 5-3
 - MIN, 5-3
 - STDDEV, 5-3
 - SUM, 5-3
 - treatment of nulls, 5-3
 - VARIANCE, 5-3

H

handler, exception, 6-2
handling exceptions, 6-1
 raised in declaration, 6-16
 raised in handler, 6-17
 using OTHERS handler, 6-15
handling of nulls, 2-48
hidden declaration, 8-2
hiding, information, 1-16
host variable, 5-19
hypertext markup language (HTML), 8-17
hypertext transfer protocol (HTTP), 8-17

I

identifier
 forming, 2-4
 maximum length, 2-5
 quoted, 2-6
 scope rules, 2-37
IF statement, 3-2
 ELSE clause, 3-3
 ELSIF clause, 3-4
 syntax, 11-85
 THEN clause, 3-3
implicit cursor, 5-14
 attribute, 5-42
implicit datatype conversion, 2-26
 effect on performance, 5-59
implicit declaration
 cursor FOR loop record, 5-16
 FOR loop counter, 3-13
IN comparison operator, 2-46, 5-6
IN OUT parameter mode, 7-14
IN parameter mode, 7-13
incomplete object type, 9-30
index, cursor FOR loop, 5-16
index-by table, 4-3
indicator, 10-14
INDICATOR property, 10-14
infinite loop, 3-6
information hiding, 1-16, 8-4
initialization
 collection, 4-9

 object, 9-24
 package, 8-8
 record, 4-31
 using DEFAULT, 2-29
 variable, 2-40
 when required, 2-30
INSERT statement
 RETURNING clause, 5-55
 syntax, 11-88
instance, 9-4
INT subtype, 2-13
INTEGER subtype, 2-13
interoperability, cursor, 5-19
INTERSECT set operator, 5-6
INTO clause, 5-26
INTO list, 5-12
INVALID_CURSOR exception, 6-5
INVALID_NUMBER exception, 6-5
IS DANGLING predicate, 9-34
IS NULL comparison operator, 2-45, 5-6
%ISOPEN cursor attribute, 5-38, 5-42
iteration
 scheme, 3-10
 versus recursion, 7-27
iterative control, 3-6

J

join, 7-26

L

label
 block, 2-39
 GOTO statement, 3-15
 loop, 3-8
LANGUAGE clause, 10-4
large object (LOB) datatypes, 2-19
LAST collection method, 4-23
LENGTH property, 10-14
LEVEL pseudocolumn, 5-5
lexical unit, 2-2
library, 8-1
LIBRARY clause, 10-4
library, alias, 10-3

- LIKE comparison operator, 2-45, 5-6
- LIMIT collection method, 4-22
- literal, 2-7
 - Boolean, 2-8
 - character, 2-7
 - numeric, 2-7
 - string, 2-8
 - syntax, 11-91
- LOB (large object) datatypes, 2-19
- local subprogram, 1-19
- locator, 2-19
- lock, 5-45
 - modes, 5-45
 - overriding, 5-51
 - using FOR UPDATE clause, 5-51
- LOCK TABLE statement, 5-52
 - syntax, 11-94
- LOGIN_DENIED exception, 6-5
- LONG datatype, 2-15
 - maximum length, 2-15
 - restrictions, 2-15
- LONG RAW datatype, 2-15
 - converting, 2-28
 - maximum length, 2-15
- loop
 - counter, 3-10
 - kinds, 3-6
 - label, 3-8
- LOOP statement, 3-6
 - forms, 3-6
 - syntax, 11-96
- LUB group function, 5-3

M

- maintainability, 7-3
- map method, 9-10
- MAX group function, 5-3
- maximum length
 - CHAR value, 2-14
 - identifier, 2-5
 - LONG RAW value, 2-15
 - LONG value, 2-15
 - NCHAR value, 2-18
 - NVARCHAR2 value, 2-19

- Oracle error message, 6-18
- RAW value, 2-15
- VARCHAR2 value, 2-16
- maximum precision, 2-12
- maximum size
 - LOB, 2-19
- MAXLEN property, 10-14
- membership test, 2-46
- method
 - COUNT, 4-22
 - DELETE, 4-26
 - EXISTS, 4-22
 - EXTEND, 4-24
 - FIRST, 4-23
 - LAST, 4-23
 - LIMIT, 4-22
 - map, 9-10
 - NEXT, 4-23
 - object, 9-3, 9-8
 - order, 9-10
 - PRIOR, 4-23
 - TRIM, 4-25
- method calls
 - chaining, 9-27
- method, collection, 4-21
- MIN group function, 5-3
- MINUS set operator, 5-6
- mixed notation, 7-12
- MLSLABEL datatype, 2-22
- mode, parameter
 - IN, 7-13
 - IN OUT, 7-14
 - OUT, 7-13
- modularity, 1-11, 7-3, 8-4
- multi-line comment, 2-9
- mutual recursion, 7-26

N

- name
 - cursor, 5-10
 - qualified, 2-34
 - savepoint, 5-48
 - variable, 2-35
- NAME clause, 10-4

- name resolution, 2-35, E-1
- named notation, 7-12
- naming conventions, 2-34
- national character set, 2-18
- National Language Support (NLS), 2-17
- NATURAL subtype, 2-12
- NATURALN subtype, 2-12
- NCHAR datatype, 2-18
- NCHAR_CS value, 2-28
- NCLOB datatype, 2-21
- nested table, 4-2
 - manipulating, 4-14
 - versus index-by table, 4-3
- nesting
 - block, 1-3
 - FOR loop, 3-14
 - object, 9-7
 - record, 4-29
- network traffic
 - reducing, 1-22
- new features, A-1
- NEXT collection method, 4-23
- NEXTVAL pseudocolumn, 5-4
- nibble, 2-28
- NLS (National Language Support), 2-17
- NLS datatype, 2-17
- NLS_CHARSET_ID function, 2-28
- NLS_CHARSET_NAME function, 2-28
- NO_DATA_FOUND exception, 6-5
- non-blank-padding semantics, C-3
- NOT logical operator
 - treatment of nulls, 2-49
- NOT NULL constraint
 - effect on %TYPE declaration, 2-31
 - effect on performance, 5-58
 - restriction, 5-10, 7-3
 - using in collection declaration, 4-7
 - using in field declaration, 4-31
 - using in variable declaration, 2-30
- NOT_LOGGED_ON exception, 6-5
- notation
 - mixed, 7-12
 - positional versus named, 7-12
- %NOTFOUND cursor attribute, 5-39
- NOWAIT parameter, 5-51

- NVARCHAR2 datatype, 2-19
- NVL function
 - treatment of nulls, 2-50
- null handling, 2-48
- NULL statement, 3-19
 - syntax, 11-102
 - using in a procedure, 7-4
- nullity, 2-45
- NUMBER datatype, 2-12
- numeric literal, 2-7
- NUMERIC subtype, 2-13

O

- object, 9-4
 - declaring, 9-23
 - initializing, 9-24
 - manipulating, 9-31
 - sharing, 9-28
- object attribute, 9-3, 9-7
 - accessing, 9-25
 - allowed datatypes, 9-7
 - maximum number, 9-7
- object constructor
 - calling, 9-26
 - passing parameters to, 9-27
- object method, 9-3, 9-8
 - calling, 9-27
- object table, 9-31
- object type, 9-1, 9-3
 - advantages, 9-5
 - defining, 9-14
 - examples, 9-14
 - structure, 9-5
 - syntax, 11-103
- object-oriented programming, 9-1
- OPEN statement, 5-11
 - syntax, 11-111
- OPEN-FOR statement, 5-22
 - syntax, 11-113
- operator
 - comparison, 2-44
 - concatenation, 2-46
 - DEREF, 9-34
 - precedence, 2-42

- REF, 9-33
 - relational, 2-45
 - VALUE, 9-32
- OR keyword, 6-16
- Oracle, Trusted, 2-10
- order method, 9-10
- order of evaluation, 2-42, 2-43
- OTHERS exception handler, 6-2, 6-15
- OUT parameter mode, 7-13
- overloading, 7-18
 - object method, 9-10
 - packaged subprogram, 8-14
 - restrictions, 7-19
 - using subtypes, 7-20

P

- package, 8-1, 8-2
 - advantages, 8-4
 - bodiless, 8-6
 - body, 8-2
 - creating, 8-3
 - DEBUG_EXTPROC, 10-24
 - initializing, 8-8
 - private versus public objects, 8-14
 - referencing, 8-6
 - scope, 8-5
 - serially reusable, 5-55
 - specification, 8-2
 - syntax, 11-117
- package, product-specific, 8-16
- packaged cursor, 5-15
- packaged subprogram, 1-19, 7-9
 - calling, 8-6
 - overloading, 8-14
- parameter
 - actual versus formal, 7-11
 - cursor, 5-11
 - default values, 7-15
 - modes, 7-13
 - SELF, 9-8
- parameter passing
 - by reference, 7-17
 - by value, 7-17
- PARAMETERS clause, 10-5, 10-12
- parentheses, 2-42
- Pascal Calling Standard, 10-4
- pattern matching, 2-45
- p-code, 5-8
- performance, 1-22
 - improving, 5-54
- pipe, 8-17
- PL/SQL
 - advantages, 1-21
 - architecture, 1-18
 - block structure, 1-2
 - execution environments, 1-18
 - new features, A-1
 - performance, 1-22
 - portability, 1-23
 - procedural aspects, 1-2
 - reserved words, F-1
 - sample programs, B-1
 - support for SQL, 1-21
- PL/SQL block
 - anonymous, 1-2, 7-2
 - maximum size, 5-60
 - syntax, 11-7
- PL/SQL compiler
 - how calls are resolved, 7-21
 - how it works, 5-8
 - how references are resolved, 5-7
- PL/SQL engine, 1-18
 - in Oracle Server, 1-19
 - in Oracle tools, 1-20
- PL/SQL syntax, 11-1
- PL/SQL Wrapper, D-1
 - input and output files, D-3
 - running, D-2
- PLS_INTEGER datatype, 2-13
- PLSQL_V2_COMPATIBILITY flag, 5-62
- pointer, 5-19
- portability, 1-23
- positional notation, 7-12
- POSITIVE subtype, 2-12
- POSITIVEN subtype, 2-12
- pragma, 6-8
 - EXCEPTION_INIT, 6-8
 - RESTRICT_REFERENCES, 7-6, 9-12
 - SERIALLY_REUSABLE, 5-55

- precedence, operator, 2-42
- precision of digits
 - specifying, 2-12
- predefined exception
 - list of, 6-4
 - raising explicitly, 6-11
 - redeclaring, 6-10
- predicate, 5-6
- preface
 - Send Us Your Comments, xiii
- PRIOR collection method, 4-23
- PRIOR row operator, 5-5, 5-7
- private object, 8-14
- procedural abstraction, 9-2
- procedure, 7-1, 7-3
 - body, 7-4
 - calling, 7-5
 - external, 10-2
 - parameter, 7-3
 - parts, 7-4
 - specification, 7-4
 - syntax, 11-121
- productivity, 1-23
- program unit, 1-11
- PROGRAM_ERROR exception, 6-5
- propagation, exception, 6-12
- property
 - CHARSETFORM, 10-15
 - CHARSETID, 10-15
 - INDICATOR, 10-14
 - LENGTH, 10-14
 - MAXLEN, 10-14
- pseudocolumn, 5-4
 - CURRVAL, 5-4
 - LEVEL, 5-5
 - NEXTVAL, 5-4
 - ROWID, 5-5
 - ROWNUM, 5-5
- pseudoinstruction, 6-8
- public object, 8-14
- purity level, 9-12

Q

- qualifier
 - using subprogram name as, 2-37
 - when needed, 2-34, 2-39
- query work area, 5-19
- quoted identifier, 2-6

R

- RAISE statement, 6-11
 - syntax, 11-126
 - using in exception handler, 6-15
- raise_application_error procedure, 6-9
- raising an exception, 6-11
- range operator, 3-10
- RAW datatype, 2-15
 - converting, 2-28
 - maximum length, 2-15
- read consistency, 5-45
- READ ONLY parameter, 5-50
- readability, 2-2, 3-19
- read-only transaction, 5-50
- REAL subtype, 2-13
- record, 4-28
 - %ROWTYPE, 5-16
 - assigning, 4-33
 - comparing, 4-35
 - declaring, 4-30
 - defining, 4-29
 - implicit declaration, 5-16
 - initializing, 4-31
 - manipulating, 4-35
 - nesting, 4-29
 - referencing, 4-31
 - syntax, 11-128
- RECORD datatype, 4-28
- recursion, 7-23
 - infinite, 7-24
 - mutual, 7-26
 - terminating condition, 7-24
 - versus iteration, 7-27

- ref, 9-28
 - dangling, 9-34
 - declaring, 9-29
 - dereferencing, 9-34
- REF CURSOR datatype, 5-19
 - defining, 5-20
- REF operator, 9-33
- REF type modifier, 9-29
- reference type, 2-10
- relational operator, 2-45
- remote access indicator, 2-34
- REPEAT UNTIL structure
 - mimicking, 3-10
- REPLACE function
 - treatment of nulls, 2-51
- reraising an exception, 6-14
- reserved words, F-1
 - misuse of, 2-5
 - using as quoted identifier, 2-6
- resolution, name, 2-35, E-1
- RESTRICT_REFERENCES pragma, 9-12
- result set, 1-5, 5-11
- result value, function, 7-5
- RETURN clause
 - cursor, 5-15
 - function, 7-5
- RETURN statement, 7-7
 - syntax, 11-132
- return type, 5-20, 7-21
- RETURNING clause, 5-55, 9-37
- reusability, 7-3
- reusable packages, 5-55
- REVERSE reserved word, 3-11
- rollback
 - implicit, 5-49
 - statement-level, 5-47
- rollback segment, 5-45
- ROLLBACK statement, 5-47
 - effect on savepoints, 5-48
 - syntax, 11-134
- routine
 - external, 10-2
 - service, 10-17
- row lock, 5-51

- row operator, 5-7
- %ROWCOUNT cursor attribute, 5-39, 5-43
- rowid, 2-16
- ROWID datatype, 2-16
- ROWID pseudocolumn, 5-5
- ROWIDTOCHAR function, 5-5
- ROWNUM pseudocolumn, 5-5
- %ROWTYPE attribute, 2-31
 - syntax, 11-136
- ROWTYPE_MISMATCH exception, 6-6
- RPC (remote procedure call), 6-12
- RTRIM function
 - using to insert data, C-4
- runtime error, 6-1

S

- sample database table
 - DEPT table, xx
 - EMP table, xx
- sample programs, B-1
- savepoint name
 - reusing, 5-48
- SAVEPOINT statement, 5-48
 - syntax, 11-138
- scalar type, 2-10
- scale
 - specifying, 2-13
- scheme, iteration, 3-10
- scientific notation, 2-7
- scope, 2-37
 - collection, 4-9
 - cursor, 5-10
 - cursor parameter, 5-10
 - definition, 2-37
 - exception, 6-7
 - identifier, 2-37
 - loop counter, 3-13
 - package, 8-5
- SELECT INTO statement
 - syntax, 11-139
- selector, 5-24
- SELF parameter, 9-8

- semantics
 - assignment, C-2
 - blank-padding, C-3
 - CHAR versus VARCHAR2, C-1
 - non-blank-padding, C-3
 - string comparison, C-2
- Send Us Your Comments
 - boilerplate, xiii
- separator, 2-3
- sequence, 5-4
- sequential control, 3-15
- serially reusable package, 5-55
- SERIALLY_REUSABLE pragma, 5-55
- server
 - integration with PL/SQL, 1-23
- service routine, 10-17
 - examples, 10-17
- session, 5-44
- session-specific variables, 8-11
- set operator, 5-6
- SET TRANSACTION statement, 5-50
 - syntax, 11-142
- short-circuit evaluation, 2-44
- side effects, 7-13, 9-12
- significant characters, 2-5
- SIGNTYPE subtype, 2-12
- simple symbol, 2-3
- single-line comment, 2-9
- size constraint, subtype, 2-23
- size limit, varray, 4-5
- SMALLINT subtype, 2-13
- snapshot, 5-45
- SOME comparison operator, 5-6
- spaces
 - where allowed, 2-2
- spaghetti code, 3-15
- sparse collection, 4-3
- specification
 - cursor, 5-15
 - function, 7-5
 - method, 9-8
 - object, 9-5
 - package, 8-5
 - procedure, 7-4
- SQL
 - comparison operators, 5-6
 - data manipulation statements, 5-2
 - pseudocolumn, 5-4
 - row operators, 5-7
 - set operators, 5-6
 - support in PL/SQL, 1-21
- SQL cursor
 - syntax, 11-144
- SQL standards conformance, 5-7
- SQL92 conformance, 5-7
- SQLCODE function, 6-18
 - syntax, 11-146
- SQLERRM function, 6-18
 - syntax, 11-147
- stack, 9-14
- standalone subprogram, 1-19
- START WITH clause, 5-5
- statement
 - assignment, 11-3
 - CLOSE, 5-13, 5-27, 11-14
 - COMMIT, 11-27
 - CREATE LIBRARY, 10-3
 - DELETE, 11-49
 - EXIT, 11-57
 - FETCH, 5-12, 5-26, 11-76
 - GOTO, 11-83
 - IF, 11-85
 - INSERT, 11-88
 - LOCK TABLE, 11-94
 - LOOP, 11-96
 - NULL, 11-102
 - OPEN, 5-11, 11-111
 - OPEN-FOR, 5-22, 11-113
 - RAISE, 11-126
 - RETURN, 11-132
 - ROLLBACK, 11-134
 - SAVEPOINT, 11-138
 - SELECT INTO, 11-139
 - SET TRANSACTION, 11-142
 - UPDATE, 11-151
- statement terminator, 11-12
- statement-level rollback, 5-47
- STDDEV group function, 5-3

- STEP clause
 - mimicking, 3-12
- stepwise refinement, 1-2
- STORAGE_ERROR exception, 6-6
 - when raised, 7-24
- store table, 4-5
- stored subprogram, 1-19, 7-10
- string comparison semantics, C-2
- string literal, 2-8
- STRING subtype, 2-17
- structure theorem, 3-2
- stub, 3-19, 7-3
- subprogram, 7-2
 - advantages, 7-3
 - declaring, 7-8
 - how calls are resolved, 7-21
 - local, 1-19
 - overloading, 7-18
 - packaged, 1-19, 7-9
 - parts, 7-2
 - procedure versus function, 7-5
 - recursive, 7-24
 - standalone, 1-19
 - stored, 1-19, 7-10
- subquery, 5-14
- SUBSCRIPT_BEYOND_COUNT exception, 6-6
- SUBSCRIPT_OUTSIDE_LIMIT exception, 6-6
- SUBSTR function, 6-19
- subtype, 2-12, 2-22
 - CHARACTER, 2-14
 - compatibility, 2-24
 - DEC, 2-13
 - DECIMAL, 2-13
 - defining, 2-23
 - DOUBLE PRECISION, 2-13
 - FLOAT, 2-13
 - INT, 2-13
 - INTEGER, 2-13
 - NATURAL, 2-12
 - NATURALN, 2-12
 - NUMERIC, 2-13
 - overloading, 7-20
 - POSITIVE, 2-12
 - POSITIVEN, 2-12
 - REAL, 2-13
 - SIGNTYPE, 2-12
 - SMALLINT, 2-13
 - STRING, 2-17
 - VARCHAR, 2-17
- SUM group function, 5-3
- support for SQL, 5-2
- symbol
 - compound, 2-4
 - simple, 2-3
- syntax definition, 11-1
- syntax diagram, reading, 11-2

T

- tab, 2-3
- TABLE datatype, 4-2
- table, index-by, 4-3
- table, nested, 4-2
- terminating condition, 7-24
- terminator
 - statement, 2-3
- ternary operator, 2-41
- THEN clause, 3-3
- TIMEOUT_ON_RESOURCE exception, 6-6
- TOO_MANY_ROWS exception, 6-6
- top-down design, 1-16
- trailing blanks
 - how handled, C-4
- transaction, 5-2, 5-45
 - committing, 5-46
 - distributed, 5-45
 - ending properly, 5-49
 - read-only, 5-50
 - rolling back, 5-47
- transaction processing, 5-2, 5-44
- TRIM collection method, 4-25
- TRUE value, 2-8
- Trusted Oracle, 2-10
- %TYPE attribute, 2-30
 - syntax, 11-149
- type definition
 - collection, 4-5
 - forward, 9-30
 - RECORD, 4-29
 - REF CURSOR, 5-20

U

- unary operator, 2-41
- underscore, 2-4
- unhandled exception, 6-12, 6-19
- uninitialized object
 - how treated, 9-25
- UNION ALL set operator, 5-6
- UNION set operator, 5-6
- UPDATE statement
 - RETURNING clause, 5-55
 - syntax, 11-151
- URL (universal resource locator), 8-17
- user session, 5-44
- user-defined exception, 6-6
- user-defined record, 4-28
 - declaring, 4-30
 - referencing, 4-31
- user-defined subtype, 2-22
- UTL_FILE package, 8-17
- UTL_HTTP package, 8-17

V

- VALUE operator, 9-32
- VALUE_ERROR exception, 6-6
- VARCHAR subtype, 2-17
- VARCHAR2 datatype, 2-16
- VARCHAR2 semantics, C-1
- variable
 - assigning values, 2-40
 - declaring, 2-28
 - initializing, 2-40
 - session-specific, 8-11
 - syntax, 11-29
- VARIANCE group function, 5-3
- varray
 - size limit, 4-5
- VARRAY datatype, 4-4
- visibility
 - of package contents, 8-2
 - versus scope, 2-37

W

- WHEN clause, 3-7, 6-15
- WHILE loop, 3-9
- wildcard, 2-45
- WITH CONTEXT clause, 10-5, 10-16
- words, reserved, F-1
- work area, query, 5-19

Z

- ZERO_DIVIDE exception, 6-6

