



Contents at a Glance

PART I Oracle PL/SQL

1	Oracle PL/SQL Development Overview	3
2	New Features	17
3	PL/SQL Basics	43
4	Language Fundamentals	111
5	Control Structures	153
6	Collections	217
7	Error Management	261

PART II PL/SQL Programming

8	Functions and Procedures	293
9	Packages	347
10	Large Objects	385
11	Object Types	449
12	Triggers	491
13	Dynamic SQL	545

PART III Appendixes and Glossary

A	Oracle Database Primer	595
B	SQL Primer	695

C	SQL Built-in Functions	893
D	PL/SQL Built-in Packages and Types	965
E	Regular Expression Primer	999
F	Wrapping PL/SQL Code Primer	1019
G	PL/SQL Hierarchical Profiler Primer	1029
H	PL/SQL Reserved Words and Keywords	1045
I	Mastery Check Answers	1055
	Glossary	1085
	Index	1101



Contents

Acknowledgments	xix
Introduction	xxi

PART I

Oracle PL/SQL

1 Oracle PL/SQL Development Overview	3
PL/SQL's History and Background	4
Oracle Development Architecture	6
The Database	7
The PL/SQL Language	9
The Oracle Processing Architecture	12
Two-Tier Model	13
N-Tier Model	13
Summary	15
Mastery Check	15
2 New Features	17
New SQL Features	18
Data Catalog DIRECTORY Qualifies a LIBRARY Object	19
Define Tables with Valid-Time (VT) Support	19
Enhanced Oracle Native LEFT OUTER JOIN Syntax	20
Default Values for Columns Based on Sequences	20
Default Values for Explicit Null Insertion	22
Identity Columns	23
Increased Size Limits of String and Raw Types	24
Pass Results from SQL Statements to External Programs	24
Native SQL Support for Query Row Limits and Offsets	26
Oracle Database Driver for MySQL Applications	29
SQL CROSS APPLY, OUTER APPLY, and LATERAL	29
Bequeath CURRENT_USER Views	31

New PL/SQL Features	32
Caching of Invoker Rights Functions	32
Ability to White List PL/SQL Program Unit Callers	32
Native Client API Support for PL/SQL Types	34
New PL/SQL Package UTL_CALL_STACK	34
DBMS_UTILITY Adds EXPAND_SQL_TEXT Subprogram	34
DBMS_SQL Adds a New Formal Schema to the PARSE Procedure	35
PL/SQL Functions in SQL WITH Clause	35
PL/SQL-Specific Data Types Allowed in SQL	37
Implicit REF CURSOR Parameter Binding	40
Supporting Scripts	40
Summary	41
Mastery Check	41
3 PL/SQL Basics	43
Block Structure	44
Execution Block	44
Basic Block Structure	45
Declaration Block	48
Exception Block	49
Behavior of Variables in Blocks	50
Anonymous Blocks	50
Nested Anonymous Blocks	55
Local Named Blocks	57
Stored Named Blocks	60
Basic Scalar and Composite Data Types	63
Scalar Data Types	63
Attribute and Table Anchoring	65
Composite Data Types	68
Control Structures	81
Conditional Structures	81
Iterative Structures	83
Exceptions	92
User-Defined Exceptions	93
Dynamic User-Defined Exceptions	94
Bulk Operations	95
Functions, Procedures, and Packages	97
Functions	97
Procedures	99
Packages	100
Transaction Scope	106
Single Transaction Scope	106
Multiple Transaction Scopes	107

Database Triggers	108
Summary	109
Mastery Check	109
4 Language Fundamentals	111
Lexical Units	112
Delimiters	112
Identifiers	118
Literals	119
Comments	121
Variables and Data Types	122
Variable Data Types	123
Scalar Data Types	126
Large Objects (LOBs)	142
Composite Data Types	144
System Reference Cursors	147
Summary	150
Mastery Check	150
5 Control Structures	153
Conditional Statements	154
IF Statements	162
CASE Statements	166
Conditional Compilation Statements	169
Iterative Statements	172
Simple Loop Statements	172
FOR Loop Statements	179
WHILE Loop Statements	181
Cursor Structures	185
Implicit Cursors	185
Explicit Cursors	190
Bulk Statements	203
BULK COLLECT INTO Statements	203
FORALL Statements	208
Supporting Scripts	213
Summary	214
Mastery Check	214
6 Collections	217
Introduction to Collections	218
Object Types: Varray and Table Collections	221
Varray Collections	221
Table Collections	225
Associative Arrays	240
Defining and Using Associative Arrays	241

X Oracle Database 12c PL/SQL Programming

Oracle Collection API	247
COUNT Method	250
DELETE Method	251
EXISTS Method	252
EXTEND Method	253
FIRST Method	254
LAST Method	255
LIMIT Method	255
NEXT Method	256
PRIOR Method	256
TRIM Method	257
Supporting Scripts	259
Summary	259
Mastery Check	259

7 Error Management 261

Exception Types and Scope	262
Compilation Errors	263
Runtime Errors	266
Exception Management Built-in Functions	274
User-Defined Exceptions	276
Declaring User-Defined Exceptions	276
Dynamic User-Defined Exceptions	278
Exception Stack Functions	281
Supporting Scripts	287
Summary	287
Mastery Check	288

PART II

PL/SQL Programming

8 Functions and Procedures 293

Function and Procedure Architecture	295
Transaction Scope	302
Calling Subroutines	303
Positional Notation	304
Named Notation	304
Mixed Notation	304
Exclusionary Notation	304
SQL Call Notation	305
Functions	306
Function Model Choices	307
Creation Options	308
Pass-by-Value Functions	322
Pass-by-Reference Functions	336

Procedures	338
Pass-by-Value Procedures	339
Pass-by-Reference Procedures	342
Supporting Scripts	345
Summary	345
Mastery Check	345
9 Packages	347
Package Architecture	348
Package Specification	354
Prototype Features	355
Serially Reusable Precompiler Directive	358
Variables	359
Types	361
Components: Functions and Procedures	364
Package Body	365
Prototype Features	366
Variables	368
Types	371
Components: Functions and Procedures	371
Definer vs. Invoker Rights Mechanics	375
Managing Packages in the Database Catalog	378
Finding, Validating, and Describing Packages	379
Checking Dependencies	380
Comparing Validation Methods: Timestamp vs. Signature	381
Summary	382
Mastery Check	382
10 Large Objects	385
Working with Internally Stored LOB Types	387
LOB Assignments Under 32K	387
LOB Assignments over 32K	389
Reading Files into Internally Stored Columns	398
Reading Local Files into CLOB or NCLOB Columns	399
Reading Local Files into BLOB Columns	402
Working with LOBs Through Web Pages	404
Working with Binary Files (BFILES)	413
Creating and Using Virtual Directories	413
Reading Canonical Path Names and Filenames	419
Understanding the DBMS_LOB Package	427
Package Constants	427
Package Exceptions	428
Opening and Closing Methods	429
Manipulation Methods	430
Introspection Methods	436

BFILE Methods	440
Temporary LOB Methods	441
Security Link Methods	442
Supporting Scripts	446
The LONG to CLOB Script	446
Manage LOBs from the File System	446
Manage CLOB and BLOB LOBs Through the Web	446
Manage BFILE LOBs Through the Web	446
Summary	446
Mastery Check	447
11 Object Types	449
Object Basics	453
Declaring Objects Types	453
Implementing Object Bodies	456
White Listing Object Types	461
Getters and Setters	463
Static Member Methods	465
Comparing Objects	467
Inheritance and Polymorphism	475
Declaring Subclasses	477
Implementing Subclasses	478
Type Evolution	481
Implementing Object Type Collections	483
Declaring Object Type Collections	483
Implementing Object Type Collections	483
Supporting Scripts	487
Summary	487
Mastery Check	488
12 Triggers	491
Introduction to Triggers	492
Database Trigger Architecture	495
Data Definition Language Triggers	499
Event Attribute Functions	501
Building DDL Triggers	512
Data Manipulation Language Triggers	515
Statement-Level Triggers	516
Row-Level Triggers	518
Compound Triggers	527
INSTEAD OF Triggers	532
System and Database Event Triggers	536
Trigger Restrictions	538
Maximum Trigger Size	538
SQL Statements	538
LONG and LONG RAW Data Types	539

Mutating Tables	539
System Triggers	540
Supporting Scripts	541
Summary	541
Mastery Check	541
13 Dynamic SQL	545
Dynamic SQL Architecture	547
Native Dynamic SQL (NDS)	547
Dynamic Statements	548
Dynamic Statements with Inputs	550
Dynamic Statements with Inputs and Outputs	554
Dynamic Statements with an Unknown Number of Inputs	558
DBMS_SQL Package	560
Dynamic Statements	561
Dynamic Statements with Input Variables	564
Dynamic Statements with Variable Inputs and Fixed Outputs	566
Dynamic Statements with Variable Inputs and Outputs	571
DBMS_SQL Package Definition	576
Supporting Scripts	591
Summary	591
Mastery Check	591

PART III

Appendixes and Glossary

A Oracle Database Primer	595
Oracle Database Architecture	596
Starting and Stopping the	
Oracle Database 12c Server	603
Unix or Linux Operations	604
Microsoft Windows Operations	609
Starting and Stopping the Oracle Listener	610
Multiversion Concurrency Control	615
Data Transactions	616
DML Locking and Isolation Control	619
Definer Rights and Invoker Rights	620
Definer Rights	620
Invoker Rights	621
SQL Interactive and Batch Processing	622
SQL*Plus Command-Line Interface	622
Oracle SQL Developer Interface	644
Database Administration	652
Provisioning Users	652
Using Database Constraints	661

Security Hardening	670
Data Governance	681
SQL Tuning	684
EXPLAIN PLAN Statement	685
DBMS_XPLAN Package	686
SQL Tracing	690
Tracing Session Statements	691
Convert Raw Trace Files to Readable Trace Files	693
Summary	694
B SQL Primer	695
Oracle SQL Data Types	699
Data Definition Language (DDL)	703
CREATE Statement	704
ALTER Statement	773
RENAME Statement	791
DROP Statement	792
TRUNCATE Statement	794
COMMENT Statement	795
Data Manipulation Language (DML)	795
ACID Compliant Transactions	795
INSERT Statement	799
UPDATE Statement	815
DELETE Statement	829
MERGE Statement	834
Transaction Control Language (TCL)	841
Queries: SELECT Statements	843
Queries that Return Columns or Results from Columns	845
Queries that Aggregate	861
Queries that Return Columns or Results Selectively	866
Join Results	876
Joins that Splice Together Rows	878
Joins that Splice Collections	888
Summary	891
C SQL Built-in Functions	893
Character Functions	894
ASCII Function	894
ASCIISTR Function	895
CHR Function	895
CONCAT Function	896
INITCAP Function	896
INSTR Function	897
LENGTH Function	897
LOWER Function	898

LPAD Function	898
LTRIM Function	899
REPLACE Function	899
REVERSE Function	900
RPAD Function	900
RTRIM Function	901
UPPER Function	901
Data Type Conversion Functions	902
CAST Function	902
CONVERT Function	904
TO_CHAR Function	905
TO_CLOB Function	907
TO_DATE Function	907
TO_LOB Function	908
TO_NCHAR Function	910
TO_NCLOB Function	910
TO_NUMBER Function	910
Date-time Conversion Functions	911
ADD_MONTHS Function	911
CURRENT_DATE Function	911
CURRENT_TIMESTAMP Function	912
DBTIMEZONE Function	912
EXTRACT Function	912
FROM_TZ Function	913
LAST_DAY Function	913
LOCALTIMESTAMP Function	914
MONTHS_BETWEEN Function	914
NEW_TIME Function	915
ROUND Function	916
SYSDATE Function	916
SYSTEMTIMESTAMP Function	917
TO_CHAR(date) Function	917
TO_DSINTERVAL Function	918
TO_TIMESTAMP Function	918
TO_TIMESTAMP_TZ Function	919
TO_YMINTERVAL Function	919
TRUNC(date) Function	920
TZ_OFFSET Function	920
Collection Management Functions	921
CARDINALITY Function	921
COLLECT Function	921
POWERMULTISET Function	925
POWERMULTISET_BY_CARDINALITY Function	926
SET Function	926

Collection Set Operators	926
CARDINALITY Operator	928
EMPTY Operator	929
MULTISET Operator	929
MULTISET EXCEPT Operator	930
MULTISET INTERSECT Operator	930
MULTISET UNION Operator	931
SET Operator	932
SUBMULTISET OF Operator	933
Number Functions	933
CEIL Function	933
FLOOR Function	934
MOD Function	934
POWER Function	936
REMAINDER Function	937
ROUND Function	938
Error Reporting Functions	938
SQLCODE Function	938
SQLERRM Function	939
Miscellaneous Functions	940
BFILENAME Function	941
COALESCE Function	943
DECODE Function	944
DUMP Function	945
EMPTY_BLOB Function	945
EMPTY_CLOB Function	948
GREATEST Function	949
LEAST Function	951
NANVL Function	953
NULLIF Function	953
NVL Function	954
SYS_CONTEXT Function	954
TABLE Function	958
TREAT Function	960
USERENV Function	961
VSIZE Function	963
Summary	963
D PL/SQL Built-in Packages and Types	965
Oracle Database 11g and 12c New Packages	966
Examples of Package Use	974
DBMS_APPLICATION_INFO Example	974
DBMS_COMPARISON	979
DBMS_CRYPT0	986
DBMS_FGA	990
Case Study: Query Tool	991

Supporting Scripts	997
Summary	997
E Regular Expression Primer	999
Regular Expression Introduction	1000
Character Classes	1000
Collation Classes	1003
Metacharacters	1004
Metasequences	1006
Literals	1007
Regular Expression Implementation	1007
REGEXP_COUNT Function	1007
REGEXP_INSTR Function	1011
REGEXP_LIKE Function	1013
REGEXP_REPLACE Function	1014
REGEXP_SUBSTR Function	1015
Supporting Scripts	1017
Summary	1017
F Wrapping PL/SQL Code Primer	1019
Limitations of Wrapping PL/SQL	1020
Limitations of the PL/SQL wrap Utility	1021
Limitations of the DBMS_DDL.WRAP Function	1021
Using the wrap Command-Line Utility	1021
Using the DBMS_DDL Command-Line Utility	1021
WRAP Function	1022
CREATE_WRAPPED Procedure	1026
Summary	1028
G PL/SQL Hierarchical Profiler Primer	1029
Configuring the Schema	1030
Collecting Profiler Data	1032
Understanding Profiler Data	1035
Reading the Raw Output	1035
Defining the PL/SQL Profiler Tables	1037
Querying the Analyzed Data	1039
Using the plshprof Command-Line Utility	1040
Supporting Scripts	1043
Summary	1043
H PL/SQL Reserved Words and Keywords	1045
Summary	1053
I Mastery Check Answers	1055
Chapter 1	1056
Chapter 2	1058
Chapter 3	1060

Chapter 4	1063
Chapter 5	1065
Chapter 6	1067
Chapter 7	1069
Chapter 8	1071
Chapter 9	1074
Chapter 10	1076
Chapter 11	1078
Chapter 12	1080
Chapter 13	1082
Glossary	1085
Index	1101