Oracle Database 11*g*: Advanced PL/SQL

Volume I • Student Guide

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Before You Begin This Course

Before you begin this course, you should have a thorough knowledge of SQL, SQL*Plus, and have working experience on developing applications with PL/SQL. The prerequisites are *Oracle Database 11g: Develop PL/SQL Program Units* and *Oracle Database 11g: Introduction to SQL*.

How This Course Is Organized

Oracle Database 11g: Advanced PL/SQL is an instructor-led course featuring lectures and hands-on exercises. Online demonstrations and written practice sessions reinforce the concepts and skills.

Related Publications

Oracle Publications

Title	Part Number
Oracle Database Concepts 11g Release 1 (11.1)	*B28318-03*
Oracle Database SQL Language Reference 11g Release 1 (11.1)	*B28286-02*
Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)	*B28419-02*
Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)	*B28370-02*
Oracle Database Advanced Developer's Guide 11g Release 1 (11.1)	*B28424-02*
Oracle Database Object-Relational Developer's Guide 11g Release 1 (11.1)	*B28371-02*
Oracle Database Performance Tuning Guide 11g Release 1 (11.1)	*B28274-01*

Additional Publications

- System release bulletins
- Installation and user's guides
- *read.me* files
- International Oracle User's Group (IOUG) articles
- *Oracle Magazine*

Typographic Conventions

The following table lists the typographical conventions that are used in text and code.

Typographical Conventions in Text

Convention	Object or Term	Example
Uppercase	Commands, functions, column names, table names, PL/SQL objects, schemas	Use the `SELECT` command to view information stored in the `LAST_NAME` column of the `EMPLOYEES` table.
Lowercase, italic	File names, syntax variables, usernames, passwords	**where:** *role* is the name of the role to be created.
Initial cap	Trigger and button names	Assign a When-Validate-Item trigger to the ORD block. Select Cancel.
Italic	Books, names of courses and manuals, and emphasized words or phrases	For more information about the subject, see *Oracle SQL Reference Manual* Do *not* save changes to the database.
Quotation marks	Lesson module titles referenced within a course	This subject is covered in Lesson 3, “Working with Objects.”

Typographic Conventions (continued)

Typographical Conventions in Code

Convention	Object or Term	Example
Uppercase	Commands, functions	`SELECT employee_id` `FROM   employees;`
Lowercase, italic	Syntax variables	`CREATE ROLE` ***`role`***`;`

Initial cap	Forms, triggers	`Form module: ORD`
		`Trigger level: S_ITEM.QUANTITY item`
		`Trigger name: When-Validate-Item`
		`. . .`

Lowercase	Column names, table names, file names, PL/SQL objects	`. . .`
		`OG_ACTIVATE_LAYER`
		` (OG_GET_LAYER ('prod_pie_layer'))`
		`. . .`
		
		`SELECT last_name`
		`FROM   employees;`

Bold	Text that must be entered by a user	**`CREATE USER scott`** **`IDENTIFIED BY tiger;`**

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Introduction

Course Objectives

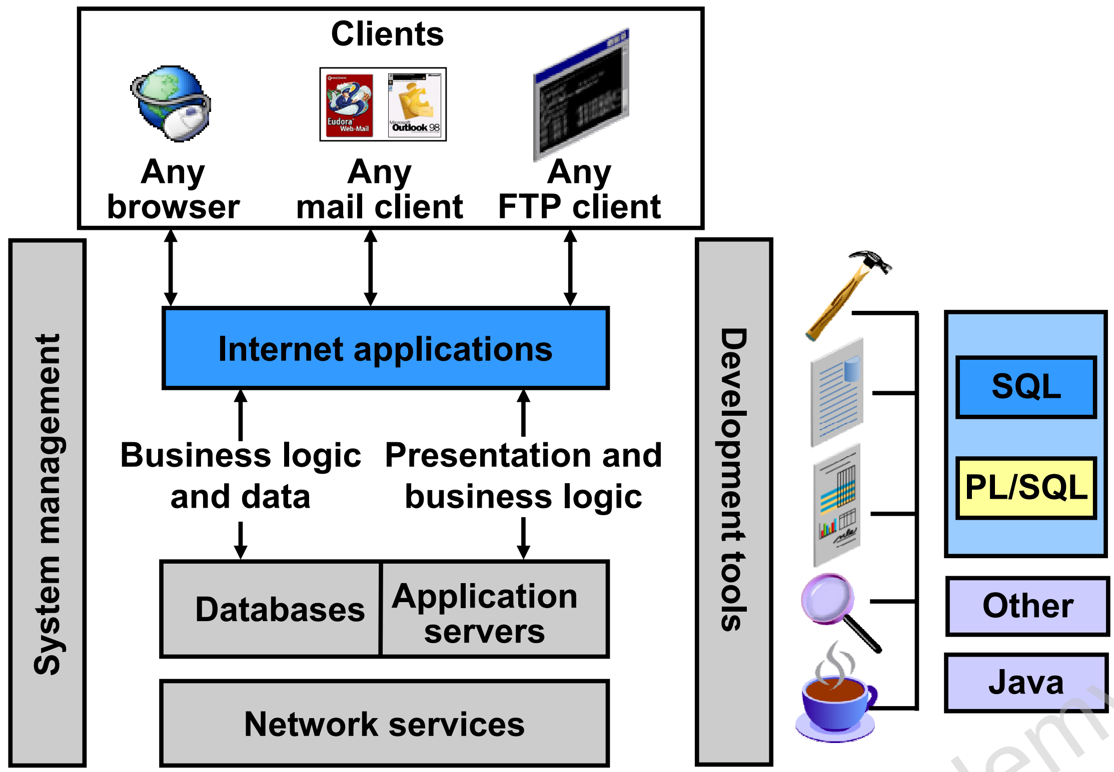
After completing this course, you should be able to do the following:

- Design PL/SQL packages and program units that execute efficiently
- Write code to interface with external applications and the operating system
- Create PL/SQL applications that use collections
- Write and tune PL/SQL code effectively to maximize performance
- Implement a virtual private database with fine-grained access control
- Write code to interface with large objects and use SecureFile LOBs
- Perform code analysis to find program ambiguities, test, trace, and profile PL/SQL code

Course Objectives

In this course, you learn how to use the advanced features of PL/SQL in order to design and tune PL/SQL to interface with the database and other applications in the most efficient manner. Using the advanced features of program design, packages, cursors, extended interface methods, and collections, you learn how to write powerful PL/SQL programs. Programming efficiency, use of external C and Java routines, and fine-grained access are covered in this course.

Oracle Complete Solution



Oracle Complete Solution

The Oracle Internet Platform is built on three core components:

- Browser-based clients to process presentation
- Application servers to execute business logic and serve presentation logic to browser-based clients
- Databases to execute database-intensive business logic and serve data

Oracle offers a wide variety of the most advanced graphical user interface (GUI)–driven development tools to build business applications, as well as a large suite of software applications for many areas of business and industry. Stored procedures, functions, and packages can be written by using SQL, PL/SQL, Java, C, and Net languages. This course concentrates on the advanced features of PL/SQL.

Lesson Agenda

- Previewing the course agenda
- Describing the development environments
- Using SQL Developer
- Using SQL*Plus
- Identifying the tables, data, and tools used in this course

Course Agenda

- Day 1
  - Lesson 1: Introduction
  - Lesson 2: PL/SQL Review
  - Lesson 3: Designing PL/SQL Code
  - Lesson 4: Working with Collections
- Day 2
  - Lesson 4: Working with Collections
  - Lesson 5: Using Advanced Interface Methods
  - Lesson 6: Implementing Fine-Grained Access Control for VPD
  - Lesson 7: Manipulating Large Objects
  - Lesson 8: Administering SecureFile LOBs
  - Lesson 9: Performance and Tuning

Agenda

In this three-day course, you start with a review of PL/SQL concepts before progressing into the new and advanced topics. By the end of day one, you should have covered design considerations for your program units, and how to use collections effectively.

On day two, you learn how to use advanced interface methods to call C and Java code from your PL/SQL programs, how to implement and test fine-grained access control for virtual private databases, how to manipulate large objects programmatically through PL/SQL, how to administer the features of the new SecureFile LOB format of Database 11*g*, and how to tune PL/SQL code and deal with memory issues.

Course Agenda

- Day 3
  - Lesson 10: Improving Performance with Caching
  - Lesson 11: Analyzing PL/SQL Code
  - Lesson 12: Profiling and Tracing PL/SQL Code
  - Lesson 13: Safeguarding Your Code Against SQL Injection Attacks

Agenda (continued)

On day three, you learn how to improve performance by using Oracle database 11*g* caching techniques, how to write PL/SQL routines that analyze PL/SQL applications, how to profile and trace PL/SQL code, and how to protect your code from SQL injection security attacks.

Lesson Agenda

- Previewing the course agenda
- Describing the development environments
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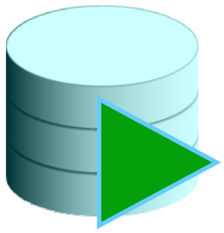
Development Environments: Overview

- Introduction to SQL Developer
- SQL*Plus



SQL Developer

PL/SQL Development Environments

Oracle provides several tools that can be used to write PL/SQL code. Some of the development tools that are available for use in this course are:

- **Oracle SQL Developer:** A graphical tool
- **Oracle SQL*Plus:** A command-line application

Note: The code and screen examples presented in the course notes were generated from the output in the SQL Developer environment.

Lesson Agenda

- Previewing the course agenda
- Describing the development environments
- Using SQL Developer
- Using SQL*Plus
- Identifying the tables, data, and tools used in this course

What Is Oracle SQL Developer?

- Oracle SQL Developer is a free graphical tool that enhances productivity and simplifies database development tasks.
- You can connect to any target Oracle database schema by using the standard Oracle database authentication.
- You can use either SQL Developer or SQL*Plus in this course.

What Is Oracle SQL Developer?

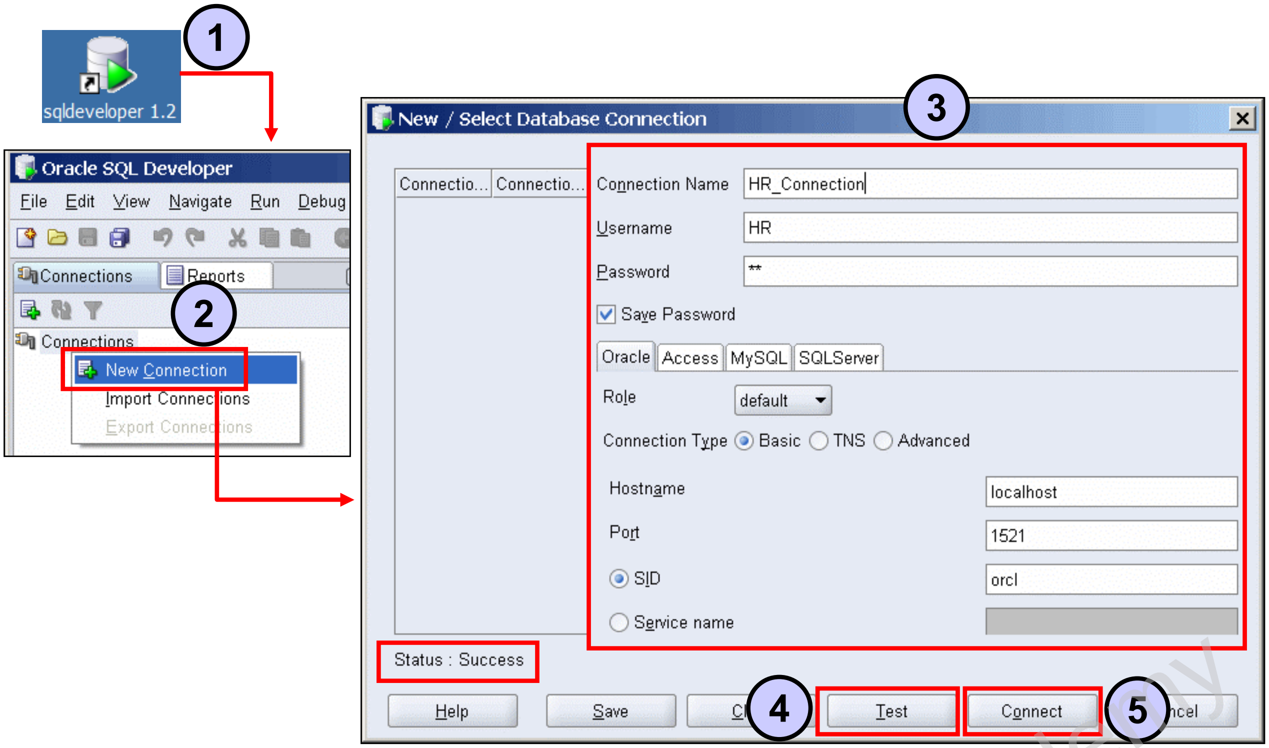
Oracle SQL Developer is a free graphical tool designed to improve your productivity and simplify the development of everyday database tasks. With just a few clicks, you can easily create and debug stored procedures, test SQL statements, and view optimizer plans.

SQL Developer, the visual tool for database development, simplifies the following tasks:

- Browsing and managing database objects
- Executing SQL statements and scripts
- Editing and debugging PL/SQL statements
- Creating reports

You can connect to any target Oracle database schema by using the standard Oracle database authentication. When connected, you can perform operations on the objects in the database.

Starting SQL Developer and Creating a Database Connection



Starting SQL Developer and Creating a Database Connection

To create a database connection, perform the following steps:

1. Double-click <your_path>\sqldeveloper\sqldeveloper.exe.
2. On the Connections tabbed page, right-click Connections and select **New Database Connection**.
3. Enter the connection name, username, password, host name, and SID for the database that you want to connect to.
4. Click Test to make sure that the connection is set correctly.
5. Click Connect.

On the basic tabbed page, at the bottom, enter the following options:

- **Hostname:** Host system for the Oracle database
- **Port:** Listener port
- **SID:** Database name
- **Service Name:** Network service name for a remote database connection

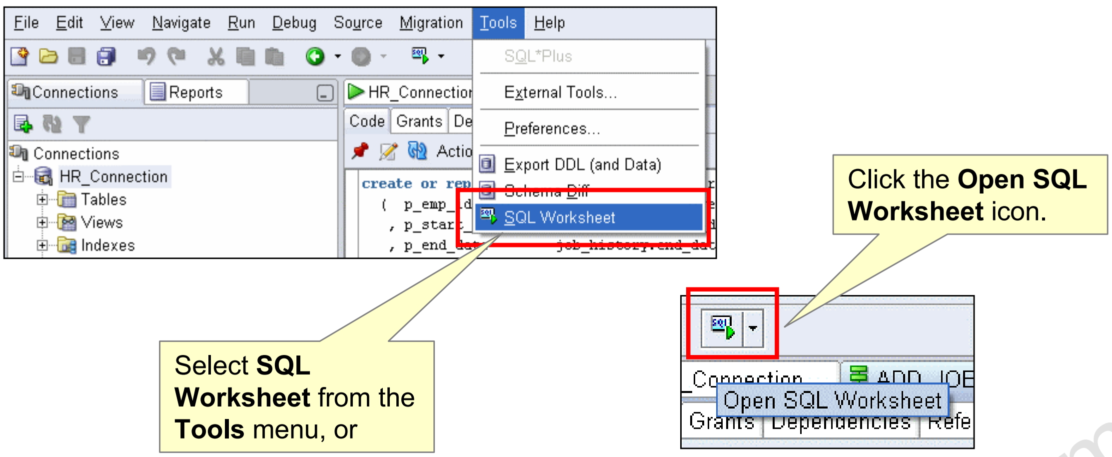
If you select the Save Password check box, the password is saved to an XML file. After you close the SQL Developer connection and open it again, you are not prompted for the password.

Creating Schema Objects

- You can create any schema object in SQL Developer by using one of the following methods:
  - Executing a SQL statement in the SQL worksheet
  - Using the context menu
- Edit the objects by using an edit dialog box or one of the many context-sensitive menus
- View the DDL for adjustments such as creating a new object or editing an existing schema object

Using the SQL Worksheet

- Use the SQL worksheet to enter and execute SQL, PL/SQL, and SQL*Plus statements.
- Specify any actions that can be processed by the database connection associated with the worksheet.



Using the SQL Worksheet

When you connect to a database, a SQL worksheet window for that connection automatically opens. This example uses the HR_Connection. However, you use the OE_Connection and SH_Connection later in this course.

You can use the SQL worksheet to enter and execute SQL, PL/SQL, and SQL*Plus statements. The SQL worksheet supports some SQL*Plus statements. However, SQL*Plus statements that are not supported by the SQL worksheet are ignored and not passed to the database.

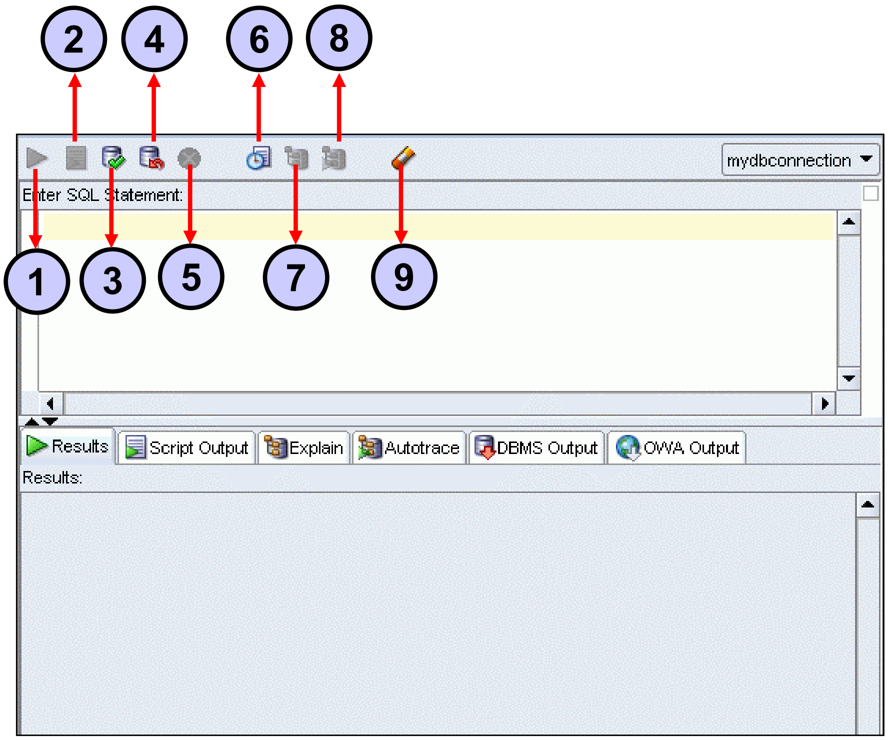
You can specify any actions that can be processed by the database connection associated with the worksheet, such as:

- Creating a table
- Inserting data
- Creating and editing a trigger
- Selecting data from a table
- Saving the selected data to a file

You can display a SQL worksheet by using one of the following options:

- Select **Tools > SQL Worksheet**.
- Click the **Open SQL Worksheet icon**.

Using the SQL Worksheet



Using the SQL Worksheet (continued)

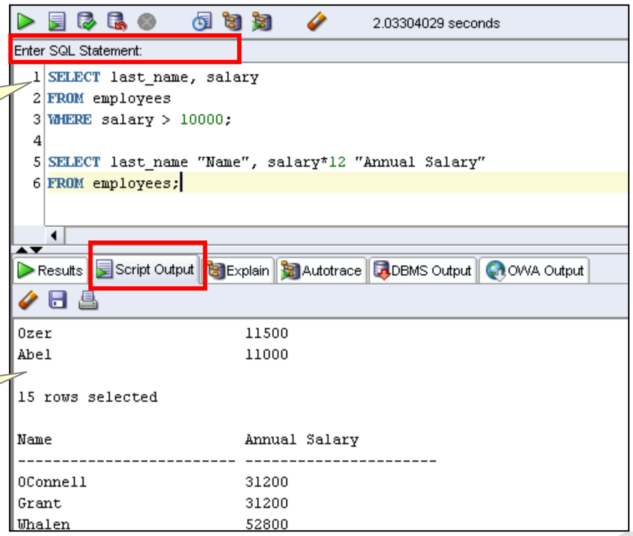
You may want to use the shortcut keys or icons to perform certain tasks, such as executing a SQL statement, running a script, or viewing the history of the SQL statements that you executed. You can use the SQL worksheet toolbar that contains icons to perform the following tasks:

1. **Execute Statement:** Executes the statement at the cursor in the Enter SQL Statement box. You can use bind variables in the SQL statements. You cannot use substitution variables.
2. **Run Script:** Executes all statements in the Enter SQL Statement box by using the Script. Runner. You can use substitution variables in the SQL statements. You cannot use bind variables.
3. **Commit:** Writes changes to the database and ends the transaction.
4. **Rollback:** Discards changes to the database without writing them to the database, and ends the transaction.
5. **Cancel:** Stops the execution of statements that are being executed.
6. **SQL History:** Displays a dialog box with information about the SQL statements that you executed.
7. **Execute Explain Plan:** Generates the execution plan, which you can see by clicking the Explain tab.
8. **Autotrace:** Generates trace information for the statement.
9. **Clear:** Erases the statement or statements in the Enter SQL Statement box.

Executing SQL Statements

Use the Enter SQL Statement box to enter single or multiple SQL statements.

Use the **Enter SQL Statement** box to enter single or multiple SQL statements.



View the results on the **Script Output** tabbed page.

Executing SQL Statements

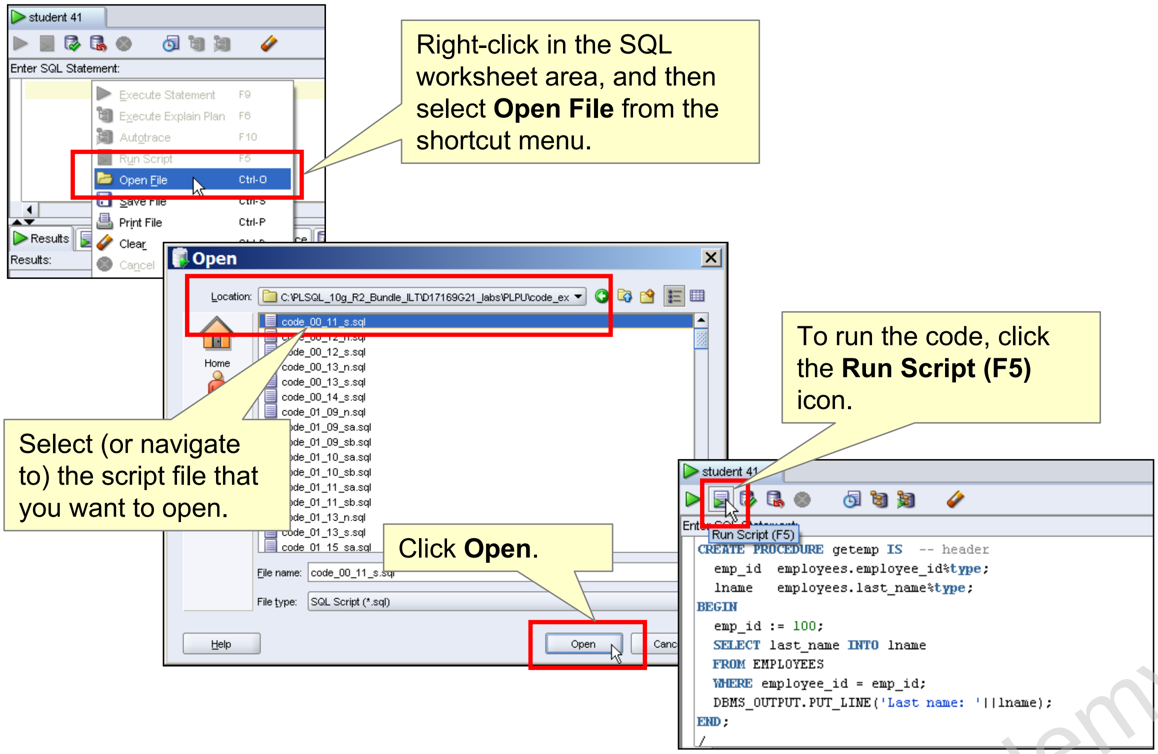
In the SQL worksheet, you can use the Enter SQL Statement box to enter a single statement or multiple SQL statements. For a single statement, the semicolon at the end is optional.

When you enter the statement, the SQL keywords are automatically highlighted. To execute a SQL statement, ensure that your cursor is within the statement and click the **Execute Statement** icon. Alternatively, you can press **F9**.

To execute multiple SQL statements and see the results, click the **Run Script** icon. Alternatively, you can press **F5**.

In the example in the slide, because there are multiple SQL statements, the first statement is terminated with a semicolon. The cursor is in the first statement, and therefore, when the statement is executed, results corresponding to the first statement are displayed in the Results box.

Executing Saved Script Files: Method 1



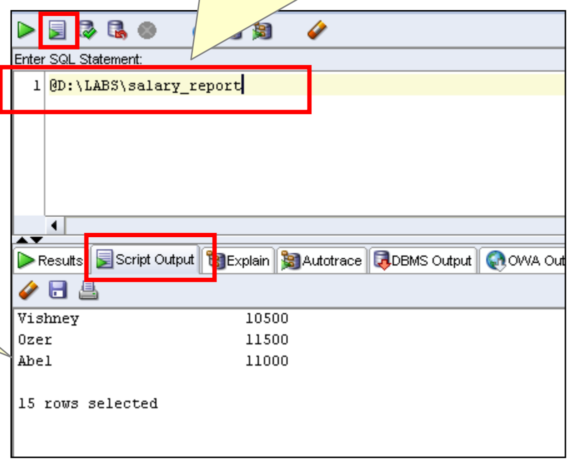
Executing Saved Script Files: Method 1

To open a script file and display the code in the SQL worksheet area, you can use one of the following methods:

1. Right-click in the SQL worksheet area, and then select **Open File** from the shortcut menu. The Open dialog box appears.
2. In the Open dialog box, select (or navigate to) the script file that you want to open.
3. Click Open. The code of the script file is displayed in the SQL worksheet area.
4. To run the code, click the **Run Script (F5)** icon on the SQL worksheet toolbar.

Executing Saved SQL Scripts: Method 2

Use the @ command followed by the location and name of the file that you want to execute, and then click the **Run Script** icon.



The output from the script is displayed on the Script Output tabbed page.

ORACLE

Executing Saved Script Files: Method 2

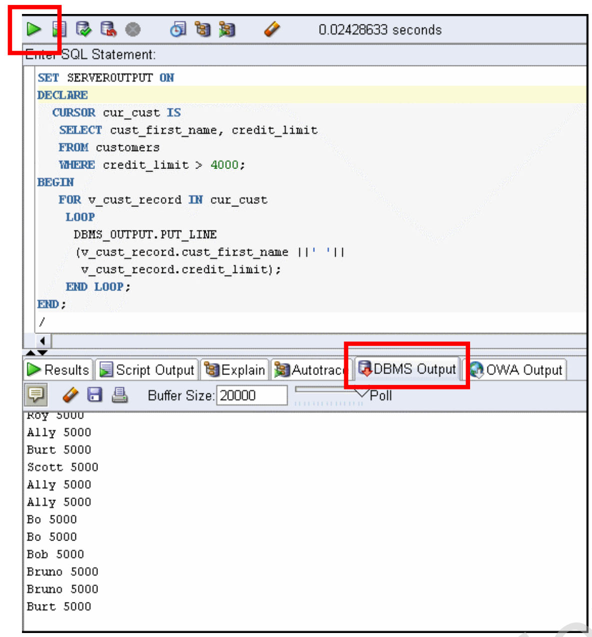
To run a saved SQL script, follow these steps:

1. In the Enter SQL Statement box, use the @ command followed by the location and name of the file that you want to run.
2. Click the **Run Script** icon.

The results from running the file are displayed on the Script Output tabbed page. You can also save the script output by clicking the Save icon on the Script Output tabbed page. The Windows File Save dialog box appears and you can identify a name and location for your file.

Creating an Anonymous Block

Create an anonymous block and display the output of the `DBMS_OUTPUT` package.



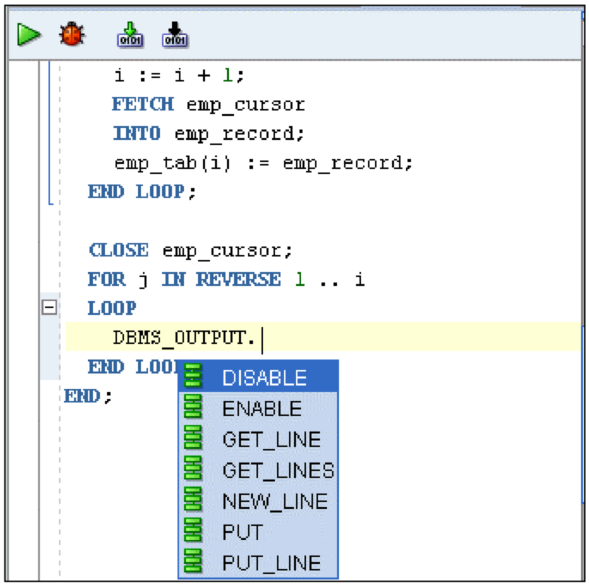
Creating an Anonymous Block

You can create an anonymous block (a unit of code without a name) and display the output of the `DBMS_OUTPUT` package. To create an anonymous block and view the results, perform the following steps:

1. Enter the PL/SQL code in the Enter SQL Statement box.
2. Click the **DBMS Output** tab. Click the **Enable DBMS Output** icon to set the server output ON.
3. Click the **Execute Statement** icon above the Enter SQL Statement box. Click the **DBMS Output** tab to see the results.

Editing the PL/SQL Code

Use the full-featured editor for PL/SQL program units.



Editing the PL/SQL Code

You may want to make changes to your PL/SQL code. SQL Developer includes a full-featured editor for PL/SQL program units. It includes customizable PL/SQL syntax highlighting in addition to common editor functions, such as:

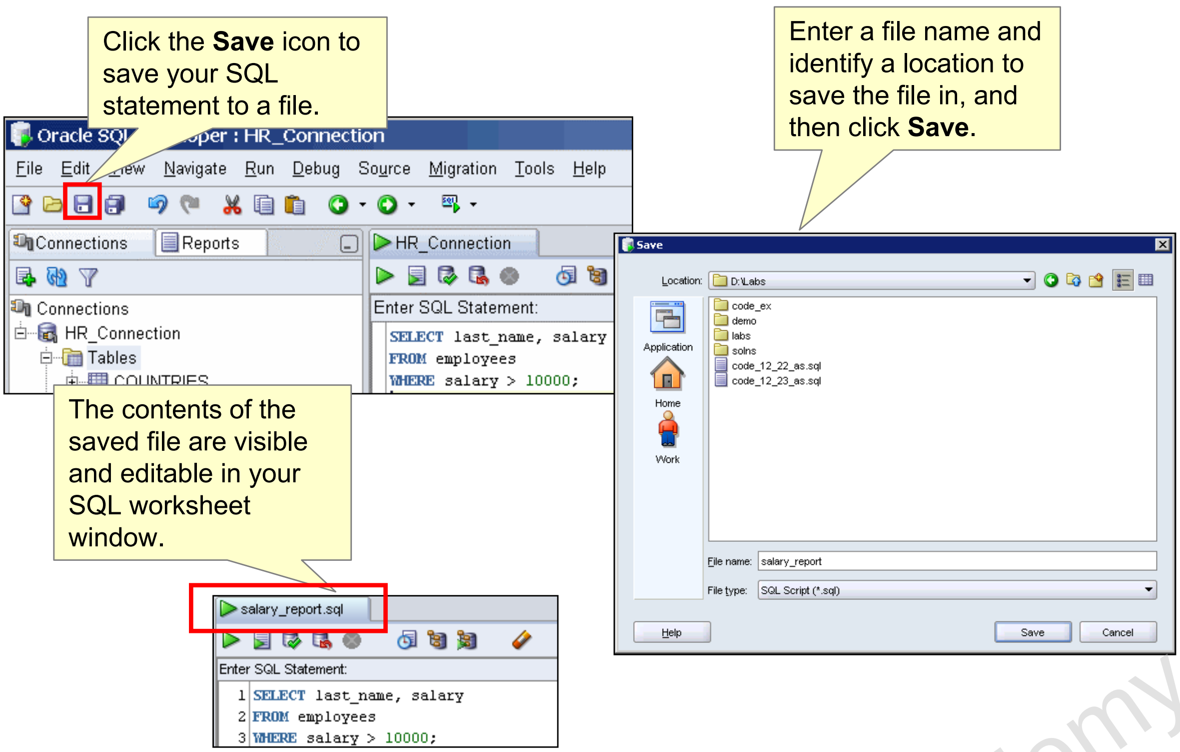
- Bookmarks
- Code Completion
- Code Folding
- Search and Replace

To edit the PL/SQL code, click the object name in the Connections Navigator, and then click the **Edit** icon. Optionally, double-click the object name to invoke the Object Definition page with its tabs and the Edit page. You can update only if you are on the Edit tabbed page.

The slide shows the Code Insight feature. For example, if you enter `DBMS_OUTPUT`, and then press Ctrl + Spacebar, you can select from a list of members of that package. Note that, by default, Code Insight is invoked automatically if you pause after entering a period (“.”) for more than one second.

When using the Code Editor to edit PL/SQL code, you can use Compile or Compile for Debug. Use the Compile for Debug option if you plan on using the SQL Developer Debugger. This option adds some debugging directives.

Saving SQL Scripts



Saving SQL Scripts

You can save your SQL statements from the SQL worksheet into a text file. To save the contents of the Enter SQL Statement box, perform the following steps:

1. Click the Save icon or use the **File > Save** menu option.
2. In the Windows Save dialog box, enter a file name and the location where you want to save the file.
3. Click Save.

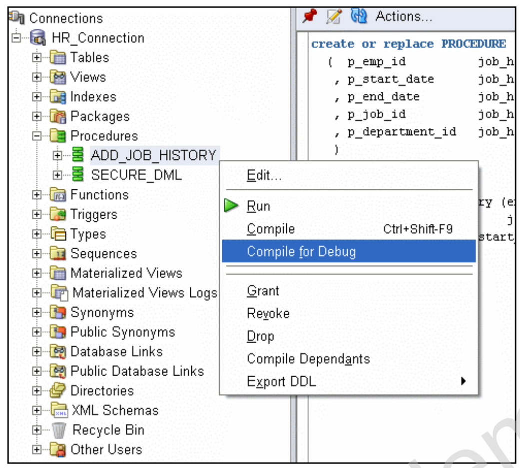
After you save the contents to a file, the Enter SQL Statement box displays a tabbed page of your file contents. You can have multiple files open simultaneously. Each file is displayed as a tabbed page.

Script Pathing

You can select a default path to look for scripts and to save scripts. Under **Tools > Preferences > Database > Worksheet Parameters**, enter a value in the **Select default path to look for scripts** field.

Debugging Procedures and Functions

- Use SQL Developer to debug PL/SQL functions and procedures.
- Use the Compile for Debug option to perform a PL/SQL compilation so that the procedure can be debugged.
- Use the Debug menu options to set breakpoints, and to perform step into and step over tasks.



Debugging Procedures and Functions

You can use the SQL Developer Debugger to debug PL/SQL procedures and functions. Using the Debug menu options, you can perform the following debugging tasks:

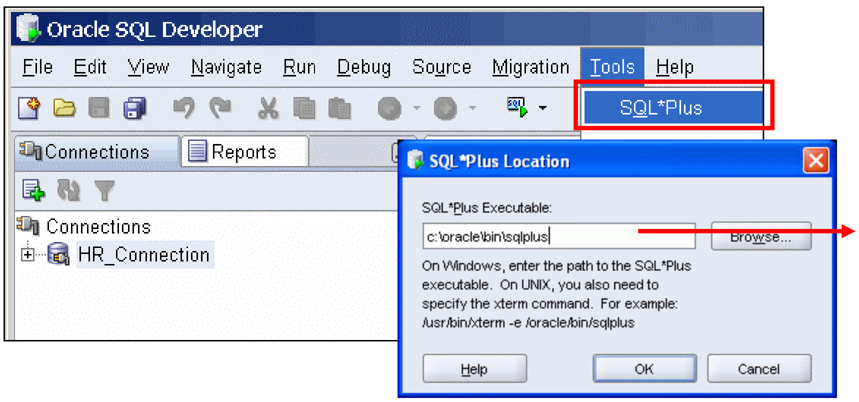
- **Find Execution Point** goes to the next execution point.
- **Resume** continues execution.
- **Step Over** bypasses the next method and goes to the next statement after the method.
- **Step Into** goes to the first statement in the next method.
- **Step Out** leaves the current method and goes to the next statement.
- **Step to End of Method** goes to the last statement of the current method.
- **Pause** halts execution but does not exit, thus allowing you to resume execution.
- **Terminate** halts and exits the execution. You cannot resume execution from this point; instead, to start running or debugging from the beginning of the function or procedure, click the Run or Debug icon on the Source tab toolbar.
- **Garbage Collection** removes invalid objects from the cache in favor of the more frequently accessed and more valid objects.

Lesson Agenda

- Previewing the course agenda
- Describing the development environments
- Using SQL Developer
- Using SQL*Plus
- Identifying the tables, data, and tools used in this course

Using SQL*Plus

- You can invoke the SQL*Plus command-line interface from SQL Developer.
- Close all SQL worksheets to enable the SQL*Plus menu option.



Provide the location of the `sqlplus.exe` file only for the first time you invoke SQL*Plus.

Using SQL*Plus

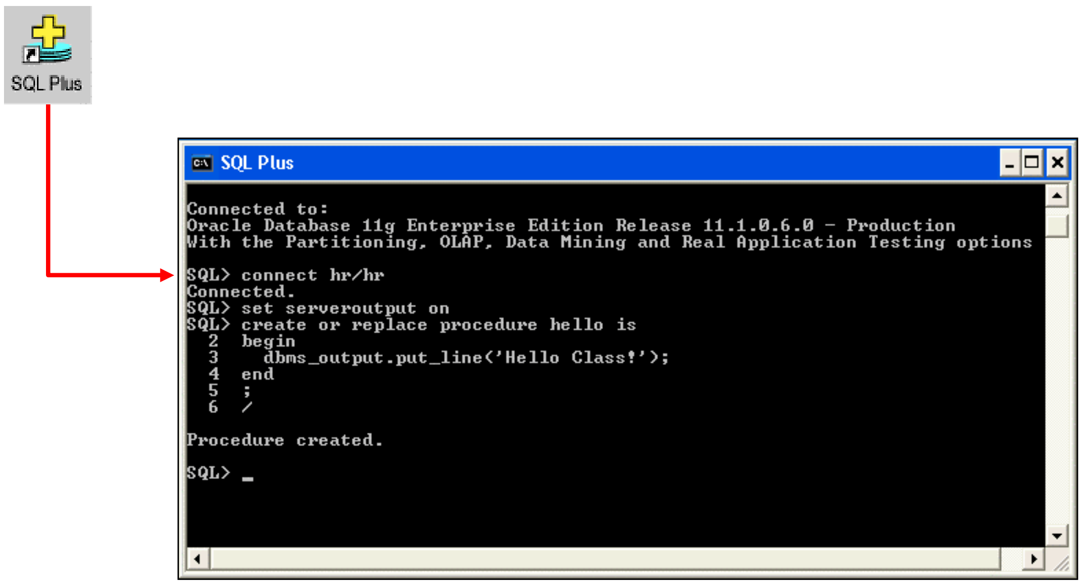
The SQL worksheet supports most of the SQL*Plus statements. SQL*Plus statements must be interpreted by the SQL worksheet before being passed to the database; any SQL*Plus statements that are not supported by the SQL worksheet are ignored and not passed to the database. To display the SQL*Plus command window, from the Tools menu, select **SQL*Plus**. To use the SQL*Plus command-line interface within SQL Developer, the system on which you are using SQL Developer must have an Oracle home directory or folder, with a SQL*Plus executable under that location. If the location of the SQL*Plus executable is not already stored in your SQL Developer preferences, you are asked to specify its location.

For example, some of the SQL*Plus statements that are not supported by SQL worksheet are:

- `append`
- `archive`
- `attribute`
- `break`

For a complete list of SQL*Plus statements that are either supported or not supported by the SQL worksheet, refer to the "SQL*Plus Statements Supported and Not Supported in SQL Worksheet" topic in the SQL Developer online Help.

Coding PL/SQL in SQL*Plus



Coding PL/SQL in SQL*Plus

You can also invoke Oracle SQL*Plus from the `sqlplus.exe` executable that is located in your Oracle home `//bin` directory. SQL*Plus is a command-line application that enables you to submit SQL statements and PL/SQL blocks for execution, and receive the results in an application or command window.

SQL*Plus is:

- Shipped with the database
- Installed on a client and on the database server system
- Accessed from an icon or the command line

When coding PL/SQL subprograms by using SQL*Plus, remember the following:

- You create subprograms by using the `CREATE` SQL statement.
- You execute subprograms by using either an anonymous PL/SQL block or the `EXECUTE` command.
- If you use the `DBMS_OUTPUT` package procedures to print text to the screen, you must first execute the `SET SERVEROUTPUT` ON command in your session.

Lesson Agenda

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Tables Used in This Course

- The sample schemas used are:
  - Order Entry (`OE`) schema
  - Human Resources (HR) schema
- Primarily, the `OE` schema is used.
- The `OE` schema user can read data in the `HR` schema tables.
- Appendix B contains more information about the sample schemas.

Tables Used in This Course

The sample company portrayed by Oracle Database Sample Schemas operates worldwide to fulfill orders for several different products. The company has several divisions:

- The Human Resources division tracks information about the employees and the facilities of the company.
- The Order Entry division tracks product inventories and sales of the company's products through various channels.
- The Sales History division tracks business statistics to facilitate business decisions. Although not used in this course, the SH schema is part of the "Example" sample schemas shipped with the database.

Each of these divisions is represented by a schema.

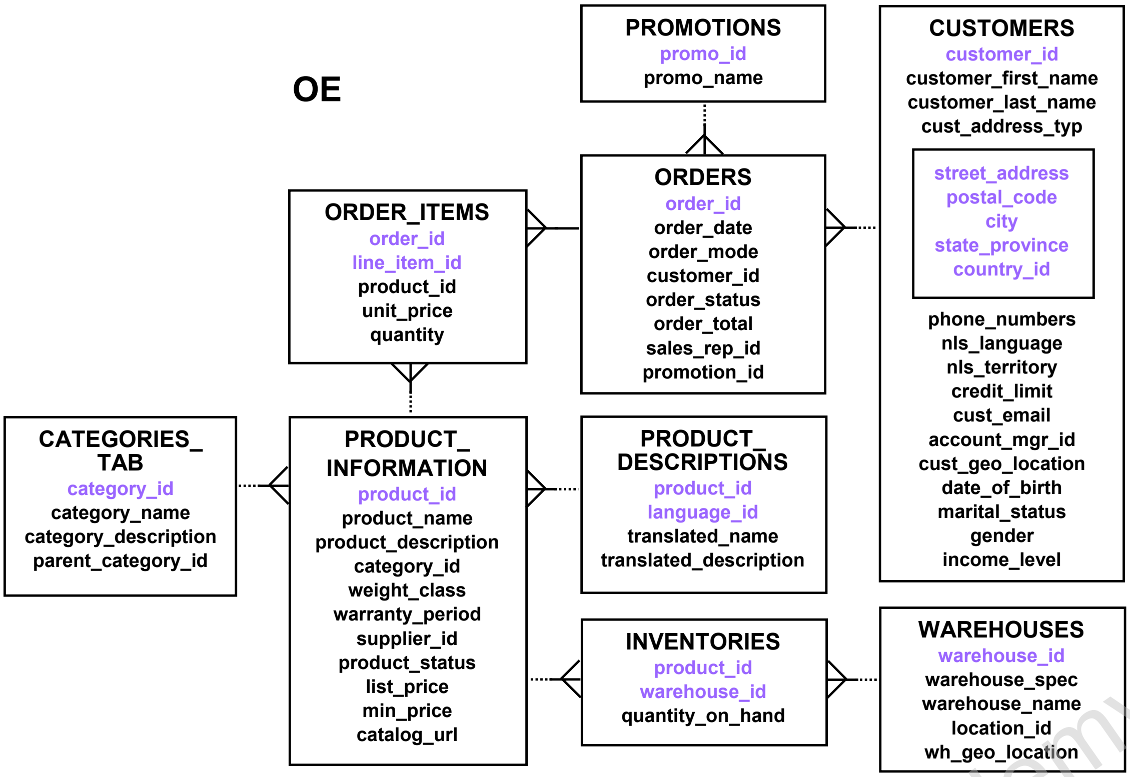
This course primarily uses the Order Entry (OE) sample schema.

Note: More details about the sample schema are found in Appendix B.

All scripts necessary to create the OE schema reside in the `$ORACLE_HOME/demo/schema/order_entry` folder.

All scripts necessary to create the HR schema reside in the `$ORACLE_HOME/demo/schema/human_resources` folder.

The Order Entry Schema



The Order Entry (OE) Schema

The company sells several categories of products, including computer hardware and software, music, clothing, and tools. The company maintains product information that includes product identification numbers, the category into which the product falls, the weight group (for shipping purposes), the warranty period if applicable, the supplier, the status of the product, a list price, a minimum price at which a product will be sold, and a URL address for manufacturer information.

Inventory information is also recorded for all products, including the warehouse where the product is available and the quantity on hand. Because products are sold worldwide, the company maintains the names of the products and their descriptions in several different languages.

The company maintains warehouses in several locations to facilitate filling customer orders. Each warehouse has a warehouse identification number, name, and location identification number.

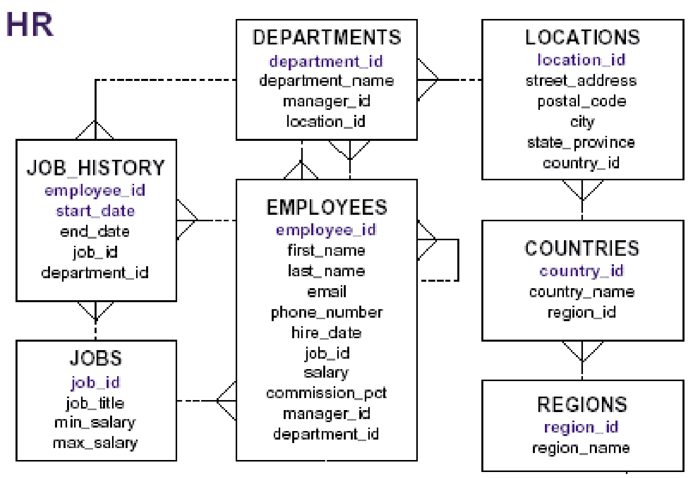
The Order Entry (OE) Schema (continued)

Customer information is tracked in some detail. Each customer is assigned an identification number. Customer records include name, street address, city or province, country, phone numbers (up to five phone numbers for each customer), and postal code. Some customers order through the Internet, so email addresses are also recorded. Because of language differences among customers, the company records the NLS language and territory of each customer. The company places a credit limit on its customers to limit the amount for which they can purchase at one time. Some customers have account managers, whom the company monitors. It keeps track of a customer's phone number. At present, you do not know how many phone numbers a customer might have, but you try to keep track of all of them. Because of the language differences among our customers, you also identify the language and territory of each customer.

When a customer places an order, the company tracks the date of the order, the mode of the order, status, shipping mode, total amount of the order, and the sales representative who helped place the order. This may be the same individual as the account manager for a customer, it may be someone else, or, in the case of an order over the Internet, the sales representative is not recorded. In addition to the order information, the company also tracks the number of items ordered, the unit price, and the products ordered.

For each country in which it does business, the company records the country name, currency symbol, currency name, and the region where the country resides geographically. This data is useful to interact with customers who are living in different geographic regions of the world.

The Human Resources Schema



The Human Resources (HR) Schema

In the human resources records, each employee has an identification number, email address, job identification code, salary, and manager. Some employees earn a commission in addition to their salary.

The company also tracks information about the jobs within the organization. Each job has an identification code, job title, and a minimum and maximum salary range for the job. Some employees have been with the company for a long time and have held different positions within the company. When an employee switches jobs, the company records the start date and end date of the former job, the job identification number, and the department.

The sample company is regionally diverse, so it tracks the locations of not only its warehouses but also its departments. Each company employee is assigned to a department. Each department is identified by a unique department number and a short name. Each department is associated with one location. Each location has a full address that includes the street address, postal code, city, state or province, and country code.

For each location where it has facilities, the company records the country name, currency symbol, currency name, and the region where the country resides geographically.

Note: For more information about the "Example" sample schemas, refer to Appendix B.

Summary

In this lesson, you should have learned how to:

- Describe the goals of the course
- Identify the environments that can be used in this course
- Describe the database schema and tables that are used in the course
- List the available documentation and resources

Summary

In this lesson, you were introduced to the goals of the course, the SQL Developer and SQL*Plus environments used in the course, and the database schema and tables used in the lectures and lab practices.

Practice 1 Overview: Getting Started

This practice covers the following topics:

- Reviewing the available SQL Developer resources
- Starting SQL Developer and creating new database connections and browsing the `HR`, `OE`, and `SH` tables
- Setting some SQL Developer preferences
- Executing SQL statements and an anonymous PL/SQL block by using SQL worksheet
- Accessing and bookmarking the Oracle Database 11*g* documentation and other useful Web sites

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Practice 1: Overview

In this practice, you use SQL Developer to execute SQL statements for examining the data in the "Example" sample schemas: `HR`, `OE`, and `SH`. You also create a simple anonymous block. Optionally, you can experiment by creating and executing the PL/SQL code in SQL*Plus.

Note: All written practices use SQL Developer as the development environment. Although it is recommended that you use SQL Developer, you can also use the SQL*Plus environment that is available in this course.

Practice 1

This is the first of many practices in this course. The solutions (if you require them) can be found in Appendix A. Practices are intended to cover most of the topics presented in the corresponding lesson.

In this practice, you review the available SQL Developer resources. You also learn about the user account that you use in this course. You start SQL Developer, create a new database connection, and browse your `SH`, `HR`, and `OE` tables. You also set some SQL Developer preferences, execute SQL statements, access and bookmark the Oracle Database 11*g* documentation and other useful Web sites that you can use in this course.

Identifying the Available SQL Developer Resources

1. Familiarize yourself with Oracle SQL Developer as needed by referring to Appendix C: Using SQL Developer.
2. Access the SQL Developer Home page that is available online at:
   http://www.oracle.com/technology/products/database/sql_developer/index.html
3. Bookmark the page for easier future access.
4. Access the SQL Developer tutorial that is available online at:
   http://st-curriculum.oracle.com/tutorial/SQLDeveloper/index.htm
5. Preview and experiment with the available links and demonstrations in the tutorial as needed, especially the Creating a Database Connection and Accessing Data links.

Creating and Using the New SQL Developer Database Connections

6. Start SQL Developer.
7. Create a database connection to `SH` using the following information:
   a. Connection Name: `sh_connection`
   b. Username: `sh`
   c. Password: `sh`
   d. Hostname: `localhost`
   e. Port: `1521`
   f. SID: `orcl`
8. Test the new connection. If the Status is Success, connect to the database using this new connection.
   a. Double-click the `sh_connection` icon on the Connections tabbed page.
   b. Click the Test button in the New/Select Database Connection window. If the status is Success, click the Connect button.
9. Create a new database connection named `hr_connection`.
   a. Right-click the `sh_connection` connection in the Object Navigation tree, and select the Properties menu option.
   b. Enter `hr_connection` as the connection name and `hr` as the username and password, and click Save. This creates the new connection.
   c. Repeat step 8 to test the new `hr_connection` connection.

Practice 1 (continued)

10. Repeat step 9 to create and test a new database connection named `oe_connection`. Enter `oe` as the database connection username and password.
11. Repeat step 9 to create and test a new database connection named `sys_connection`. Enter `sys` as the database connection username, `oracle` as the password, and `SYSDBA` as the role.

Browsing the `HR`, `SH`, and `OE` Schema Tables

12. Browse the structure of the `EMPLOYEES` table.
    a. Expand the `hr_connection` connection by clicking the plus symbol next to it.
    b. Expand the Tables icon by clicking the plus symbol next to it.
    c. Display the structure of the `EMPLOYEES` table.
13. Browse the `EMPLOYEES` table and display its data.
14. Use the SQL worksheet to select the last names and salaries of all employees whose annual income is greater than $10,000. Use both the Execute Statement (F9) and the Run Script (F5) icons to execute the `SELECT` statement. Review the results of both methods of executing the `SELECT` statements on the appropriate tabs.

    Note: Take a few minutes to familiarize yourself with the data, or consult "Appendix B, Table Descriptions," which provides the description and data for all tables in the `HR`, `SH`, and `OE` schemas that you will use in this course.
15. Create and execute a simple anonymous block that outputs "Hello World."
    a. Enable `SET SERVEROUTPUT ON` to display the output of the `DBMS_OUTPUT` package statements.
    b. Use the SQL worksheet area to enter the code for your anonymous block.
    c. Click the Run Script icon (F5) to run the anonymous block.
16. Browse the structure of the `SALES` table in the `SH Schema` connection and display its data.
    a. Double-click the `sh_connection` connection.
    b. Expand the Tables icon by clicking the plus symbol next to it.
    c. Display the structure of the `SALES` table.
    d. Browse the `SALES` table and display its data.
17. Browse the structure of the `ORDERS` table in the `OE Schema` and display its data.
    a. Double-click the `oe_connection` connection.
    b. Expand the Tables icon by clicking the plus symbol next to it.
    c. Display the structure of the `ORDERS` table.
    d. Browse the `ORDERS` table and display its data.

Accessing the Oracle Database 11*g* Release 1 Online Documentation Library

18. Access the Oracle Database 11*g* Release documentation Web page at: http://www.oracle.com/pls/db111/homepage
19. Bookmark the page for easier future access.
20. Display the complete list of books available for Oracle Database 11*g*, Release 1.

Practice 1 (continued)

Accessing the Oracle Database 11*g* Release 1 Online Documentation Library (continued)

21. Make a note of the following documentation references that you will use in this course as needed:
    a. *Advanced Application Developer's Guide*
    b. *New Features Guide*
    c. *PL/SQL Language Reference*
    d. *Oracle Database Reference*
    e. *Oracle Database Concepts*
    f. *SQL Developer User's Guide*
    g. *SQL Language Reference Guide*
    h. *SQL*Plus User's Guide and Reference*

2

PL/SQL Programming Concepts: Review

Objectives

After completing this lesson, you should be able to do the following:

- Describe PL/SQL basics
- List restrictions on calling functions from SQL expressions
- Identify how explicit cursors are processed
- Handle exceptions
- Use the `raise_application_error` procedure
- Manage dependencies
- Use Oracle-supplied packages

Objectives

PL/SQL supports various programming constructs. This lesson reviews the basic concept of PL/SQL programming. This lesson also reviews how to:

- Create subprograms
- Use cursors
- Handle exceptions
- Identify predefined Oracle server errors
- Manage dependencies

A quiz at the end of the lesson will assess your knowledge of PL/SQL.

Note: The quiz is optional. Solutions to the quiz are provided in Appendix A.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
- Reviewing PL/SQL packages
- Identifying how explicit cursors are processed
- Handling exceptions
- Using the `raise_application_error` procedure
- Managing dependencies
- Using Oracle-supplied packages

PL/SQL Block Structure

```
DECLARE
•••
BEGIN
•••
EXCEPTION
•••
END;
```

Anonymous PL/SQL block

```
<header>
IS|AS
•••
BEGIN
•••
EXCEPTION
•••
END;
```

Stored program unit

PL/SQL Block Structure

An anonymous PL/SQL block structure consists of an optional `DECLARE` section, a mandatory `BEGIN-END` block, and an optional `EXCEPTION` section before the `END` statement of the main block.

A stored program unit has a mandatory header section. This section defines whether the program unit is a function, procedure, or a package, and contains the optional argument list and their modes. A stored program unit also has the other sections mentioned for the anonymous PL/SQL block. However, a stored program unit does not have an optional `DECLARE` section, but it does contain an `IS | AS` section that is mandatory and acts the same as the `DECLARE` section in an anonymous block.

Every PL/SQL construct is made from one or more blocks. These blocks can be entirely separate or nested within one another. Therefore, one block can represent a small part of another block, which in turn can be part of the whole unit of code.

Naming Conventions

Advantages of proper naming conventions:
- Easier to read
- Understandable
- Gives information about the functionality
- Easier to debug
- Ensures consistency
- Can improve performance

Naming Conventions

A proper naming convention makes the code easier to read and more understandable. It helps you understand the functionality of the identifier. If the code is written using proper naming conventions, you can easily find an error and rectify it. Most importantly, it ensures consistency among the code written by different developers.

The following table shows the naming conventions followed in this course:

Identifier	**Convention**	**Example**
Variable	`v_prefix`	`v_product_name`
Constant	`c_prefix`	`c_tax`
Parameter	`p_prefix`	`p_cust_id`
Exception	`e_prefix`	`e_check_credit_limit`
Cursor	`cur_prefix`	`cur_orders`
Type	`typ_prefix`	`typ_customer`

Procedures

A procedure is:

- A named PL/SQL block that performs a sequence of actions and optionally returns a value or values
- Stored in the database as a schema object
- Used to promote reusability and maintainability

```
CREATE [OR REPLACE] PROCEDURE procedure_name
 [(parameter1 [mode] datatype1,
   parameter2 [mode] datatype2, ...)]
IS|AS
  [local_variable_declarations; …]
BEGIN
  -- actions;
END [procedure_name];
```


Procedures

A procedure is a named PL/SQL block that can accept parameters (sometimes referred to as *arguments*). Generally, you use a procedure to perform an action. A procedure is compiled and stored in the database as a schema object. Procedures promote reusability and maintainability.

Parameters are used to transfer data values to and from the calling environment and the procedure (or subprogram). Parameters are declared in the subprogram header, after the name and before the declaration section for local variables.

Parameters are subject to one of the three parameter-passing modes: `IN`, `OUT`, or `IN OUT`.

- An `IN` parameter passes a constant value from the calling environment into the procedure.
- An `OUT` parameter passes a value from the procedure to the calling environment.
- An `IN OUT` parameter passes a value from the calling environment to the procedure and a possibly different value from the procedure back to the calling environment using the same parameter.

Procedure: Example

```
CREATE OR REPLACE PROCEDURE get_avg_order
(p_cust_id NUMBER, p_cust_last_name VARCHAR2,
p_order_tot NUMBER)
IS
   v_cust_ID customers.customer_id%type;
   v_cust_name customers.cust_last_name%type;
   v_avg_order NUMBER;
BEGIN
SELECT customers.customer_id, customers.cust_last_name,
AVG(orders.order_total)
INTO v_cust_id, v_cust_name, v_avg_order
FROM CUSTOMERS, ORDERS
WHERE customers.customer_id=orders.customer_id
GROUP BY customers.customer_id, customers.cust_last_name;
END;
/
```


Procedure: Example

This reusable procedure has a parameter with a `SELECT` statement for getting average order totals for whatever customer value is passed in.

Note: If a developer drops a procedure, and then re-creates it, all applicable grants to execute the procedure are gone. Alternatively, the `OR REPLACE` command removes the old procedure and re-creates it but leaves all the grants against the said procedure in place. Thus, the `OR REPLACE` command is recommended wherever there is an existing procedure, function, or package; not merely for convenience, but also to protect granted privileges. If you grant object privileges, these privileges remain after you re-create the subprogram with the `OR REPLACE` option; otherwise, the privileges are not preserved.

Functions

A function is:
- A named block that must return a value
- Stored in the database as a schema object
- Called as part of an expression or used to provide a parameter value

```
CREATE [OR REPLACE] FUNCTION function_name
 [(parameter1 [mode1] datatype1, ...)]
RETURN datatype IS|AS
 [local_variable_declarations; …]
BEGIN
  -- actions;
  RETURN expression;
END [function_name];
```


Functions

A function is a named PL/SQL block that can accept parameters, be invoked, and return a value. In general, you use a function to compute a value. Functions and procedures are structured alike. A function must return a value to the calling environment, whereas a procedure returns zero or more values to its calling environment. Like a procedure, a function has a header, a declarative section, an executable section, and an optional exception-handling section. A function must have a `RETURN` clause in the header and at least one `RETURN` statement in the executable section, and must return a value in each exception handler to avoid the “ORA-06503: PL/SQL: Function returned without value” error.

Functions can be stored in the database as schema objects for repeated execution. A function that is stored in the database is referred to as a *stored function*. Functions can also be created on client-side applications.

Functions promote reusability and maintainability. When validated, they can be used in any number of applications. If the processing requirements change, only the function needs to be updated.

A function may also be called as part of a SQL expression or as part of a PL/SQL expression. In the context of a SQL expression, a function must obey specific rules to control side effects. In a PL/SQL expression, the function identifier acts like a variable whose value depends on the parameters passed to it.

Function: Example

- Create the function:

```
CREATE OR REPLACE FUNCTION get_credit
 (v_id customers.customer_id%TYPE) RETURN NUMBER IS
  v_credit customers.credit_limit%TYPE := 0;
BEGIN
  SELECT credit_limit
  INTO   v_credit
  FROM   customers
  WHERE  customer_id = v_id;
  RETURN (v_credit);
END get_credit;
/
```

- Invoke the function as an expression or as a parameter value:

```
EXECUTE dbms_output.put_line(get_credit(101))
```


Function: Example

The `get_credit` function is created with a single input parameter and returns the credit limit as a number, as shown in the first code box in the slide. The `get_credit` function follows the common programming practice of assigning a returning value to a local variable and uses a single `RETURN` statement in the executable section of the code to return the value stored in the local variable. If your function has an exception section, it may also contain a `RETURN` statement.

Invoke a function as part of a PL/SQL expression, because the function returns a value to the calling environment. The second code box uses the SQL*Plus `EXECUTE` command to call the `DBMS_OUTPUT.PUT_LINE` procedure whose argument is the return value from the `get_credit` function. In this case, `DBMS_OUTPUT.PUT_LINE` is invoked first; it calls `get_credit` to calculate the credit limit of the customer with ID 101. The `credit_limit` value returned is supplied as the value of the `DBMS_OUTPUT.PUT_LINE` parameter, which then displays the result (if you have executed `SET SERVEROUTPUT ON`).

Note: The `%TYPE` attribute casts the data type to the type defined for the column in the table identified. You can use the `%TYPE` attribute as a data type specifier when declaring constants, variables, fields, and parameters.

A function must always return a value. The example does not return a value if a row is not found for a given ID. Ideally, create an exception handler to return a value as well.

Ways to Execute Functions

- Invoke as part of a PL/SQL expression
  - Using a host variable to obtain the result:

```
VARIABLE v_credit NUMBER
EXECUTE :v_credit := get_credit(101)
```

  - Using a local variable to obtain the result:

```
DECLARE v_credit customers.credit_limit%type;
BEGIN
  v_credit := get_credit(101); ...
END;
```

- Use as a parameter to another subprogram

```
EXECUTE dbms_output.put_line(get_credit(101))
```

- Use in a SQL statement (subject to restrictions)

```
SELECT get_credit(customer_id) FROM customers;
```

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Ways to Execute Functions

If functions are designed thoughtfully, they can be powerful constructs. Functions can be invoked in the following ways:

- **As part of PL/SQL expressions:** You can use host or local variables to hold the returned value from a function. The first example in the slide uses a host variable and the second example uses a local variable in an anonymous block.
- **As a parameter to another subprogram:** The third example in the slide demonstrates this usage. The `get_credit` function, with all its arguments, is nested in the parameter required by the `DBMS_OUTPUT.PUT_LINE` procedure. This comes from the concept of nesting functions, as discussed in the *Oracle Database 10g: SQL Fundamentals I* course.
- **As an expression in a SQL statement:** The last example shows how a function can be used as a single-row function in a SQL statement.

Note: The restrictions and guidelines that apply to functions when used in a SQL statement are discussed in the next few pages.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
- Reviewing PL/SQL packages
- Identifying how explicit cursors are processed
- Handling exceptions
- Using the `raise_application_error` procedure
- Managing dependencies
- Using Oracle-supplied packages

Restrictions on Calling Functions from SQL Expressions

- User-defined functions that are callable from SQL expressions must:
  - Be stored in the database
  - Accept only `IN` parameters with valid SQL data types, not PL/SQL-specific types
  - Return valid SQL data types, not PL/SQL-specific types
- When calling functions in SQL statements:
  - Parameters must be specified with positional notation
  - You must own the function or have the `EXECUTE` privilege

Restrictions on Calling Functions from SQL Expressions

The user-defined PL/SQL functions that are callable from SQL expressions must meet the following requirements:

- The function must be stored in the database.
- The function parameters must be input parameters and should be valid SQL data types.
- The functions must return data types that are valid SQL data types. They cannot be PL/SQL-specific data types such as `BOOLEAN`, `RECORD`, or `TABLE`. The same restriction applies to the parameters of the function.

The following restrictions apply when calling a function in a SQL statement:

- Parameters must use positional notation. Named notation is not supported.
- You must own or have the `EXECUTE` privilege on the function.

Other restrictions on a user-defined function include the following:

- It cannot be called from the `CHECK` constraint clause of a `CREATE TABLE` or `ALTER TABLE` statement.
- It cannot be used to specify a default value for a column.

Note: Only stored functions are callable from SQL statements. Stored procedures cannot be called unless invoked from a function that meets the preceding requirements.

Restrictions on Calling Functions from SQL Expressions

Functions called from:

- A `SELECT` statement cannot contain DML statements
- An `UPDATE` or `DELETE` statement on a table `T` cannot query or contain DML on the same table `T`
- SQL statements cannot end transactions (that is, cannot execute `COMMIT` or `ROLLBACK` operations)

Note: Calls to subprograms that break these restrictions are also not allowed in the function.

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Restrictions on Calling Functions from SQL Expressions (continued)

To execute a SQL statement that calls a stored function, the Oracle server must know whether the function is free of specific side effects. Side effects are unacceptable changes to database tables.

Additional restrictions also apply when a function is called in expressions of SQL statements. In particular, when a function is called from:

- A `SELECT` statement or a parallel `UPDATE` or `DELETE` statement, the function cannot modify a database table, unless the modification occurs in an autonomous transaction
- An `INSERT... SELECT` (but not an `INSERT... VALUES`), an `UPDATE`, or a `DELETE` statement, the function cannot query or modify a database table that was modified by that statement
- A `SELECT`, `INSERT`, `UPDATE`, or `DELETE` statement, the function cannot execute directly or indirectly through another subprogram or through a SQL transaction control statement such as:
  - A `COMMIT` or `ROLLBACK` statement
  - A session control statement (such as `SET ROLE`)
  - A system control statement (such as `ALTER SYSTEM`)
  - Any data definition language (DDL) statements (such as `CREATE`), because they are followed by an automatic commit

Note: The function *can* execute a transaction control statement if the transaction being controlled is autonomous.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
- Reviewing PL/SQL packages
- Identifying how explicit cursors are processed
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- Using the `raise_application_error` procedure
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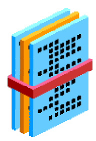
- Using Oracle-supplied packages

PL/SQL Packages: Review

PL/SQL packages:

- Group logically related components:
  – PL/SQL types
  – Variables, data structures, and exceptions
  – Subprograms: procedures and functions
- Consist of two parts:
  – A specification
  – A body



- Enable the Oracle server to read multiple objects into memory simultaneously

PL/SQL Packages: Review

PL/SQL packages enable you to bundle related PL/SQL types, variables, data structures, exceptions, and subprograms into one container. For example, an Order Entry package can contain procedures for adding and deleting customers and orders, functions for calculating annual sales, and credit limit variables.

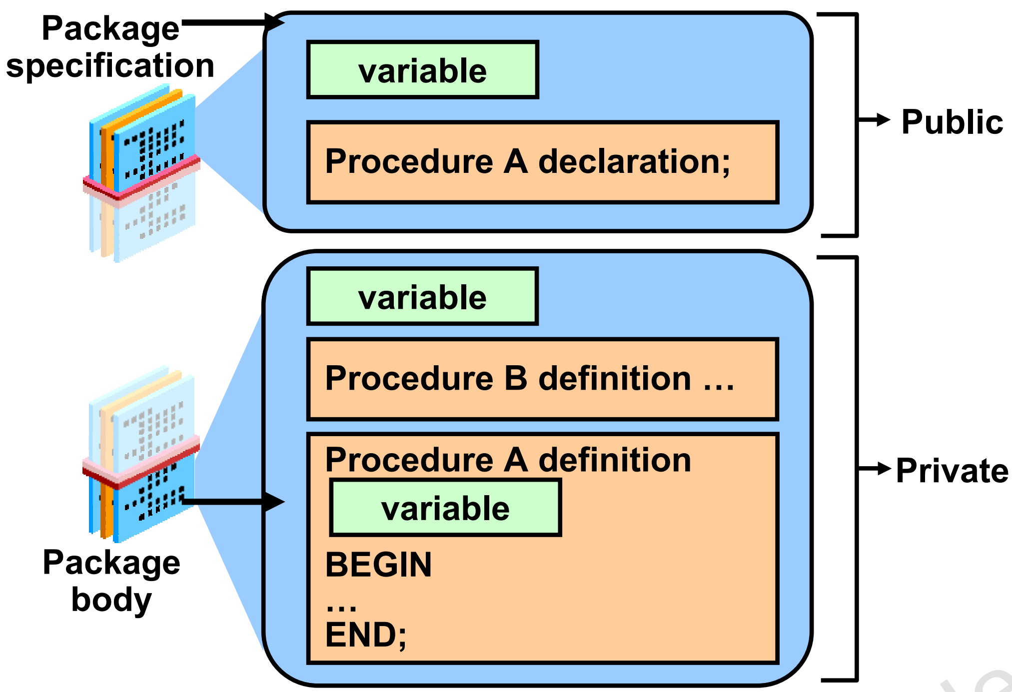
A package usually consists of two parts that are stored separately in the database:

- A specification
- A body (optional)

The package itself cannot be called, parameterized, or nested. After writing and compiling, the contents can be shared with many applications.

When a PL/SQL-packaged construct is referenced for the first time, the whole package is loaded into memory. However, subsequent access to constructs in the same package does not require disk I/O.

Components of a PL/SQL Package



Components of a PL/SQL Package

You create a package in two parts:

- The *package specification* is the interface to your applications. It declares the public types, variables, constants, exceptions, cursors, and subprograms that are available for use. The package specification may also include pragmas, which are directives to the compiler.
- The *package body* defines its own subprograms and must fully implement the subprograms that are declared in the specification part. The package body may also define PL/SQL constructs, such as object types, variables, constants, exceptions, and cursors.

Public components are declared in the package specification. The specification defines a public API for users of the package features and functionality. That is, public components can be referenced from any Oracle server environment that is external to the package.

Private components are placed in the package body but not referenced in the specification and can be referenced only by other constructs within the same package body. Alternatively, private components can reference the public components of the package.

Note: If a package specification does not contain subprogram declarations, there is no requirement for a package body.

Creating the Package Specification

Syntax:

```
CREATE [OR REPLACE] PACKAGE package_name IS|AS
    public type and variable declarations
    subprogram specifications
END [package_name];
```

- The `OR REPLACE` option drops and re-creates the package specification.
- Variables declared in the package specification are initialized to `NULL` by default.
- All constructs declared in a package specification are visible to users who are granted privileges on the package.

Creating the Package Specification

- To create packages, you declare all public constructs within the package specification.
  - Specify the `OR REPLACE` option if overwriting an existing package specification.
  - Initialize a variable with a constant value or formula within the declaration, if required; otherwise, the variable is initialized implicitly to `NULL`.
- The following are the definitions of items in the package syntax:
  - ***package_name*** specifies a name for the package that must be unique among objects within the owning schema. Including the package name after the `END` keyword is optional.
  - ***public type and variable declarations*** declares public variables, constants, cursors, exceptions, user-defined types, and subtypes.
  - ***subprogram specifications*** specifies the public procedure or function declarations.

Note: The package specification should contain procedure and function signatures terminated by a semicolon. The signature is every thing above `IS|AS` keywords. The implementation of a procedure or function that is declared in a package specification is done in the package body.

Creating the Package Body

Syntax:

```
CREATE [OR REPLACE] PACKAGE BODY package_name IS|AS
    private type and variable declarations
    subprogram bodies
[BEGIN initialization statements]
END [package_name];
```

- The `OR REPLACE` option drops and re-creates the package body.
- Identifiers defined in the package body are private and not visible outside the package body.
- All private constructs must be declared before they are referenced.
- Public constructs are visible to the package body.

Creating the Package Body

Create a package body to define and implement all public subprograms and the supporting private constructs. When creating a package body, perform the following:

- Specify the `OR REPLACE` option to overwrite a package body.
- Define the subprograms in an appropriate order. The basic principle is that you must declare a variable or subprogram before it can be referenced by other components in the same package body. It is common to see all private variables and subprograms defined first and the public subprograms defined last in the package body.
- The package body must complete the implementation for all procedures or functions declared in the package specification.

The following are the definitions of items in the package body syntax:

- ***package_name*** specifies a name for the package that must be the same as its package specification. Using the package name after the `END` keyword is optional.
- ***private type and variable declarations*** declares private variables, constants, cursors, exceptions, user-defined types, and subtypes.
- ***subprogram bodies*** specifies the full implementation of any private and/or public procedures or functions.
- **[BEGIN *initialization statements*]** is an optional block of initialization code that executes when the package is first referenced.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
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Cursor

- A cursor is a pointer to the private memory area allocated by the Oracle server.
- There are two types of cursors:
  - Implicit cursors: Created and managed internally by the Oracle server to process SQL statements
  - Explicit cursors: Explicitly declared by the programmer

Cursor

You have already learned that you can include SQL statements that return a single row in a PL/SQL block. The data retrieved by the SQL statement should be held in variables using the `INTO` clause.

Where Does Oracle Process SQL Statements?

The Oracle server allocates a private memory area, called the *context area,* to process SQL statements. The SQL statement is parsed and processed in this area. The information required for processing and the information retrieved after processing are stored in this area. Because this area is internally managed by the Oracle server, you have no control over this area. A cursor is a pointer to the context area. However, this cursor is an implicit cursor and is automatically managed by the Oracle server. When the executable block contains a SQL statement, an implicit cursor is created.

There are two types of cursors:

- **Implicit cursors:** Implicit cursors are created and managed by the Oracle server. You do not have access to them. The Oracle server creates such a cursor when it executes a SQL statement, such as `SELECT`, `INSERT`, `UPDATE`, or `DELETE`.

Cursor (continued)

- **Explicit cursors:** As a programmer, you may want to retrieve multiple rows from a database table, have a pointer to each row that is retrieved, and work on the rows one at a time. In such cases, you can declare cursors explicitly, depending on your business requirements. Such cursors that are declared by programmers are called *explicit cursors*. You declare these cursors in the declarative section of a PL/SQL block. Remember that you can also declare variables and exceptions in the declarative section.

Processing Explicit Cursors

The following three commands are used to process an explicit cursor:

- `OPEN`
- `FETCH`
- `CLOSE`

Alternatively, you can also use a cursor `FOR` loop.

Processing Explicit Cursors

You declare an explicit cursor when you need exact control over query processing. You use three commands to control a cursor:

- `OPEN`
- `FETCH`
- `CLOSE`

You initialize the cursor with the `OPEN` command, which recognizes the result set. Then, you execute the `FETCH` command repeatedly in a loop until all rows are retrieved. Alternatively, you can use a `BULK COLLECT` clause to fetch all rows at once. After the last row is processed, you release the cursor by using the `CLOSE` command.

Explicit Cursor Attributes

Every explicit cursor has the following attributes:

- *cursor_name*%FOUND
- *cursor_name*%ISOPEN
- *cursor_name*%NOTFOUND
- *cursor_name*%ROWCOUNT

Cursor Attributes

When cursor attributes are appended to the cursors, they return useful information about the execution of the data manipulation language (DML) statement. The following are the four cursor attributes:

- ***cursor_name*%FOUND:** Returns TRUE if the last fetch returned a row; returns NULL before the first fetch from an OPEN cursor; returns FALSE if the last fetch failed to return a row
- ***cursor_name*%ISOPEN:** Returns TRUE if the cursor is open, otherwise returns FALSE
- ***cursor_name*%NOTFOUND:** Returns FALSE if the last fetch returned a row; returns NULL before the first fetch from an OPEN cursor; returns TRUE if the last fetch failed to return a row
- ***cursor_name*%ROWCOUNT:** Returns zero before the first fetch; after every fetch, returns the number of rows fetched so far

Cursor FOR Loops

Syntax:

```
FOR record_name IN cursor_name LOOP
  statement1;
  statement2;
  . . .
END LOOP;
```

- The cursor FOR loop is a shortcut to process explicit cursors.
- Implicit open, fetch, exit, and close occur.
- The record is implicitly declared.

Cursor FOR Loops

A cursor FOR loop processes rows in an explicit cursor. It is a shortcut, because the cursor is opened, a row is fetched once for each iteration in the loop, the loop exits when the last row is processed, and the cursor is closed automatically. The loop itself is terminated automatically at the end of the iteration where the last row is fetched.

In the syntax:

record_name	Is the name of the implicitly declared record
cursor_name	Is a PL/SQL identifier for the previously declared cursor

Guidelines

- Do not declare the record in the loop, because it is declared implicitly.
- Test the cursor attributes during the loop, if required.
- Supply the parameters for a cursor, if required, in parentheses following the cursor name in the FOR statement.

Cursor: Example

```
SET SERVEROUTPUT ON
DECLARE
  CURSOR cur_cust IS
   SELECT cust_first_name, credit_limit
   FROM customers
   WHERE credit_limit > 4000;
BEGIN
    FOR v_cust_record IN cur_cust
     LOOP
      DBMS_OUTPUT.PUT_LINE
      (v_cust_record.cust_first_name ||' '||
       v_cust_record.credit_limit);
     END LOOP;
END;
/
```


Cursor: Example

The example shows the use of a cursor FOR loop.

cust_record is the record that is implicitly declared. You can access the fetched data with this implicit record as shown in the slide.

Note: An INTO clause or a FETCH statement is not required because the FETCH INTO is implicit. The code does not have OPEN and CLOSE statements to open and close the cursor, respectively.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
- Reviewing PL/SQL packages
- Identifying how explicit cursors are processed
- Handling exceptions
- Using the `raise_application_error` procedure
- Managing dependencies
- Using Oracle-supplied packages

Handling Exceptions

- An exception is an error in PL/SQL that is raised during program execution.
- An exception can be raised:
  - Implicitly by the Oracle server
  - Explicitly by the program
- An exception can be handled:
  - By trapping it with a handler
  - By propagating it to the calling environment
  - By trapping and propagating it

Handling Exceptions

An exception is an error in PL/SQL that is raised during the execution of a block. A block always terminates when PL/SQL raises an exception, but you can specify an exception handler to perform final actions before the block ends.

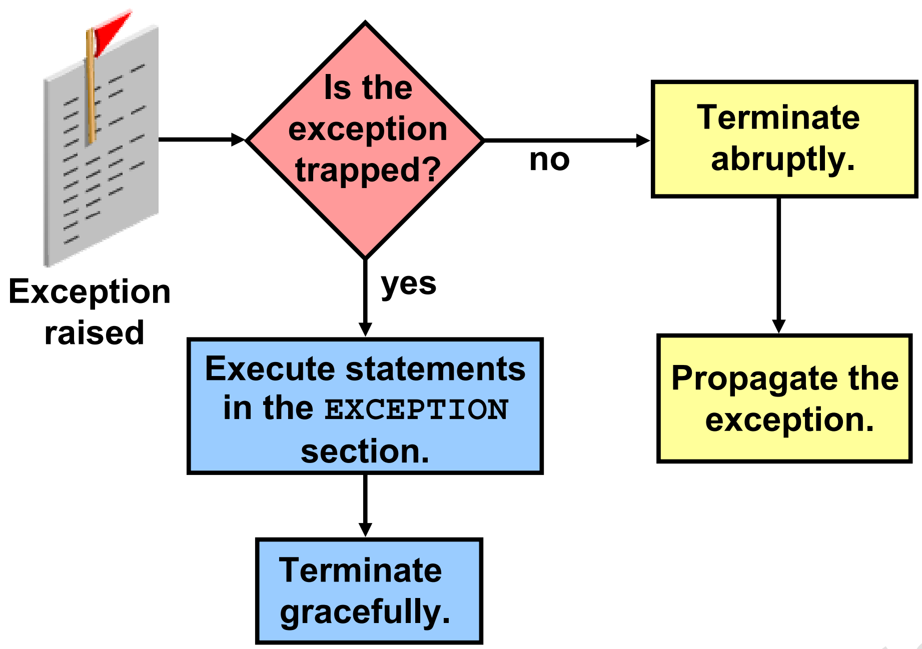
Methods for Raising an Exception

- An Oracle error occurs and the associated exception is raised automatically. For example, if the error `ORA-01403` occurs when no rows are retrieved from the database in a `SELECT` statement, PL/SQL raises the `NO_DATA_FOUND` exception. These errors are converted into predefined exceptions.
- Depending on the business functionality that your program is implementing, you may have to explicitly raise an exception by issuing the `RAISE` statement within the block. The exception being raised may be either user-defined or predefined.
- There are some non-predefined Oracle errors. These errors are any standard Oracle errors that are not predefined. You can explicitly declare exceptions and associate them with the nonpredefined Oracle errors.

Methods for Handling an Exception

The third method in the slide for handling an exception involves trapping and propagating. It is often very important to be able to handle an exception after propagating it to the invoking environment, by issuing a simple `RAISE` statement.

Handling Exceptions



Handling Exceptions (continued)

Trapping an Exception

Include an `EXCEPTION` section in your PL/SQL program to trap exceptions. If the exception is raised in the executable section of the block, processing branches to the corresponding exception handler in the exception section of the block. If PL/SQL successfully handles the exception, the exception does not propagate to the enclosing block or to the calling environment. The PL/SQL block terminates successfully.

Propagating an Exception

If the exception is raised in the executable section of the block and there is no corresponding exception handler, the PL/SQL block terminates with failure and the exception is propagated to an enclosing block or to the calling environment. The calling environment can be any application, such as SQL*Plus, that invokes the PL/SQL program.

Exceptions: Example

```
DECLARE
  v_lname VARCHAR2(15);
BEGIN
  SELECT cust_last_name INTO v_lname FROM customers
  WHERE cust_first_name='Ally';
  DBMS_OUTPUT.PUT_LINE ('Ally''s last name is : '
                                ||v_lname);
EXCEPTION
  WHEN TOO_MANY_ROWS THEN
  DBMS_OUTPUT.PUT_LINE (' Your select statement
  retrieved multiple rows. Consider using a
  cursor.');
END;
/
```


Exceptions: Example

You have written PL/SQL blocks with a declarative section (beginning with the keyword `DECLARE`) and an executable section (beginning and ending with the keywords `BEGIN` and `END`, respectively). For exception handling, include another optional section called the `EXCEPTION` section. This section begins with the keyword `EXCEPTION`. If present, this is the last section in a PL/SQL block.

Examine the code in the slide to see the `EXCEPTION` section.

The output of this code is shown below:

```
Your select statement retrieved multiple rows. Consider using a
cursor.
PL/SQL procedure successfully completed.
```

When the exception is raised, the control shifts to the `EXCEPTION` section and all statements in the specified `EXCEPTION` section are executed. The PL/SQL block terminates with normal, successful completion. Only one exception handler is executed.

Note the `SELECT` statement in the executable block. That statement requires that a query must return *only* one row. If multiple rows are returned, a "too many rows" exception is raised. If no rows are returned, a "no data found" exception is raised. The block of code in the slide tests for the "too many rows" exception.

Predefined Oracle Server Errors

- Reference the predefined name in the exception-handling routine.
- Sample predefined exceptions:
  - NO_DATA_FOUND
  - TOO_MANY_ROWS
  - INVALID_CURSOR
  - ZERO_DIVIDE
  - DUP_VAL_ON_INDEX

Predefined Oracle Server Errors

You can reference predefined Oracle server errors by using its predefined name within the corresponding exception-handling routine.

For a complete list of predefined exceptions, see the *PL/SQL User's Guide and Reference*.

Note: PL/SQL declares predefined exceptions in the `STANDARD` package.

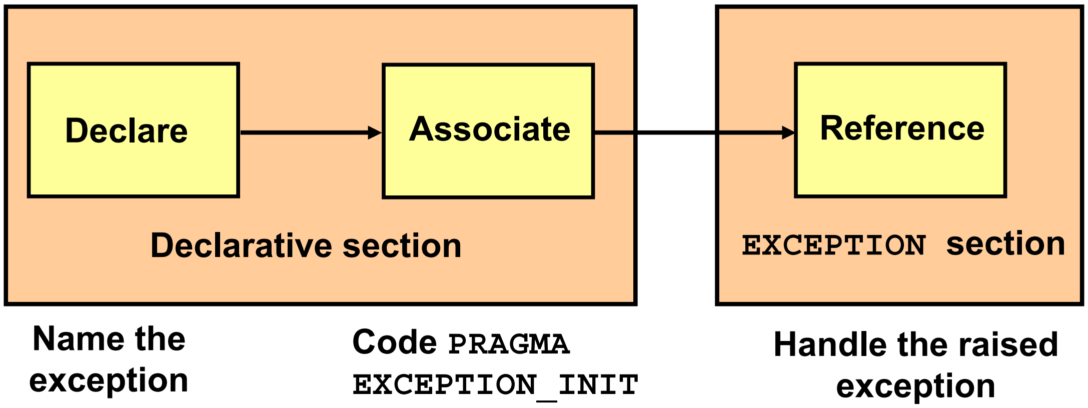
Predefined Oracle Server Errors (continued)

Exception Name	Oracle Server Error Number	Description
ACCESS_INTO_NULL	ORA-06530	Attempted to assign values to the attributes of an uninitialized object.
CASE_NOT_FOUND	ORA-06592	None of the choices in the WHEN clauses of a CASE statement is selected, and there is no ELSE clause.
COLLECTION_IS_NULL	ORA-06531	Attempted to apply collection methods other than EXISTS to an uninitialized nested table or varray.
CURSOR_ALREADY_OPEN	ORA-06511	Attempted to open an already open cursor.
DUP_VAL_ON_INDEX	ORA-00001	Attempted to insert a duplicate value.
INVALID_CURSOR	ORA-01001	Illegal cursor operation occurred.
INVALID_NUMBER	ORA-01722	Conversion of character string to number failed.
LOGIN_DENIED	ORA-01017	Logging on to the Oracle server with an invalid username or password.
NO_DATA_FOUND	ORA-01403	Single-row SELECT returned no data.
NOT_LOGGED_ON	ORA-01012	PL/SQL program issued a database call without being connected to the Oracle server.
PROGRAM_ERROR	ORA-06501	PL/SQL has an internal problem.
ROWTYPE_MISMATCH	ORA-06504	Host cursor variable and PL/SQL cursor variable involved in an assignment have incompatible return types.

Predefined Oracle Server Errors (continued)

Exception Name	Oracle Server Error Number	Description
STORAGE_ERROR	ORA-06500	PL/SQL ran out of memory or memory is corrupted.
SUBSCRIPT_BEYOND_COUNT	ORA-06533	Referenced a nested table or varray element by using an index number larger than the number of elements in the collection.
SUBSCRIPT_OUTSIDE_LIMIT	ORA-06532	Referenced a nested table or varray element by using an index number that is outside the legal range (for example –1).
SYS_INVALID_ROWID	ORA-01410	The conversion of a character string into a universal ROWID failed because the character string did not represent a valid ROWID.
TIMEOUT_ON_RESOURCE	ORA-00051	Time-out occurred while the Oracle server was waiting for a resource.
TOO_MANY_ROWS	ORA-01422	Single-row SELECT returned more than one row.
VALUE_ERROR	ORA-06502	Arithmetic, conversion, truncation, or size-constraint error occurred.
ZERO_DIVIDE	ORA-01476	Attempted to divide by zero.

Trapping Non-Predefined Oracle Server Errors



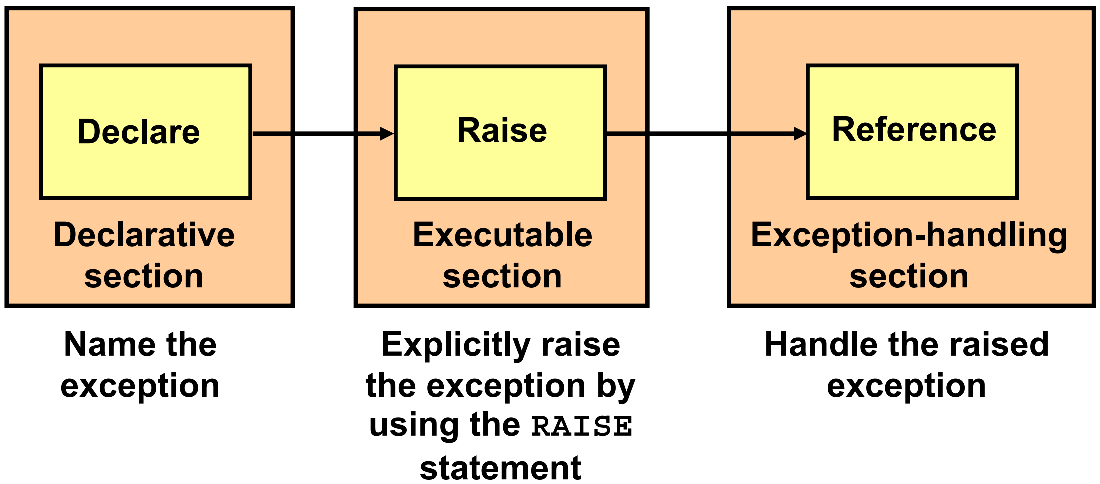
Trapping Non-Predefined Oracle Server Errors

Non-predefined exceptions are similar to predefined exceptions; however, they are not defined as PL/SQL exceptions in the Oracle server. They are standard Oracle errors. You can create exceptions with standard Oracle errors by using the `PRAGMA EXCEPTION_INIT` function. Such exceptions are called nonpredefined exceptions.

You can trap a nonpredefined Oracle server error by declaring it first. The declared exception is raised implicitly. In PL/SQL, `PRAGMA EXCEPTION_INIT` instructs the compiler to associate an exception name with an Oracle error number. This allows you to refer to any internal exception by name and to write a specific handler for it.

Note: `PRAGMA` (also called pseudoinstructions) is the keyword that signifies that the statement is a compiler directive, which is not processed when the PL/SQL block is executed. Rather, it directs the PL/SQL compiler to interpret all occurrences of the exception name within the block as the associated Oracle server error number.

Trapping User-Defined Exceptions



Trapping User-Defined Exceptions

With PL/SQL, you can define your own exceptions. You define exceptions depending on the requirements of your application. For example, you may prompt the user to enter a department number.

Define an exception to deal with error conditions in the input data. Check whether the department number exists. If it does not, you may have to raise the user-defined exception. PL/SQL exceptions must be:

- Declared in the declarative section of a PL/SQL block
- Raised explicitly with `RAISE` statements
- Handled in the `EXCEPTION` section

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
- Reviewing PL/SQL packages
- Identifying how explicit cursors are processed
- Handling exceptions
- Using the `raise_application_error` procedure
- Managing dependencies
- Using Oracle-supplied packages

The RAISE_APPLICATION_ERROR Procedure

Syntax:

```
raise_application_error (error_number,
                message[, {TRUE | FALSE}]);
```

- You can use this procedure to issue user-defined error messages from stored subprograms.
- You can report errors to your application and avoid returning unhandled exceptions.

The RAISE_APPLICATION_ERROR Procedure

Use the `raise_application_error` procedure to communicate a predefined exception interactively by returning a nonstandard error code and error message. With `raise_application_error`, you can report errors to your application and avoid returning unhandled exceptions.

In the syntax:

error_number	Is a user-specified number for the exception between –20,000 and –20,999 (this is not an Oracle-defined exception number).
message	Is the user-specified message for the exception. It is a character string up to 2,048 bytes long.
TRUE | FALSE	Is an optional Boolean parameter. (If TRUE, the error is placed on the stack of previous errors. If FALSE, the default, the error replaces all previous errors.)

The `RAISE_APPLICATION_ERROR` Procedure

- Is used in two places:
  - Executable section
  - Exception section
- Returns error conditions to the user in a manner consistent with other Oracle server errors

The `RAISE_APPLICATION_ERROR` Procedure (continued)

The `raise_application_error` procedure can be used in either the executable section or the exception section of a PL/SQL program, or both. The returned error is consistent with how the Oracle server processes a predefined, nonpredefined, or user-defined error. The error number and message are displayed to the user.

Lesson Agenda

- Describing PL/SQL basics
- Listing restrictions on calling functions from SQL expressions
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Dependencies

Dependent objects	Referenced objects
Table	Function
View	Package specification
Database trigger	Procedure
Procedure	Sequence
Function	Synonym
Package body	Table
Package specification	View
User-defined object and collection types	User-defined object and collection types

ORACLE

Dependencies

Some objects reference other objects as part of their definitions. For example, a stored procedure could contain a `SELECT` statement that selects columns from a table. For this reason, the stored procedure is called a *dependent object*, whereas the table is called a *referenced object*.

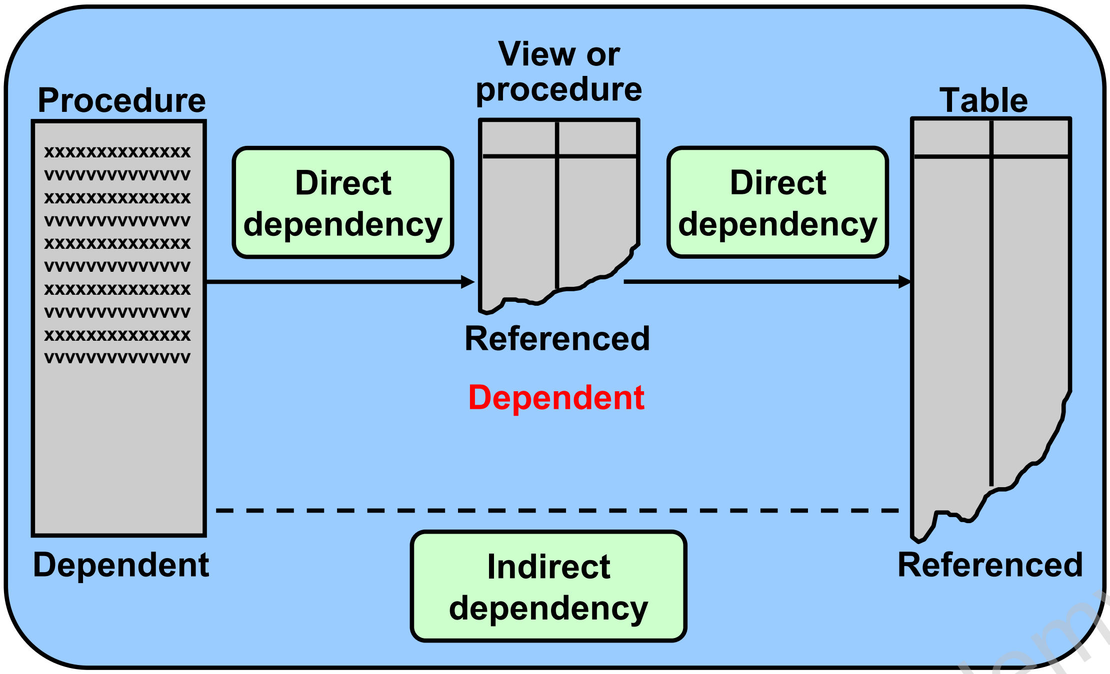
Dependency Issues

If you alter the definition of a referenced object, dependent objects may or may not continue to work properly. For example, if the table definition is changed, a procedure may or may not continue to work without an error.

The Oracle server automatically records dependencies among objects. To manage dependencies, all schema objects have a status (valid or invalid) that is recorded in the data dictionary, and you can view the status in the `USER_OBJECTS` data dictionary view.

Status	Significance
`VALID`	The schema object was compiled and can be immediately used when referenced.
`INVALID`	The schema object must be compiled before it can be used.

Dependencies



Dependencies (continued)

A procedure or function can directly or indirectly (through an intermediate view, procedure, function, or packaged procedure or function) reference the following objects:

- Tables
- Views
- Sequences
- Procedures
- Functions
- Packaged procedures or functions

Displaying Direct and Indirect Dependencies

1. Run the `utldtree.sql` script to create the objects that enable you to display the direct and indirect dependencies.
2. Execute the `DEPTREE_FILL` procedure:

```
EXECUTE deptree_fill('TABLE','OE','CUSTOMERS')
```


Displaying Direct and Indirect Dependencies

You can display direct and indirect dependencies from additional user views called `DEPTREE` and `IDEPTREE`; these views are provided by the Oracle database.

Example

1. Make sure that the `utldtree.sql` script was executed. This script is located in the `$ORACLE_HOME/rdbms/admin` folder.
2. Populate the `DEPTREE_TEMPTAB` table with information for a particular referenced object by invoking the `DEPTREE_FILL` procedure. There are three parameters for this procedure:

object_type	Type of the referenced object
object_owner	Schema of the referenced object
object_name	Name of the referenced object

Lesson Agenda

- Describing PL/SQL basics
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- Identifying how explicit cursors are processed
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- Using Oracle-supplied packages

Using Oracle-Supplied Packages

Oracle-supplied packages:
- Are provided with the Oracle server
- Extend the functionality of the database
- Enable access to certain SQL features that are normally restricted for PL/SQL

For example, the `DBMS_OUTPUT` package was originally designed to debug PL/SQL programs.

Using Oracle-Supplied Packages

Packages are provided with the Oracle server to allow either of the following:
- PL/SQL access to certain SQL features
- The extension of the functionality of the database

You can use the functionality provided by these packages when creating your application, or you may simply want to use these packages as ideas when you create your own stored procedures.

Most of the standard packages are created by running `catproc.sql`.

Some of the Oracle-Supplied Packages

Here is an abbreviated list of some Oracle-supplied packages:

- DBMS_ALERT
- DBMS_LOCK
- DBMS_SESSION
- DBMS_OUTPUT
- HTP
- UTL_FILE
- UTL_MAIL
- DBMS_SCHEDULER

Some of the Oracle-Supplied Packages

The list of PL/SQL packages provided with an Oracle database grows with the release of new versions. It would be impossible to cover the exhaustive set of packages and their functionality in this course. For more information, refer to the *PL/SQL Packages and Types Reference 10g* (previously known as the *PL/SQL Supplied Packages Reference)*.

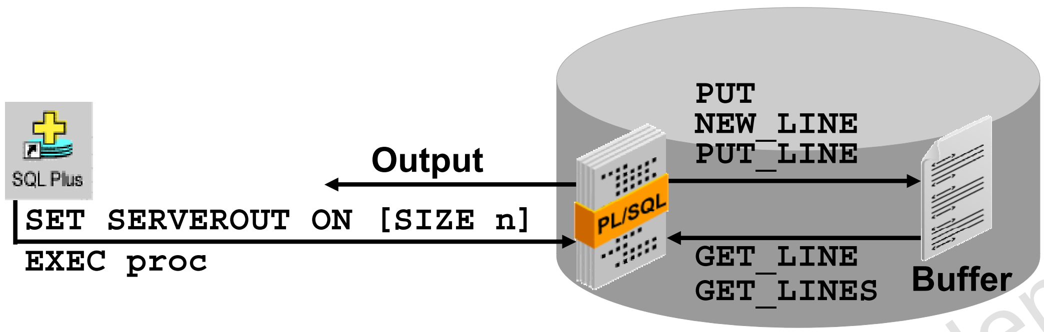
The following is a brief description of some listed packages:

- The `DBMS_ALERT` package supports asynchronous notification of database events. Messages or alerts are sent on a `COMMIT` command.
- The `DBMS_LOCK` package is used to request, convert, and release locks through Oracle Lock Management services.
- The `DBMS_SESSION` package enables programmatic use of the `ALTER SESSION` SQL statement and other session-level commands.
- The `DBMS_OUTPUT` package provides debugging and buffering of text data.
- The `HTP` package writes HTML-tagged data into database buffers.
- The `UTL_FILE` package enables reading and writing of operating system text files.
- The `UTL_MAIL` package enables composing and sending of email messages.
- The `DBMS_SCHEDULER` package enables scheduling and automated execution of PL/SQL blocks, stored procedures, and external procedures or executables.

DBMS_OUTPUT Package

The DBMS_OUTPUT package enables you to send messages from stored subprograms and triggers.

- PUT and PUT_LINE place text in the buffer.
- GET_LINE and GET_LINES read the buffer.
- Use SET SERVEROUTPUT ON to display messages in SQL*Plus. (The default is OFF.)



DBMS_OUTPUT Package

The DBMS_OUTPUT package sends textual messages from any PL/SQL block into a buffer in the database. The procedures provided by the package include:

- PUT to append text from the procedure to the current line of the line output buffer
- NEW_LINE to place an end-of-line marker in the output buffer
- PUT_LINE to combine the action of PUT and NEW_LINE; to trim leading spaces
- GET_LINE to retrieve the current line from the buffer into a procedure variable
- GET_LINES to retrieve an array of lines into a procedure-array variable
- ENABLE/DISABLE to enable or disable calls to the DBMS_OUTPUT procedures

The buffer size can be set by using:

- The SIZE *n* option appended to the SET SERVEROUTPUT ON command, where *n* is between 2,000 (the default) and 1,000,000 (1 million characters)
- An integer parameter between 2,000 and 1,000,000 in the ENABLE procedure

Practical Uses

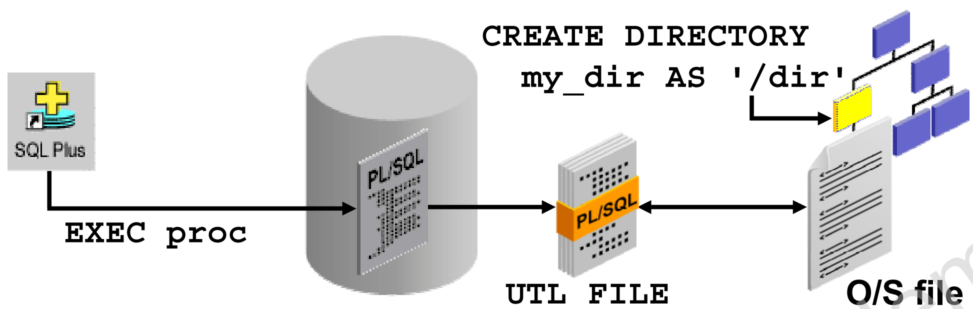
- You can output results to the window for debugging purposes.
- You can trace the code execution path for a function or procedure.
- You can send messages between subprograms and triggers.

Note: There is no mechanism to flush output during the execution of a procedure.

UTL_FILE Package

The UTL_FILE package extends PL/SQL programs to read and write operating system text files.

- It provides a restricted version of operating system stream file I/O for text files.
- It can access files in operating system directories defined by a CREATE DIRECTORY statement.



UTL_FILE Package

The Oracle-supplied UTL_FILE package is used to access text files in the operating system of the database server. The database provides read and write access to specific operating system directories by using:

- A CREATE DIRECTORY statement that associates an alias with an operating system directory. The database directory alias can be granted the READ and WRITE privileges to control the type of access to files in the operating system. For example:

```
CREATE DIRECTORY my_dir AS '/temp/my_files';
GRANT READ, WRITE ON DIRECTORY my_dir TO public;
```

This approach of using the directory alias created by the CREATE DIRECTORY statement does not require the database to be restarted. The operating system directories specified should be accessible to and on the same machine as the database server processes. The path (directory) names may be case-sensitive for some operating systems.

Note: The DBMS_LOB package can be used to read binary files on the operating system.

Summary

In this lesson, you should have learned how to:

- Identify a PL/SQL block
- Create subprograms
- List restrictions on calling functions from SQL expressions
- Use cursors
- Handle exceptions
- Use the `raise_application_error` procedure
- Identify Oracle-supplied packages

Summary

This lesson reviewed some basic PL/SQL concepts, such as:

- PL/SQL block structure
- Subprograms
- Cursors
- Exceptions
- Oracle-supplied packages

The quiz on the following pages is designed to test and review your PL/SQL knowledge. This knowledge is necessary as a baseline for the subsequent chapters to build upon.

Practice 2: Overview

This practice covers the review of the following topics:

- PL/SQL basics
- Cursor basics
- Exceptions
- Dependencies

Practice 2: Overview

In this practice, you test and review your PL/SQL knowledge. This knowledge is necessary as a base line for the subsequent chapters to build upon.

For answers to the questions in this practice, see Appendix A, "Practice Solutions."

Practice 2: PL/SQL Knowledge Quiz

The questions are designed as a refresher. Use the space provided for your answers. If you do not know the answer, go on to the next question. For solutions to this quiz, see Appendix A.

PL/SQL Basics

1. Which are the four key areas of the basic PL/SQL block? What happens in each area?
2. What is a variable and where is it declared?
3. What is a constant and where is it declared?
4. What are the different modes for parameters and what does each mode do?
5. How does a function differ from a procedure?
6. Which are the two main components of a PL/SQL package?
   a. In what order are they defined?
   b. Are both required?
7. How does the syntax of a `SELECT` statement used within a PL/SQL block differ from a `SELECT` statement issued in SQL*Plus?
8. What is a record?
9. What is an index by table?
10. How are loops implemented in PL/SQL?
11. How is branching logic implemented in PL/SQL?

Practice 2: PL/SQL Knowledge Quiz (continued)

Cursor Basics

12. What is an explicit cursor?

13. Where do you define an explicit cursor?

14. Name the five steps for using an explicit cursor.

15. What is the syntax used to declare a cursor?

16. What does the `FOR UPDATE` clause do within a cursor definition?

17. Which command opens an explicit cursor?

18. Which command closes an explicit cursor?

19. Name five implicit actions that a cursor `FOR` loop provides.

20. Describe what the following cursor attributes do:
    - `cursor_name%ISOPEN`
    - `cursor_name%FOUND`
    - `cursor_name%NOTFOUND`
    - `cursor_name%ROWCOUNT`

Practice 2: PL/SQL Knowledge Quiz (continued)

Exceptions

21. An exception occurs in your PL/SQL block, which is enclosed in another PL/SQL block. What happens to this exception?

22. An exception handler is mandatory within a PL/SQL subprogram. (True/False)

23. What syntax do you use in the exception handler area of a subprogram?

24. How do you code for a `NO_DATA_FOUND` error?

25. Name three types of exceptions.

26. To associate an exception identifier with an Oracle error code, what pragma would you use and where?

27. How do you explicitly raise an exception?

28. What types of exceptions are implicitly raised?

29. What does the `raise_application_error` procedure do?

Practice 2: PL/SQL Knowledge Quiz (continued)

Dependencies

30. Which objects can a procedure or function directly reference?

31. Which are the two statuses that a schema object can have and where are they recorded?

32. The Oracle server automatically recompiles invalid procedures when they are called from the same ______. To avoid compile problems with remote database calls, you can use the ________ model instead of the timestamp model.

33. Which data dictionary contains information on direct dependencies?

34. What script would you run to create the `deptree` and `ideptree` views?

35. What does the `deptree_fill` procedure do and what are the arguments that you need to provide?

Oracle-Supplied Packages

36. What does the `dbms_output` package do?

37. How do you write “This procedure works.” from within a PL/SQL program by using `dbms_output`?

38. What does `dbms_sql` do and how does this compare with Native Dynamic SQL?

3

Designing PL/SQL Code

Objectives

After completing this lesson, you should be able to do the following:

- Identify guidelines for cursor design
- Use cursor variables
- Create subtypes based on the existing types for an application

Objectives

This lesson discusses several concepts that apply to the designing of PL/SQL program units. This lesson explains how to:

- Design and use cursor variables
- Describe the predefined data types
- Create subtypes based on existing data types for an application

Lesson Agenda

- Identifying guidelines for cursor design
- Using cursor variables
- Creating subtypes based on existing types

Guidelines for Cursor Design

Fetch into a record when fetching from a cursor.

```
DECLARE
  CURSOR cur_cust IS
    SELECT customer_id, cust_last_name, cust_email
    FROM customers
    WHERE credit_limit = 1200;
  v_cust_record     cur_cust%ROWTYPE;
BEGIN
  OPEN cur_cust;
  LOOP
    FETCH cur_cust INTO v_cust_record;
...
```


Guidelines for Cursor Design

When fetching from a cursor, fetch into a record. This way you do not need to declare individual variables, and you reference only the values that you want to use. Additionally, you can automatically use the structure of the SELECT column list.

Guidelines for Cursor Design

Create cursors with parameters.

```
CREATE OR REPLACE PROCEDURE cust_pack
 (p_crd_limit_in NUMBER, p_acct_mgr_in NUMBER)
IS
  v_credit_limit NUMBER := 1500;
   CURSOR cur_cust
          (p_crd_limit NUMBER, p_acct_mgr NUMBER)
     IS
     SELECT customer_id, cust_last_name, cust_email
     FROM customers
     WHERE credit_limit = p_crd_limit
     AND   account_mgr_id = p_acct_mgr;
BEGIN
   OPEN cur_cust(p_crd_limit_in, p_acct_mgr_in);
...
   CLOSE cur_cust;
...
   OPEN cur_cust(v_credit_limit, 145);
...
END;
```


Guidelines for Cursor Design (continued)

Whenever you need to use a cursor in multiple places with different values for the WHERE clause, create parameters for your cursor. Parameters increase the flexibility and reusability of cursors, because you can pass different values to the WHERE clause when you open a cursor, rather than hard-code a value for the WHERE clause.

Additionally, parameters help avoid scoping problems, because the result set for the cursor is not tied to a specific variable in a program. You can define a cursor at a higher level and use it in any subblock with variables defined in the local block.

Guidelines for Cursor Design

Reference implicit cursor attributes immediately after the SQL statement executes.

```
BEGIN
  UPDATE customers
    SET   credit_limit = p_credit_limit
    WHERE customer_id  = p_cust_id;
  get_avg_order(p_cust_id);   -- procedure call
  IF SQL%NOTFOUND THEN
   ...
```


Guidelines for Cursor Design (continued)

If you are using an implicit cursor and reference a SQL cursor attribute, make sure you reference it immediately after a SQL statement is executed. This is because SQL cursor attributes are set on the result of the most recently executed SQL statement. The SQL statement can be executed in another program. Referencing a SQL cursor attribute immediately after a SQL statement executes ensures that you are dealing with the result of the correct SQL statement.

In the example in the slide, you cannot rely on the value of `SQL%NOTFOUND` for the `UPDATE` statement, because it is likely to be overwritten by the value of another SQL statement in the `get_avg_order` procedure. To ensure accuracy, the cursor attribute function `SQL%NOTFOUND` needs to be called immediately after the data manipulation language (DML) statement:

```
DECLARE
  v_flag BOOLEAN;
BEGIN
  UPDATE customers
    SET   credit_limit = p_credit_limit
    WHERE customer_id  = p_cust_id;
    v_flag := SQL%NOTFOUND
  get_avg_order(p_cust_id);   -- procedure call
  IF v_flag THEN
...
```

Guidelines for Cursor Design

Simplify coding with cursor `FOR` loops.

```
CREATE OR REPLACE PROCEDURE cust_pack
 (p_crd_limit_in NUMBER, p_acct_mgr_in NUMBER)
IS
  v_credit_limit NUMBER := 1500;
   CURSOR cur_cust
           (p_crd_limit NUMBER, p_acct_mgr NUMBER)
     IS
     SELECT customer_id, cust_last_name, cust_email
     FROM customers
     WHERE credit_limit = p_crd_limit
     AND   account_mgr_id = p_acct_mgr;
BEGIN
  FOR cur_rec IN cur_cust (p_crd_limit_in, p_acct_mgr_in)
  LOOP          -- implicit open and fetch
  ...
  END LOOP;     -- implicit close
  ...
END;
```


Guidelines for Cursor Design (continued)

Whenever possible, use cursor `FOR` loops that simplify coding. Cursor `FOR` loops reduce the volume of code that you need to write to fetch data from a cursor and also reduce the chances of introducing loop errors in your code.

A cursor `FOR` loop automatically handles the open, fetch, and close operations, and defines a record type that matches the cursor definition. After it processes the last row, the cursor is closed automatically. If you do not use a cursor `FOR` loop, forgetting to close your cursor results in increased memory usage.

Guidelines for Cursor Design

- Close a cursor when it is no longer needed.
- Use column aliases in cursors for calculated columns fetched into records declared with `%ROWTYPE`.

```
CREATE OR REPLACE PROCEDURE cust_list
IS
 CURSOR  cur_cust IS
  SELECT customer_id, cust_last_name, credit_limit*1.1
  FROM   customers;
 cust_record cur_cust%ROWTYPE;
BEGIN
  OPEN cur_cust;
  LOOP
    FETCH cur_cust INTO cust_record;
    DBMS_OUTPUT.PUT_LINE('Customer ' ||
      cust_record.cust_last_name || ' wants credit '
      || cust_record.(credit_limit * 1.1));
    EXIT WHEN cur_cust%NOTFOUND;
  END LOOP;
...
```

Use col. alias

Guidelines for Cursor Design (continued)

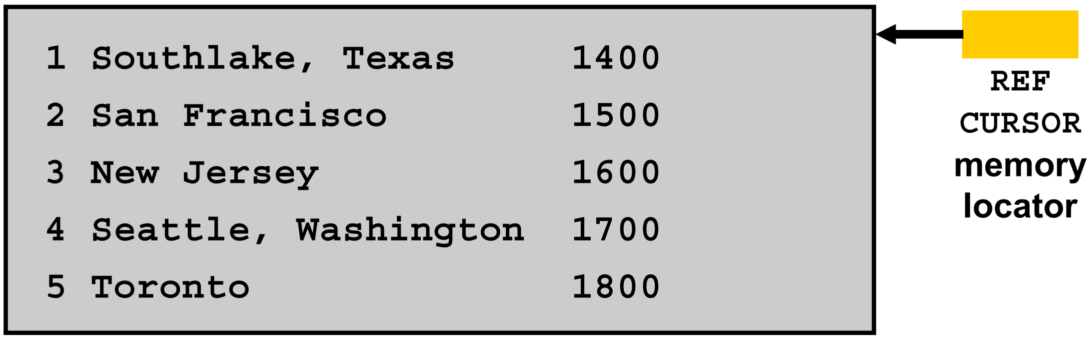
- If you no longer need a cursor, close it explicitly. If your cursor is in a package, its scope is not limited to any particular PL/SQL block. The cursor remains open until you explicitly close it. An open cursor takes up memory space and continues to maintain row-level locks, if created with the `FOR UPDATE` clause, until a commit or rollback. Closing the cursor releases memory. Ending the transaction by committing or rolling back releases the locks. Along with a `FOR UPDATE` clause, you can also use a `WHERE CURRENT OF` clause with the DML statements inside the `FOR` loop. This automatically performs a DML transaction for the current row in the cursor's result set, thereby improving performance.
  Note: It is a good programming practice to explicitly close your cursors. Leaving cursors open can generate an exception, because the number of cursors allowed to remain open within a session is limited.
- Make sure that you use column aliases in your cursor for calculated columns that you fetch into a record declared with a `%ROWTYPE` declaration. You would also need column aliases if you want to reference the calculated column in your program.
  The code in the slide does not compile successfully, because it lacks a column alias for the calculation `credit_limit*1.1`. After you give it an alias, use the same alias later in the code to make a reference to the calculation.

Lesson Agenda

- Identifying guidelines for cursor design
- Using cursor variables
- Creating subtypes based on existing types

Cursor Variables: Overview

Memory



Cursor Variables: Overview

Like a cursor, a cursor variable points to the current row in the result set of a multiple-row query. Cursor variables, however, are like C pointers: they hold the memory location of an item instead of the item itself. Thus, cursor variables differ from cursors the way constants differ from variables. A cursor is static, a cursor variable is dynamic. In PL/SQL, a cursor variable has a **`REF CURSOR`** data type, where `REF` stands for reference, and `CURSOR` stands for the class of the object.

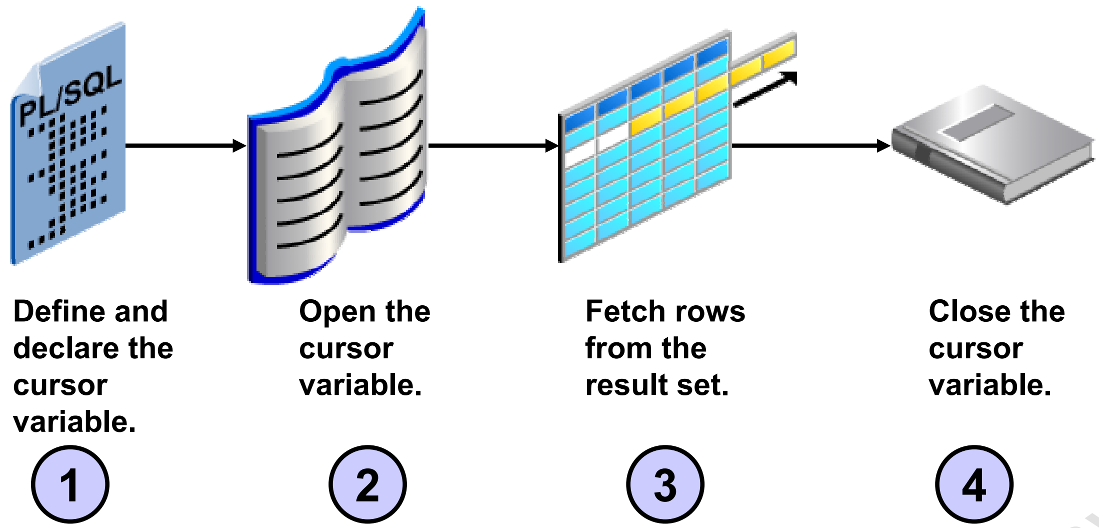
Using Cursor Variables

To execute a multiple-row query, the Oracle server opens a work area called a "cursor" to store the processing information. To access the information, you either explicitly name the work area, or you use a cursor variable that points to the work area. Whereas a cursor always refers to the same work area, a cursor variable can refer to different work areas. Therefore, cursors and cursor variables are not interoperable.

An explicit cursor is static and is associated with one SQL statement. A cursor variable can be associated with different statements at run time.

Primarily, you use a cursor variable to pass a pointer to query result sets between PL/SQL-stored subprograms and various clients, such as a Developer Forms application. None of them owns the result set. They simply share a pointer to the query work area that stores the result set.

Working with Cursor Variables



Working with Cursor Variables

There are four steps for handling a cursor variable. The next few sections contain detailed information about each step.

Strong Versus Weak `REF CURSOR` Variables

- Strong `REF CURSOR`:
  - Is restrictive
  - Specifies a `RETURN` type
  - Associates only with type-compatible queries
  - Is less error prone
- Weak `REF CURSOR`:
  - Is nonrestrictive
  - Associates with any query
  - Is very flexible

Strong Versus Weak `REF CURSOR` Variables

`REF CURSOR` types can be strong (restrictive) or weak (nonrestrictive). A strong `REF CURSOR` type definition specifies a return type; a weak definition does not. PL/SQL enables you to associate a strong type only with type-compatible queries, whereas a weak type can be associated with any query. This makes strong `REF CURSOR` types less prone to error, but weak `REF CURSOR` types more flexible.

In the following example, the first definition is strong, whereas the second is weak:

```
DECLARE
  TYPE rt_cust IS REF CURSOR RETURN customers%ROWTYPE;
  TYPE rt_general_purpose IS REF CURSOR;
  ...
```

Step 1: Defining a `REF CURSOR` Type

Define a `REF CURSOR` type:

```
TYPE  ref_type_name IS REF CURSOR
  [RETURN return_type];
```

- *`ref_type_name`* is a type specified in subsequent declarations.
- *`return_type`* represents a record type.
- *`RETURN`* keyword indicates a strong cursor.

```
DECLARE
  TYPE rt_cust IS REF CURSOR
    RETURN  customers%ROWTYPE;
  ...
```


Step 1: Defining a Cursor Variable

To create a cursor variable, you first define a `REF CURSOR` type, and then declare a variable of that type.

Defining the `REF CURSOR` type:

```
TYPE  ref_type_name IS REF CURSOR  [RETURN return_type];
```

where: *`ref_type_name`* is a type specified in subsequent declarations.

`return_type` represents a row in a database table.

The `REF` keyword indicates that the new type is to be a pointer to the defined type. The `return_type` is a record type indicating the types of the select list that are eventually returned by the cursor variable. The return type must be a record type.

Example

```
DECLARE
TYPE rt_cust IS REF CURSOR RETURN customers%ROWTYPE;
...
```

Step 1: Declaring a Cursor Variable

Declare a cursor variable of a cursor type:

```
cursor_variable_name ref_type_name;
```

- *cursor_variable_name* is the name of the cursor variable.
- *ref_type_name* is the name of a REF CURSOR type.

```
DECLARE
  TYPE rt_cust IS REF CURSOR
    RETURN  customers%ROWTYPE;
  cv_cust rt_cust;
```


Declaring a Cursor Variable

After the cursor type is defined, declare a cursor variable of that type.

```
cursor_variable_name ref_type_name;
```

where: *cursor_variable_name* is the name of the cursor variable.

ref_type_name is the name of the REF CURSOR type.

Cursor variables follow the same scoping and instantiation rules as all other PL/SQL variables.

In the following example, you declare the cursor variable `cv_cust`.

Step 1:

```
DECLARE
  TYPE ct_cust IS REF CURSOR RETURN customers%ROWTYPE;
  cv_cust rt_cust;
```

Step 1: Declaring a `REF CURSOR` Return Type

Options:

- Use %`TYPE` and %`ROWTYPE`.
- Specify a user-defined record in the `RETURN` clause.
- Declare the cursor variable as the formal parameter of a stored procedure or function.

Step 1: Declaring a `REF CURSOR` Return Type

The following are other examples of cursor variable declarations:

- Use `%TYPE` and `%ROWTYPE` to provide the data type of a record variable:

```
DECLARE
 cust_rec customers%ROWTYPE; --a recd variable based on a row
 TYPE rt_cust IS REF CURSOR RETURN cust_rec%TYPE;
 cv_cust      rt_cust;  --cursor variable
```

- Specify a user-defined record in the `RETURN` clause:

```
DECLARE
  TYPE cust_rec_typ IS RECORD
   (custno     NUMBER(4),
    custname   VARCHAR2(10),
    credit     NUMBER(7,2));
  TYPE rt_cust IS REF  CURSOR RETURN cust_rec_typ;
  cv_cust   rt_cust;
```

- Declare a cursor variable as the formal parameter of a stored procedure or function:

```
DECLARE
  TYPE rt_cust IS REF  CURSOR RETURN customers%ROWTYPE;
  PROCEDURE use_cust_cur_var(cv_cust IN OUT  rt_cust)
  IS ...
```

Step 2: Opening a Cursor Variable

- Associate a cursor variable with a multiple-row SELECT statement.
- Execute the query.
- Identify the result set:

```
OPEN cursor_variable_name
     FOR select_statement;
```

  – *cursor_variable_name* is the name of the cursor variable.
  – *select_statement* is the SQL SELECT statement.

Step 2: Opening a Cursor Variable

Other OPEN-FOR statements can open the same cursor variable for different queries. You do not need to close a cursor variable before reopening it. You must note that when you reopen a cursor variable for a different query, the previous query is lost.

In the following example, the packaged procedure declares a variable used to select one of several alternatives in an IF THEN ELSE statement. When called, the procedure opens the cursor variable for the chosen query.

```
CREATE OR REPLACE PACKAGE cust_data
IS
   TYPE rt_cust IS REF CURSOR RETURN customers%ROWTYPE;
   PROCEDURE open_cust_cur_var(cv_cust IN OUT rt_cust,
                               p_your_choice IN NUMBER);
END cust_data;
/
```

Step 2: Opening a Cursor Variable (continued)

```
CREATE OR REPLACE PACKAGE BODY cust_data
IS
   PROCEDURE open_cust_cur_var(cv_cust IN OUT rt_cust,
                          p_your_choice IN NUMBER)
   IS
   BEGIN
        IF p_your_choice = 1 THEN
          OPEN cv_cust FOR SELECT * FROM customers;
 ELSIF p_your_choice = 2 THEN
    OPEN cv_cust FOR SELECT * FROM customers
                          WHERE credit_limit > 3000;
 ELSIF p_your_choice = 3 THEN
    ...
 END IF;
  END open_cust_cur_var;
END cust_data;
/
```

Step 3: Fetching from a Cursor Variable

- Retrieve rows from the result set one at a time.

```
FETCH cursor_variable_name
  INTO variable_name1
       [,variable_name2,. . .]
       | record_name;
```

- The return type of the cursor variable must be compatible with the variables named in the `INTO` clause of the `FETCH` statement.

Step 3: Fetching from a Cursor Variable

The `FETCH` statement retrieves rows from the result set one at a time. PL/SQL verifies that the return type of the cursor variable is compatible with the `INTO` clause of the `FETCH` statement. For each query column value returned, there must be a type-compatible variable in the `INTO` clause. Also, the number of query column values must equal the number of variables. In case of a mismatch in number or type, the error occurs at compile time for strongly typed cursor variables and at run time for weakly typed cursor variables.

Note: When you declare a cursor variable as the formal parameter of a subprogram that fetches from a cursor variable, you must specify the `IN` (or `IN OUT`) mode. If the subprogram also opens the cursor variable, you must specify the `IN OUT` mode.

Step 4: Closing a Cursor Variable

- Disable a cursor variable.
- The result set is undefined.

```
CLOSE cursor_variable_name;
```

- Accessing the cursor variable after it is closed raises the predefined exception `INVALID_CURSOR`.

Step 4: Closing a Cursor Variable

The `CLOSE` statement disables a cursor variable, after which the result set is undefined. The syntax is:

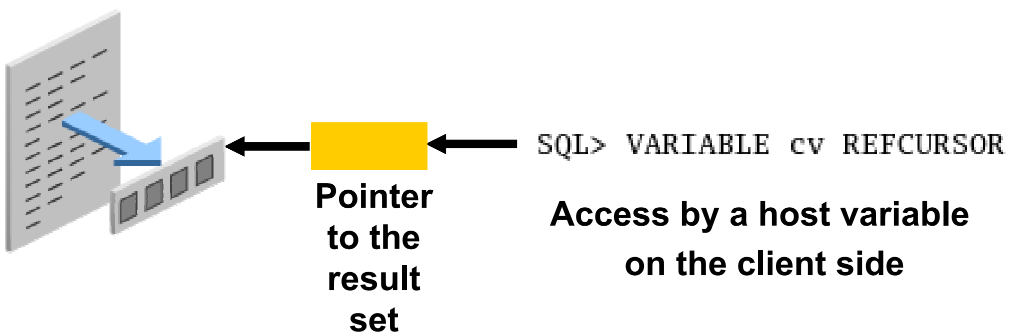
```
CLOSE cursor_variable_name;
```

In the following example, the cursor is closed when the last row is processed:

```
...
  LOOP
    FETCH cv_cust INTO cust_rec;
    EXIT WHEN cv_cust%NOTFOUND;
    ...
  END LOOP;
  CLOSE cv_cust;
...
```

Passing Cursor Variables as Arguments

You can pass query result sets among PL/SQL-stored subprograms and various clients.



Passing Cursor Variables as Arguments

Cursor variables are very useful for passing 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 that identifies the result set. For example, an Oracle Call Interface (OCI) client, or an Oracle Forms application, or the Oracle server can all refer to the same work area. This might be useful in Oracle Forms, for instance, when you want to populate a multiple-block form.

Example

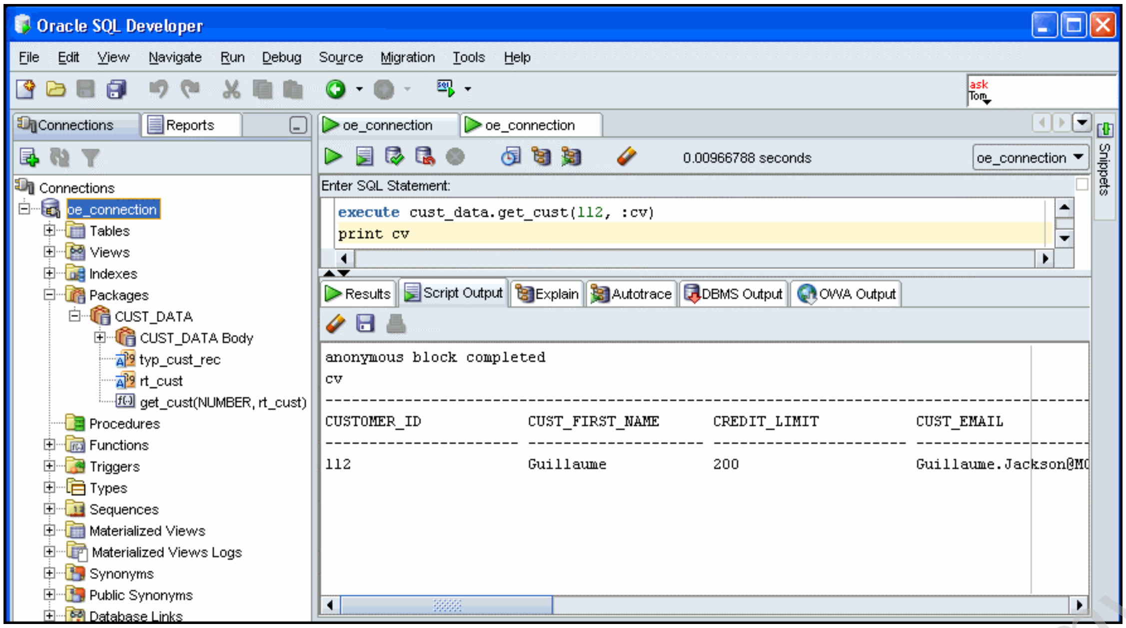
Using SQL*Plus, define a host variable with a data type of `REFCURSOR` to hold the query results generated from a `REF CURSOR` in a stored subprogram. Use the SQL*Plus `PRINT` command to view the host variable results. Optionally, you can set the SQL*Plus command `SET AUTOPRINT ON` to display the query results automatically.

```
SQL> VARIABLE cv REFCURSOR
```

Next, create a subprogram that uses a `REF CURSOR` to pass the cursor variable data back to the SQL*Plus environment.

Note: You can define a host variable in SQL*Plus or SQL Developer. This slide uses SQL*Plus. The next slide shows the use of SQL Developer.

Passing Cursor Variables as Arguments



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Passing Cursor Variables as Arguments (continued)

```
CREATE OR REPLACE PACKAGE cust_data AS
TYPE typ_cust_rec IS RECORD
   (cust_id NUMBER(6), custname VARCHAR2(20),
    credit   NUMBER(9,2), cust_email VARCHAR2(30));
TYPE rt_cust IS REF CURSOR RETURN typ_cust_rec;
PROCEDURE get_cust
  (p_custid IN NUMBER, p_cv_cust IN OUT rt_cust);
END;
/
```

Passing Cursor Variables as Arguments (continued)

```
CREATE OR REPLACE PACKAGE BODY cust_data AS
 PROCEDURE get_cust
   (p_custid IN NUMBER, p_cv_cust IN OUT rt_cust)
 IS
 BEGIN
   OPEN p_cv_cust FOR
SELECT customer_id, cust_first_name, credit_limit, cust_email
     FROM customers
     WHERE customer_id = p_custid;
-- CLOSE p_cv_cust
 END;
END;
/
```

Note that the `CLOSE p_cv_cust` statement is commented. This is done because, if you close the `REF` cursor, it is not accessible from the host variable.

Using the Predefined Type SYS_REFCURSOR

```
CREATE OR REPLACE PROCEDURE REFCUR
(p_num IN NUMBER)
IS
refcur sys_refcursor;
empno          emp.empno%TYPE;
ename          emp.ename%TYPE;
BEGIN
IF p_num = 1 THEN
    OPEN refcur FOR SELECT empno, ename FROM emp;
    DBMS_OUTPUT.PUT_LINE('Employee#    Name');
    DBMS_OUTPUT.PUT_LINE('-----    -------');
    LOOP
        FETCH refcur INTO empno, ename;
        EXIT WHEN refcur%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(empno || '         ' || ename);
    END LOOP;
ELSE
....
```

SYS_REFCURSOR is a built-in REF CURSOR type that allows any result set to be associated with it.

Using the Predefined Type SYS_REFCURSOR

You can define a cursor variable by using the built-in SYS_REFCURSOR data type as well as by creating a REF CURSOR type, and then declaring a variable of that type. SYS_REFCURSOR is a REF CURSOR type that allows any result set to be associated with it. As mentioned earlier, this is known as a *weak* (nonrestrictive) REF CURSOR.

SYS_REFCURSOR can be used to:

- Declare a cursor variable in an Oracle stored procedure or function
- Pass cursors from and to an Oracle stored procedure or function

Note: *Strong* (restrictive) REF CURSORS require the result set to conform to a declared number and order of fields with compatible data types, and can also, optionally, return a result set.

```
CREATE OR REPLACE PROCEDURE REFCUR
(p_num IN NUMBER)
IS
refcur sys_refcursor;
empno          emp.empno%TYPE;
ename          emp.ename%TYPE;
BEGIN
```

-- continued on the next page

Using the Predefined Type SYS_REFCURSOR (continued)

```
-- continued from the previous page
IF p_num = 1 THEN
    OPEN refcur FOR SELECT empno, ename FROM emp;
    DBMS_OUTPUT.PUT_LINE('Employee#    Name');
    DBMS_OUTPUT.PUT_LINE('-----    -------');
    LOOP
        FETCH refcur INTO empno, ename;
        EXIT WHEN refcur%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(empno || '        ' || ename);
    END LOOP;
ELSE
OPEN refcur FOR
  SELECT empno, ename
  FROM emp WHERE deptno = 30;
    DBMS_OUTPUT.PUT_LINE('Employee#    Name');
    DBMS_OUTPUT.PUT_LINE('-----    -------');
    LOOP
        FETCH refcur INTO empno, ename;
        EXIT WHEN refcur%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(empno || '        ' || ename);
    END LOOP;
END IF;
    CLOSE refcur;
END;
/
```

Rules for Cursor Variables

- You cannot use cursor variables with remote subprograms on another server.
- You cannot use comparison operators to test cursor variables.
- You cannot assign a null value to cursor variables.
- You cannot use `REF CURSOR` types in `CREATE TABLE` or `VIEW` statements.
- Cursors and cursor variables are not interoperable.

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Restrictions

- Remote subprograms on another server cannot accept the values of cursor variables. Therefore, you cannot use remote procedure calls (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 open it in the server on the same server call.
- You cannot use comparison operators to test cursor variables for equality, inequality, or nullity.
- You cannot assign NULLs to a cursor variable.
- You cannot use the `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 the elements in an index by table, nested table, or `VARRAY` cannot store the values of cursor variables.
- Cursors and cursor variables are not interoperable, that is, you cannot use one where the other is expected.

Comparing Cursor Variables with Static Cursors

Cursor variables have the following benefits:

- Are dynamic and ensure more flexibility
- Are not tied to a single `SELECT` statement
- Hold the value of a pointer
- Can reduce network traffic
- Give access to query work areas after a block completes

Comparing Cursor Variables with Static Cursors

Cursor variables are dynamic and provide wider flexibility. Unlike static cursors, cursor variables are not tied to a single `SELECT` statement. In applications where `SELECT` statements may differ depending on various situations, the cursor variables can be opened for each of the `SELECT` statements. Because cursor variables hold the value of a pointer, they can be easily passed between programs, no matter where the programs exist.

Cursor variables can reduce network traffic by grouping `OPEN FOR` statements and sending them across the network only once. For example, the following PL/SQL block opens two cursor variables in a single round trip:

```
/* anonymous PL/SQL block in host environment */
BEGIN
   OPEN :cv_cust FOR SELECT * FROM customers;
   OPEN :cv_orders FOR SELECT * FROM orders;
END;
```

This may be useful in Oracle Forms, for instance, when you want to populate a multiple-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. This enables your OCI or Pro*C program to use these work areas for ordinary cursor operations.

Lesson Agenda

- Identifying guidelines for cursor design
- Using Cursor Variables
- Creating subtypes based on existing types

Predefined PL/SQL Data Types

Scalar Types

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

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

BOOLEAN

DATE
INTERVAL
TIMESTAMP

Composite Types

RECORD
TABLE
VARRAY

Reference Types

REF CURSOR
REF object_type

LOB Types

BFILE
BLOB
CLOB
NCLOB

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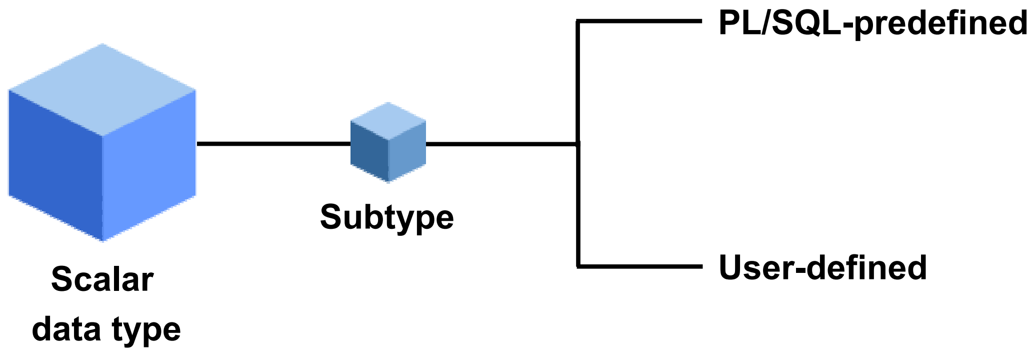
Predefined PL/SQL Data Types

Every constant, variable, and parameter has a data type, which specifies a storage format, a valid range of values, and constraints. PL/SQL provides a variety of predefined data types. For instance, you can choose from integer, floating point, character, Boolean, date, collection, reference, and LOB types. In addition, PL/SQL enables you to define subtypes.

Subtypes: Overview

A subtype is a subset of an existing data type that may place a constraint on its base type.



Subtypes: Overview

A subtype is a data type based on an existing data type. It does not define a new data type; instead, it places a constraint on an existing data type. There are several predefined subsets specified in the standard package. DECIMAL and INTEGER are subtypes of NUMBER. CHARACTER is a subtype of CHAR.

Standard Subtypes

BINARY_INTEGER	NUMBER	VARCHAR2
NATURAL NATURALN POSITIVE POSITIVEN SIGNTYPE	DEC DECIMAL DOUBLE PRECISION FLOAT INTEGER INT NUMERIC REAL SMALLINT	STRING VARCHAR

Subtypes: Overview (continued)

With NATURAL and POSITIVE subtypes, you can restrict an integer variable to nonnegative and positive values, respectively. NATURALN and POSITIVEN prevent the assigning of nulls to an integer variable. You can use SIGNTYPE to restrict an integer variable to the values –1, 0, and 1, which is useful in programming tri-state logic.

A constrained subtype is a subset of the values normally specified by the data type on which the subtype is based. POSITIVE is a constrained subtype of BINARY_INTEGER.

An unconstrained subtype is not a subset of another data type; it is an alias to another data type. FLOAT is an unconstrained subtype of NUMBER.

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.

You can even create your own user-defined subtypes.

Note: You can use these subtypes for compatibility with ANSI/ISO and IBM types. Currently, VARCHAR is synonymous with VARCHAR2. However, in future releases of PL/SQL, to accommodate emerging SQL standards, VARCHAR may become a separate data type with different comparison semantics. It is a good idea to use VARCHAR2 rather than VARCHAR.

Benefits of Subtypes

Subtypes:

- Increase reliability
- Provide compatibility with ANSI/ISO and IBM types
- Promote reusability
- Improve readability
  – Clarity
  – Code self-documents

Benefits of Subtypes

If your applications require a subset of an existing data type, you can create subtypes. By using subtypes, you can increase the reliability and improve the readability by indicating the intended use of constants and variables. Subtypes can increase reliability by detecting the out-of-range values.

With predefined subtypes, you have compatibility with other data types from other programming languages.

Declaring Subtypes

- Subtypes are defined in the declarative section of a PL/SQL block.

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

- *subtype_name* is a type specifier used in subsequent declarations.
- *base_type* is any scalar or user-defined PL/SQL type.

Declaring Subtypes

Subtypes are defined in the declarative section of a PL/SQL block, subprogram, or package.

Using the `SUBTYPE` keyword, you name the subtype and provide the name of the base type. You can use the `%TYPE` attribute on the base type to pick up a data type from a database column or from an existing variable data type. You can also use the `%ROWTYPE` attribute.

Examples

```
CREATE OR REPLACE PACKAGE mytypes
IS
  SUBTYPE    Counter IS INTEGER;   -- based on INTEGER type
  TYPE typ_TimeRec IS RECORD (minutes INTEGER, hours
  INTEGER);
  SUBTYPE Time IS typ_TimeRec;    -- based on RECORD type
  SUBTYPE ID_Num IS customers.customer_id%TYPE;
  CURSOR cur_cust IS SELECT * FROM customers;
  SUBTYPE CustFile IS cur_cust%ROWTYPE; -- based on cursor
END mytypes;
/
```

Using Subtypes

- Define a variable that uses the subtype in the declarative section.

```
identifier_name  subtype_name;
```

- You can constrain a user-defined subtype when declaring variables of that type.

```
identifier_name  subtype_name(size);
```

- You can constrain a user-defined subtype when declaring the subtype.

Using Subtypes

After a subtype is declared, you can assign an identifier for that subtype. Subtypes can increase reliability by detecting out-of-range values.

```
DECLARE
  v_rows     mytypes.Counter; --use package subtype dfn
  v_customers  mytypes.Counter;
  v_start_time mytypes.Time;
  SUBTYPE    Accumulator IS NUMBER;
  v_total     Accumulator(4,2);
SUBTYPE    Scale IS NUMBER(1,0);   -- constrained subtype
  v_x_axis     Scale;  -- magnitude range is -9 .. 9
BEGIN
  v_rows := 1;
  v_start_time.minutes := 15;
  v_start_time.hours   := 03;
 dbms_output.put_line('Start time is: '||
 v_start_time.hours|| ':' || v_start_time.minutes);
END;
/
```

Subtype Compatibility

An unconstrained subtype is interchangeable with its base type.

```
DECLARE
  SUBTYPE Accumulator IS NUMBER (4,2);
  v_amount  accumulator;
  v_total   NUMBER;
BEGIN
  v_amount := 99.99;
  v_total  := 100.00;
  dbms_output.put_line('Amount is: ' || v_amount);
  dbms_output.put_line('Total is: '  || v_total);
  v_total := v_amount;
  dbms_output.put_line('This works too: '  ||
  v_total);
  --  v_amount := v_amount + 1; Will show value error
END;
/
```


Subtype Compatibility

Some applications require constraining subtypes to a size specification for scientific purposes. The example in the slide shows that if you exceed the size of your subtype, you receive an error.

An unconstrained subtype is interchangeable with its base type. Different subtypes are interchangeable if they have the same base type. Different subtypes are also interchangeable if their base types are in the same data type family.

```
DECLARE
   v_rows      mytypes.Counter;  v_customers mytypes.Counter;
   SUBTYPE     Accumulator IS NUMBER (6,2);
   v_total     NUMBER;
BEGIN
   SELECT COUNT(*) INTO v_customers FROM customers;
   SELECT COUNT(*) INTO v_rows FROM orders;
   v_total := v_customers + v_rows;
   DBMS_OUTPUT.PUT_LINE('Total rows from 2 tables: '||
   v_total);
EXCEPTION
   WHEN value_error THEN
   DBMS_OUTPUT.PUT_LINE('Error in data type.');
END;
```

Summary

In this lesson, you should have learned how to:
- Use guidelines for cursor design
- Declare, define, and use cursor variables
- Use subtypes as data types

Summary

- Use the guidelines for designing the cursors.
- Take advantage of the features of cursor variables and pass pointers to result sets to different applications.
- You can use subtypes to organize and strongly type data types for an application.

Practice 3: Overview

This practice covers the following topics:

- Determining the output of a PL/SQL block
- Improving the performance of a PL/SQL block
- Implementing subtypes
- Using cursor variables

Practice 3: Overview

In this practice, you determine the output of a PL/SQL code snippet and modify the snippet to improve performance. Next, you implement subtypes and use cursor variables to pass values to and from a package.

Practice 3: Designing PL/SQL Code

Note: The files mentioned in the practice exercises are found in the `/labs` folder. Additionally, solution scripts are provided for each question and are located in the `/soln` folder. Your instructor will provide you with the exact location of these files. Connect as `OE` to perform the steps.

1. Determine the output of the following code snippet in the `lab_03_01.sql` file.

```
SET SERVEROUTPUT ON
BEGIN
 UPDATE orders SET order_status = order_status;
 FOR v_rec IN ( SELECT order_id FROM orders )
 LOOP
      IF SQL%ISOPEN THEN
         DBMS_OUTPUT.PUT_LINE('TRUE - ' || SQL%ROWCOUNT);
      ELSE
         DBMS_OUTPUT.PUT_LINE('FALSE - ' || SQL%ROWCOUNT);
      END IF;
 END LOOP;
END;
/
```

2. Modify the following code snippet in the `lab_03_02.sql` file to make better use of the `FOR UPDATE` clause and improve the performance of the program.

```
DECLARE
 CURSOR cur_update
    IS SELECT * FROM customers
    WHERE credit_limit < 5000 FOR UPDATE;
BEGIN
 FOR v_rec IN cur_update
 LOOP
      IF v_rec IS NOT NULL
      THEN
           UPDATE customers
           SET credit_limit = credit_limit + 200
           WHERE customer_id = v_rec.customer_id;
      END IF;
 END LOOP;
END;
/
```

Practice 3 (continued)

3. Create a package specification that defines subtypes, which can be used for the `warranty_period` field of the `product_information` table. Name this package `MY_TYPES`. The type needs to hold the month and year for a warranty period.

4. Create a package named `SHOW_DETAILS` that contains two subroutines. The first subroutine should show order details for the given `order_id`. The second subroutine should show customer details for the given `customer_id`, including the customer ID, the first name, phone numbers, credit limit, and email address. Both the subroutines should use the cursor variable to return the necessary details.

4

Working with Collections

Objectives

After completing this lesson, you should be able to do the following:

- Create collections
  - Nested table, varray
  - Associative arrays/PLSQL tables
    - Integer indexed
    - String indexed
- Use collections methods
- Manipulate collections
- Distinguish between the different types of collections and when to use them

Objectives

In this lesson, you are introduced to PL/SQL programming using collections.

A collection is an ordered group of elements, all of the same type (for example, phone numbers for each customer). Each element has a unique subscript that determines its position in the collection.

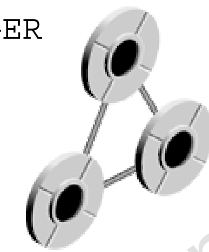
Collections work like the set, queue, stack, and hash table data structures found in most third-generation programming languages. Collections can store instances of an object type and can also be attributes of an object type. Collections can be passed as parameters. So, you can use them to move columns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

Lesson Agenda

- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Understanding Collections

- A collection is a group of elements, all of the same type.
- Collections work like arrays.
- Collections can store instances of an object type and, conversely, can be attributes of an object type.
- Types of collections in PL/SQL:
  - Associative arrays
    - String-indexed collections
    - `INDEX BY pls_integer` or `BINARY_INTEGER`
  - Nested tables
  - Varrays



Understanding Collections

A collection is a 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. Collections can also be passed as parameters. You can use them to move columns of data into and out of database tables, or between client-side applications and stored subprograms.

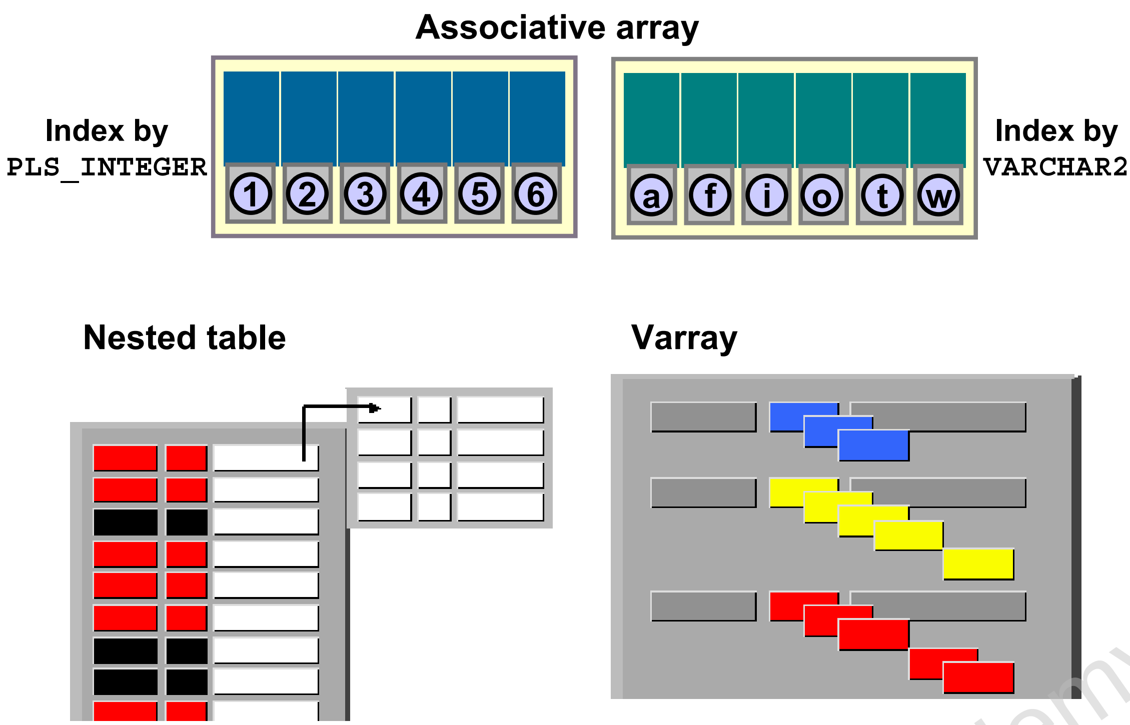
Object types are used not only to create object relational tables, but also to define collections.

You can use any of the three categories of collections:

- Associative arrays (known as "index by tables" in previous Oracle releases) are sets of key-value pairs, where each key is unique and is used to locate a corresponding value in the array. The key can be an integer or a string.
- Nested tables can have any number of elements.
- A varray is an ordered collection of elements.

Note: Associative arrays indexed by `pls_integer` are covered in the prerequisite courses—*Oracle Database 11g: Program with PL/SQL* and *Oracle Database 11g: Develop PL/SQL Program Units*—and are not emphasized in this course.

Collection Types



Collection Types

PL/SQL offers three collection types:

Associative Arrays

Associative arrays are sets of key-value pairs, where each key is unique and is used to locate a corresponding value in the array. The key can be either integer (`PLS_INTEGER` or `BINARY_INTEGER`) or character (`VARCHAR2`) based. Associative arrays may be sparse.

When you assign a value using a key for the first time, it adds that key to the associative array. Subsequent assignments using the same key update the same entry. However, it is important to choose a key that is unique. For example, the key values may come from the primary key of a database table, from a numeric hash function, or from concatenating strings to form a unique string value.

Because associative arrays are intended for storing temporary data, you cannot use them with SQL statements, such as `INSERT` and `SELECT INTO`. You can make them persistent for the life of a database session by declaring the type in a package and assigning the values in a package body. They are typically populated with a `SELECT BULK COLLECT` statement unless they are `VARCHAR2` indexed. `BULK COLLECT` prevents context switching between the SQL and PL/SQL engines, and is much more efficient on large data sets.

Collection Types (continued)

Nested Tables

A nested table holds a set of values. In other words, it is a table within a table. Nested tables are unbounded; that is, the size of the table can increase dynamically. Nested tables are available in both PL/SQL and the database. Within PL/SQL, nested tables are like one-dimensional arrays whose size can increase dynamically. Within the database, nested tables are column types that hold sets of values. The Oracle database stores the rows of a nested table in no particular order. When you retrieve a nested table from the database into a PL/SQL variable, the rows are given consecutive subscripts starting at 1. This gives you an array-like access to individual rows. Nested tables are initially dense, but they can become sparse through deletions and, therefore, have nonconsecutive subscripts.

Varrays

Variable-size arrays, or varrays, are also collections of homogeneous elements that hold a fixed number of elements (although you can change the number of elements at run time). They use sequential numbers as subscripts. You can define equivalent SQL types, thereby allowing varrays to be stored in database tables. They can be stored and retrieved through SQL, but with less flexibility than nested tables. You can reference the individual elements for array operations or manipulate the collection as a whole.

Varrays are always bounded and never sparse. You can specify the maximum size of the varray in its type definition. Its index has a fixed lower bound of 1 and an extensible upper bound. A varray can contain a varying number of elements, from zero (when empty) to the maximum specified in its type definition.

Choosing a PL/SQL Collection Type

If you already have code or business logic that uses another language, you can usually translate that language's array and set the types directly to the PL/SQL collection types.

- Arrays in other languages become varrays in PL/SQL.
- Sets and bags in other languages become nested tables in PL/SQL.
- Hash tables and other kinds of unordered lookup tables in other languages become associative arrays in PL/SQL.

If you are writing original code or designing the business logic from the start, consider the strengths of each collection type and decide which is appropriate.

Why Use Collections?

Collections offer object-oriented features such as variable-length arrays and nested tables that provide higher-level ways to organize and access data in the database. Below the object layer, data is still stored in columns and tables, but you are able to work with the data in terms of the real-world entities, such as customers and purchase orders, that make the data meaningful.

Lesson Agenda

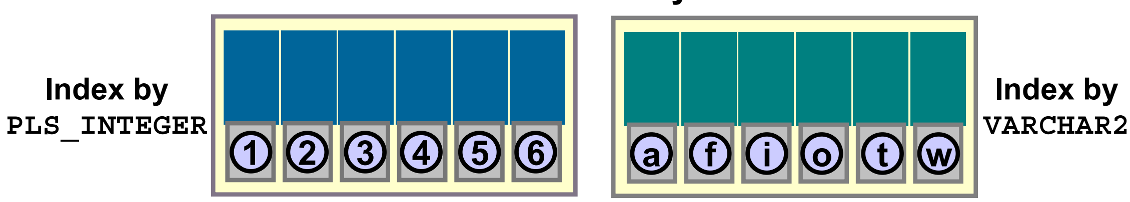
- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Using Associative Arrays

Associative arrays:

- That are indexed by strings can improve performance
- Are pure memory structures that are much faster than schema-level tables
- Provide significant additional flexibility

Associative arrays



Using Associative Arrays

Associative arrays (known as “index by tables” in previous Oracle releases) are sets of key-value pairs, where each key is unique and is used to locate a corresponding value in the array. The key can be an integer or a string.

When to Use String-Indexed Arrays

You can use `INDEX BY VARCHAR2` tables (also known as string-indexed arrays). These tables are optimized for efficiency by implicitly using the B*-tree organization of the values.

The `INDEX BY VARCHAR2` table is optimized for efficiency of lookup on a nonnumeric key, where the notion of sparseness is not applicable. In contrast, the `INDEX BY PLS_INTEGER` tables are optimized for compactness of storage on the assumption that the data is dense.

Note: Associative arrays indexed by `PLS_INTEGER` are covered in the prerequisite courses—*Oracle Database 11g: Program with PL/SQL* and *Oracle Database 11g: Develop PL/SQL Program Units*—and are not emphasized in this course.

Creating the Array

Associative array in PL/SQL (string-indexed):

```
TYPE type_name IS TABLE OF  element_type
INDEX BY VARCHAR2(size)
```

```
CREATE OR REPLACE PROCEDURE report_credit
  (p_last_name    customers.cust_last_name%TYPE,
   p_credit_limit customers.credit_limit%TYPE)
IS
  TYPE  typ_name IS TABLE OF customers%ROWTYPE
    INDEX BY customers.cust_email%TYPE;
  v_by_cust_email   typ_name;
  i VARCHAR2(30);

  PROCEDURE load_arrays IS
  BEGIN
    FOR rec IN  (SELECT * FROM customers WHERE cust_email IS NOT NULL)
      LOOP
        -- Load up the array in single pass to database table.
         v_by_cust_email (rec.cust_email) := rec;
      END LOOP;
  END;
...
```


Using String-Indexed Arrays

If you need to do heavy processing of customer information in your program that requires going back and forth over the set of selected customers, you can use string-indexed arrays to store, process, and retrieve the required information.

This can also be done in SQL but probably in a less efficient implementation. If you need to do multiple passes over a significant set of static data, you can instead move it from the database to a set of collections. Accessing collection-based data is much faster than going through the SQL engine.

After transferring the data from the database to the collections, you can use string- and integer-based indexing on those collections to, in essence, mimic the primary key and unique indexes on the table.

In the `REPORT_CREDIT` procedure shown in the slide, you may need to determine whether a customer has adequate credit. The string-indexed collection is loaded with the customer information in the `LOAD_ARRAYS` procedure. In the main body of the program, the collection is traversed to find the credit information. The email name is reported in case more than one customer has the same last name.

Populating the Array

```
...
BEGIN
  load_arrays;
  i:= v_by_cust_email.FIRST;
  dbms_output.put_line ('For credit amount of: ' || p_credit_limit);
  WHILE i IS NOT NULL LOOP
    IF v_by_cust_email(i).cust_last_name = p_last_name
    AND v_by_cust_email(i).credit_limit > p_credit_limit
      THEN dbms_output.put_line ( 'Customer '||
        v_by_cust_email(i).cust_last_name || ': ' ||
        v_by_cust_email(i).cust_email || ' has credit limit of: ' ||
        v_by_cust_email(i).credit_limit);
    END IF;
    i := v_by_cust_email.NEXT(i);
  END LOOP;
END report_credit;
/
```

```
EXECUTE report_credit('Walken', 1200)

For credit amount of: 1200
Customer Walken: Emmet.Walken@LIMPKIN.COM has credit limit of: 3600
Customer Walken: Prem.Walken@BRANT.COM has credit limit of: 3700
```


Using String-Indexed Arrays (continued)

In this example, the string-indexed collection is traversed using the `NEXT` method.

A more efficient use of the string-indexed collection is to index the collection with the customer email. Then you can immediately access the information based on the customer email key. You would need to pass the email name instead of the customer last name.

Using String-Indexed Arrays (continued)

Here is the modified code:

```
CREATE OR REPLACE PROCEDURE report_credit
  (p_email    customers.cust_last_name%TYPE,
   p_credit_limit customers.credit_limit%TYPE)
IS
  TYPE  typ_name IS TABLE OF customers%ROWTYPE
    INDEX BY customers.cust_email%TYPE;
  v_by_cust_email   typ_name;
  i VARCHAR2(30);

  PROCEDURE load_arrays IS
  BEGIN
    FOR rec IN  (SELECT * FROM customers
                 WHERE cust_email IS NOT NULL) LOOP
        v_by_cust_email (rec.cust_email) := rec;
    END LOOP;
  END;

BEGIN
  load_arrays;
  dbms_output.put_line
    ('For credit amount of: ' || p_credit_limit);
  IF v_by_cust_email(p_email).credit_limit > p_credit_limit
        THEN dbms_output.put_line ( 'Customer '||
          v_by_cust_email(p_email).cust_last_name ||
          ': ' || v_by_cust_email(p_email).cust_email ||
          ' has credit limit of: ' ||
          v_by_cust_email(p_email).credit_limit);
  END IF;
END report_credit;
/

EXECUTE report_credit('Prem.Walken@BRANT.COM', 100)

For credit amount of: 100
Customer Walken: Prem.Walken@BRANT.COM has credit limit of:
3700

PL/SQL procedure successfully completed.
```

Lesson Agenda

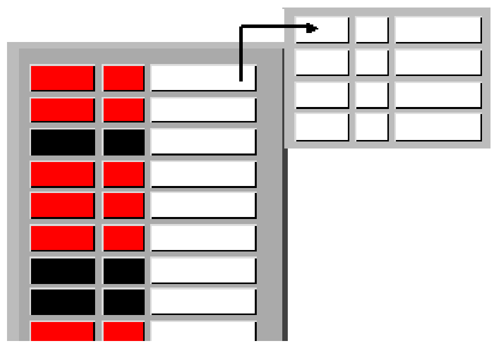
- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Using Nested Tables

Nested table characteristics:

- A table within a table
- Unbounded
- Available in both SQL and PL/SQL as well as the database
- Array-like access to individual rows

Nested table:



Nested Tables

A nested table holds a set of values. In other words, it is a table within a table. Nested tables are unbounded, meaning that the size of the table can increase dynamically. Nested tables are available in both PL/SQL as well as the database. Within PL/SQL, nested tables are like one-dimensional arrays whose size can increase dynamically. Within the database, nested tables are column types that hold sets of values. The Oracle database stores the rows of a nested table in no particular order. When you retrieve a nested table from the database into a PL/SQL variable, the rows are given consecutive subscripts starting at 1. This gives you an array-like access to individual rows.

Nested tables are initially dense, but they can become sparse through deletions and, therefore, have nonconsecutive subscripts.

Nested Table Storage

Nested tables are stored out-of-line in storage tables.

`pOrder` nested table:

ORDID	SUPPLIER	REQUESTER	ORDERED	ITEMS
500	50	5000	30-OCT-07	
800	80	8000	31-OCT-07	

Storage table:

NESTED_TABLE_ID	PRODID	PRICE
	55	555
	56	566
	57	577

NESTED_TABLE_ID	PRODID	PRICE
	88	888

Nested Table Storage

The rows for all nested tables of a particular column are stored within the same segment. This segment is called the *storage table*.

A storage table is a system-generated segment in the database that holds instances of nested tables within a column. You specify a name for the storage table by using the `NESTED TABLE STORE AS` clause in the `CREATE TABLE` statement. The storage table inherits storage options from the outermost table.

To distinguish between nested table rows belonging to different parent table rows, a system-generated nested table identifier that is unique for each outer row enclosing a nested table is created.

Operations on storage tables are performed implicitly by the system. You should not access or manipulate the storage table, except implicitly through its containing objects.

The column privileges of the parent table are transferred to the nested table.

Creating Nested Tables

To create a nested table in the database:

```
CREATE [OR REPLACE] TYPE type_name AS TABLE OF
Element_datatype [NOT NULL];
```

To create a nested table in PL/SQL:

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


Creating Collection Types

To create a collection, you first define a collection type, and then declare collections of that type. The slide shows the syntax for defining the nested table collection type in both the database (persistent) and in PL/SQL (transient).

Creating Collections in the Database

You can create a nested table data type in the database, which makes the data type available to use in places such as columns in database tables, variables in PL/SQL programs, and attributes of object types.

Before you can define a database table containing a nested table, you must first create the data type for the collection in the database.

Use the syntax shown in the slide to create collection types in the database.

Creating Collections in PL/SQL

You can also create a nested table in PL/SQL. Use the syntax shown in the slide to create collection types in PL/SQL.

Note: Collections can be nested. Collections of collections are also possible.

Declaring Collections: Nested Table

- First, define an object type:

```
CREATE TYPE typ_item AS OBJECT  --create object
  (prodid  NUMBER(5),
   price   NUMBER(7,2) )
/
CREATE TYPE typ_item_nst -- define nested table type
   AS TABLE OF typ_item
/
```

1

2

- Second, declare a column of that collection type:

```
CREATE TABLE pOrder (  -- create database table
     ordid    NUMBER(5),
     supplier NUMBER(5),
     requester      NUMBER(4),
     ordered  DATE,
     items    typ_item_nst)
     NESTED TABLE items STORE AS item_stor_tab
/
```

3

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Declaring Collections: Nested Table

To create a table based on a nested table, perform the following steps:

1. Create the `typ_item` type, which holds the information for a single line item.
2. Create the `typ_item_nst` type, which is created as a table of the `typ_item` type.
   Note: You must create the `typ_item_nst` nested table type based on the previously declared type, because it is illegal to declare multiple data types in this nested table declaration.
3. Create the `pOrder` table and use the nested table type in a column declaration, which includes an arbitrary number of items based on the `typ_item_nst` type. Thus, each row of `pOrder` may contain a table of items.
   The `NESTED TABLE STORE AS` clause is required to indicate the name of the storage table in which the rows of all values of the nested table reside. The storage table is created in the same schema and the same tablespace as the parent table.
   Note: The `USER_COLL_TYPES` dictionary view holds information about collections.

Using Nested Tables

- Add data to the nested table:

```
INSERT INTO pOrder
  VALUES (500, 50, 5000, sysdate, typ_item_nst(
      typ_item(55, 555),
      typ_item(56, 566),
      typ_item(57, 577)));

INSERT INTO pOrder
  VALUES (800, 80, 8000, sysdate,
    typ_item_nst (typ_item (88, 888)));
```

1

2

`pOrder` **nested table**

ORDID	SUPPLIER	REQUESTER	ORDERED	ITEMS
500	50	5000	30-OCT-07	
800	80	8000	31-OCT-07	

PRODID	PRICE
55	555
56	566
57	577

1

PRODID	PRICE
88	888

2

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Using Nested Tables

To insert data into the nested table, you use the `INSERT` statement. A constructor is a system-defined function that is used to identify where the data should be placed, essentially "constructing" the collection from the elements passed to it.

In the example in the slide, the constructors are `TYP_ITEM_NST()` and `TYP_ITEM()`. You pass two elements to the `TYP_ITEM()` constructor, and then pass the results to the `TYP_ITEM_NST()` constructor to build the nested table structure.

The first `INSERT` statement builds the nested table with three subelement rows.

The second `INSERT` statement builds the nested table with one subelement row.

Using Nested Tables

- Querying the results:

```
SELECT * FROM porder;

     ORDID   SUPPLIER  REQUESTER ORDERED
---------- ---------- ---------- ---------
ITEMS(PRODID, PRICE)
-----------------------------------------------------------------
       500         50       5000 31-OCT-07
TYP_ITEM_NST(TYP_ITEM(55, 555), TYP_ITEM(56, 566), TYP_ITEM(57, 577))
       800         80       8000 31-OCT-07
TYP_ITEM_NST(TYP_ITEM(88, 888))
```

- Querying the results with the `TABLE` function:

```
SELECT p2.ordid, p1.*
FROM porder p2, TABLE(p2.items) p1;

     ORDID     PRODID      PRICE
---------- ---------- ----------
       800         88        888
       500         57        577
       500         55        555
       500         56        566
```


Querying Nested Tables

You can use two general methods to query a table that contains a column or attribute of a collection type. One method returns the collections nested in the result rows that contain them. By including the collection column in the `SELECT` list, the output shows as a row associated with the other row output in the `SELECT` list.

Another method to display the output is to unnest the collection such that each collection element appears on a row by itself. You can use the `TABLE` expression in the `FROM` clause to unnest a collection.

Querying Collections with the `TABLE` Expression

To view collections in a conventional format, you must unnest, or flatten, the collection attribute of a row into one or more relational rows. You can do this by using a `TABLE` expression with the collection. A `TABLE` expression enables you to query a collection in the `FROM` clause like a table. In effect, you join the nested table with the row that contains the nested table without writing a `JOIN` statement.

The collection column in the `TABLE` expression uses a table alias to identify the containing table.

Referencing Collection Elements

Use the collection name and a subscript to reference a collection element:

- Syntax:

```
collection_name(subscript)
```

- Example:

```
v_with_discount(i)
```

- To reference a field in a collection:

```
p_new_items(i).prodid
```

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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 can specify its subscript by using the following syntax:

```
collection_name(subscript)
```

In the preceding syntax, *subscript* is an expression that yields a positive integer. For nested tables, the integer must lie in the range 1 to 2147483647. For varrays, the integer must lie in the range 1 to maximum_size.

Using Nested Tables in PL/SQL

```
CREATE OR REPLACE PROCEDURE add_order_items
(p_ordid NUMBER, p_new_items typ_item_nst)
IS
  v_num_items      NUMBER;
  v_with_discount  typ_item_nst;
BEGIN
  v_num_items := p_new_items.COUNT;
  v_with_discount := p_new_items;
  IF v_num_items > 2 THEN
  --ordering more than 2 items gives a 5% discount
    FOR i IN 1..v_num_items LOOP
      v_with_discount(i) :=
      typ_item(p_new_items(i).prodid,
               p_new_items(i).price*.95);
    END LOOP;
  END IF;
  UPDATE pOrder
    SET  items = v_with_discount
    WHERE ordid = p_ordid;
END;
```


Using Nested Tables in PL/SQL

When you define a variable of a collection type in a PL/SQL block, it is transient and available only for the scope of the PL/SQL block.

In the example shown in the slide:

- The nested table `P_NEW_ITEMS` parameter is passed into the block.
- A local variable `V_WITH_DISCOUNT` is defined with the nested table data type `TYP_ITEM_NST`.
- A collection method, called `COUNT`, is used to determine the number of items in the nested table.
- If more than two items are counted in the collection, the local nested table variable `V_WITH_DISCOUNT` is updated with the product ID and a 5% discount on the price.
- To reference an element in the collection, the subscript `i`, representing an integer from the current loop iteration, is used with the constructor method to identify the row of the nested table.

Using Nested Tables in PL/SQL

```
-- caller pgm:
DECLARE
  v_form_items  typ_item_nst:= typ_item_nst();
BEGIN
  -- let's say the form holds 4 items
  v_form_items.EXTEND(4);
  v_form_items(1) := typ_item(1804, 65);
  v_form_items(2) := typ_item(3172, 42);
  v_form_items(3) := typ_item(3337, 800);
  v_form_items(4) := typ_item(2144, 14);
  add_order_items(800, v_form_items);
END;
```

`v_form_items` **variable**

PRODID	PRICE
1804	65
3172	42
3337	800
2144	14

Resulting data in the `pOrder` **nested table**

ORDID	SUPPLIER	REQUESTER	ORDERED	ITEMS
500	50	5000	30-OCT-07	
800	80	8000	31-OCT-07	

PRODID	PRICE
1804	65
3172	42
3337	800
2144	14

Using Nested Tables in PL/SQL (continued)

In the example code shown in the slide:

- A local PL/SQL variable of nested table type is declared and instantiated with the collection method `TYP_ITEM_NST()`.
- The nested table variable is extended to hold four rows of elements with the `EXTEND(4)` method.
- The nested table variable is populated with four rows of elements by constructing a row of the nested table with the `TYP_ITEM` constructor.
- The nested table variable is passed as a parameter to the `ADD_ORDER_ITEMS` procedure shown on the previous page.
- The `ADD_ORDER_ITEMS` procedure updates the `ITEMS` nested table column in the `pOrder` table with the contents of the nested table parameter passed into the routine.

Lesson Agenda

- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Understanding Varrays

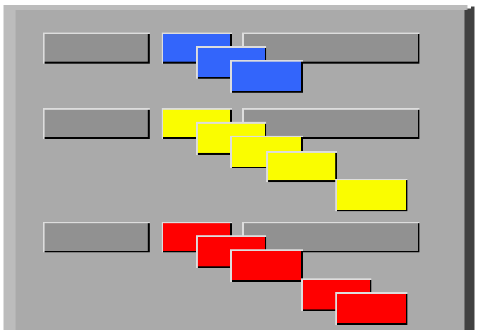
- To create a varray in the database:

```
CREATE [OR REPLACE] TYPE type_name AS VARRAY
(max_elements) OF element_datatype [NOT NULL];
```

- To create a varray in PL/SQL:

```
TYPE type_name IS VARRAY  (max_elements) OF
element_datatype [NOT NULL];
```

Varray:



Understanding Varrays

Varrays are also collections of homogeneous elements that hold a fixed number of elements (although you can change the number of elements at run time). They use sequential numbers as subscripts.

You can define varrays as a SQL type, thereby allowing varrays to be stored in database tables. They can be stored and retrieved through SQL, but with less flexibility than nested tables. You can reference individual elements for array operations, or manipulate the collection as a whole.

You can define varrays in PL/SQL to be used during PL/SQL program execution.

Varrays are always bounded and never sparse. You can specify the maximum size of the varray in its type definition. Its index has a fixed lower bound of 1 and an extensible upper bound. A varray can contain a varying number of elements, from zero (when empty) to the maximum specified in its type definition.

To reference an element, you can use the standard subscripting syntax.

Declaring Collections: Varray

- First, define a collection type:

```
CREATE TYPE typ_Project AS OBJECT(  --create object       1
   project_no NUMBER(4),
   title      VARCHAR2(35),
   cost       NUMBER(12,2))
/
CREATE TYPE typ_ProjectList AS VARRAY (50) OF typ_Project
      -- define VARRAY type                               2
/
```

- Second, declare a collection of that type:

```
CREATE TABLE department (  -- create database table      3
   dept_id  NUMBER(2),
   name     VARCHAR2(25),
   budget   NUMBER(12,2),
   projects typ_ProjectList)  -- declare varray as column
/
```


Example

The example above shows how to create a table based on a varray.

1. Create the TYP_PROJECT type, which holds the information for a project.
2. Create the TYP_ PROJECTLIST type, which is created as a varray of the project type. The varray contains a maximum of 50 elements.
3. Create the DEPARTMENT table and use the varray type in a column declaration. Each element of the varray will store a project object.

This example demonstrates how to create a varray of phone numbers, and then use it in a CUSTOMERS table (The OE sample schema uses this definition.):

```
CREATE TYPE phone_list_typ
AS VARRAY(5) OF VARCHAR2(25);
/
CREATE TABLE customers
(customer_id NUMBER(6)
,cust_first_name VARCHAR2(50)
,cust_last_name VARCHAR2(50)
,cust_address cust_address_typ(100)
,phone_numbers phone_list_typ
...
);
```

Using Varrays

Add data to the table containing a varray column:

```
INSERT INTO department
  VALUES (10, 'Executive Administration', 30000000,
      typ_ProjectList(
      typ_Project(1001, 'Travel Monitor',  400000),
      typ_Project(1002, 'Open World',    10000000)));

INSERT INTO department
  VALUES (20, 'Information Technology', 5000000,
      typ_ProjectList(
      typ_Project(2001, 'DB11gR2', 900000)));
```

DEPARTMENT table

DEPT_ID	NAME	BUDGET	PROJECTS PROJECT_NO	TITLE	COSTS
10	Executive Administration	30000000	1001 1002	Travel Monitor Open World	400000 10000000
20	Information Technology	5000000	2001	DB11gR2	900000

Example (continued)

To add rows to the DEPARTMENT table that contains the PROJECTS varray column, you use the INSERT statement. The structure of the varray column is identified with the constructor methods.

- TYP_PROJECTLIST() constructor constructs the varray data type.
- TYP_PROJECT() constructs the elements for the rows of the varray data type.

The first INSERT statement adds three rows to the PROJECTS varray for department 10.

The second INSERT statement adds one row to the PROJECTS varray for department 20.

Using Varrays

- Querying the results:

```
SELECT * FROM department;

   DEPT_ID NAME                          BUDGET
---------- ------------------------- ----------
PROJECTS(PROJECT_NO, TITLE, COST)
-----------------------------------------------------------------
        10 Executive Administration    30000000
TYP_PROJECTLIST(TYP_PROJECT(1001, 'Travel Monitor', 400000),
TYP_PROJECT(1002, 'Open World', 10000000))
        20 Information Technology       5000000
TYP_PROJECTLIST(TYP_PROJECT(2001, 'DB11gR2', 900000))
```

- Querying the results with the `TABLE` function:

```
SELECT d2.dept_id, d2.name, d1.*
FROM department d2, TABLE(d2.projects) d1;

DEPT_ID NAME                      PROJECT_NO TITLE             COST
------- ------------------------ ---------- -------------  --------
     10 Executive Administration       1001 Travel Monitor    400000
     10 Executive Administration       1002 Open World      10000000
     20 Information Technology         2001 DB11gR2           900000
```


Querying Varray Columns

You query a varray column in the same way that you query a nested table column.

In the first example in the slide, the collections are nested in the result rows that contain them. By including the collection column in the `SELECT` list, the output shows as a row associated with the other row output in the `SELECT` list.

In the second example, the output is unnested such that each collection element appears on a row by itself. You can use the `TABLE` expression in the `FROM` clause to unnest a collection.

Lesson Agenda

- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Working with Collections in PL/SQL

- You can declare collections as the formal parameters of procedures and functions.
- You can specify a collection type in the `RETURN` clause of a function specification.
- Collections follow the usual scoping and instantiation rules.

```
CREATE OR REPLACE PACKAGE manage_dept_proj
AS
  PROCEDURE allocate_new_proj_list
    (p_dept_id NUMBER, p_name VARCHAR2, p_budget NUMBER);
  FUNCTION get_dept_project (p_dept_id NUMBER)
    RETURN typ_projectlist;
  PROCEDURE update_a_project
    (p_deptno NUMBER, p_new_project typ_Project,
     p_position NUMBER);
  FUNCTION manipulate_project (p_dept_id NUMBER)
    RETURN typ_projectlist;
  FUNCTION check_costs (p_project_list typ_projectlist)
    RETURN boolean;
END manage_dept_proj;
```


Working with Collections in PL/SQL

There are several points about collections that you must know when working with them:

- 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.
- A function's `RETURN` clause can be a collection type.
- 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.

Working with Collections: Example

This is the package body for the varray examples shown on the subsequent pages.

```
CREATE OR REPLACE PACKAGE BODY manage_dept_proj
AS
  PROCEDURE allocate_new_proj_list
    (p_dept_id NUMBER, p_name VARCHAR2, p_budget NUMBER)
  IS
    v_accounting_project typ_projectlist;
  BEGIN   -- this example uses a constructor
    v_accounting_project :=
      typ_ProjectList
        (typ_Project (1, 'Dsgn New Expense Rpt', 3250),
         typ_Project (2, 'Outsource Payroll', 12350),
         typ_Project (3, 'Audit Accounts Payable',1425));
    INSERT INTO department VALUES
      (p_dept_id, p_name, p_budget, v_accounting_project);
  END allocate_new_proj_list;

  FUNCTION get_dept_project (p_dept_id NUMBER)
    RETURN typ_projectlist
  IS
    v_accounting_project typ_projectlist;
  BEGIN
   -- this example uses a fetch from the database
     SELECT  projects
       INTO  v_accounting_project
       FROM  department
       WHERE dept_id = p_dept_id;
     RETURN v_accounting_project;
  END get_dept_project;

PROCEDURE update_a_project
    (p_deptno NUMBER, p_new_project typ_Project,
     p_position NUMBER)
  IS
     v_my_projects typ_ProjectList;
  BEGIN
    v_my_projects := get_dept_project (p_deptno);
    v_my_projects.EXTEND;   --make room for new project
    /* Move varray elements forward */
    FOR i IN REVERSE p_position..v_my_projects.LAST - 1 LOOP
      v_my_projects(i + 1) := v_my_projects(i);
    END LOOP;
    v_my_projects(p_position) := p_new_project; -- add new
                                                -- project
    UPDATE department SET projects = v_my_projects
      WHERE dept_id = p_deptno;
  END update_a_project;
```

-- continued on next page

Working with Collections: Example (continued)

-- continued from previous page

```
  FUNCTION manipulate_project (p_dept_id NUMBER)
    RETURN typ_projectlist
  IS
    v_accounting_project typ_projectlist;
    v_changed_list typ_projectlist;
  BEGIN
    SELECT  projects
       INTO  v_accounting_project
       FROM  department
       WHERE dept_id = p_dept_id;
  -- this example assigns one collection to another
    v_changed_list := v_accounting_project;
    RETURN v_changed_list;
  END manipulate_project;

  FUNCTION check_costs (p_project_list typ_projectlist)
    RETURN boolean
  IS
    c_max_allowed        NUMBER := 10000000;
    i                    INTEGER;
    v_flag               BOOLEAN := FALSE;
  BEGIN
    i := p_project_list.FIRST ;
    WHILE i IS NOT NULL LOOP
      IF p_project_list(i).cost > c_max_allowed then
        v_flag := TRUE;
        dbms_output.put_line (p_project_list(i).title ||
                         ' exceeded allowable budget.');
        RETURN TRUE;
      END IF;
    i := p_project_list.NEXT(i);
    END LOOP;
    RETURN null;
  END check_costs;

END manage_dept_proj;
```

Initializing Collections

Three ways to initialize:

- Use a constructor.
- Fetch from the database.
- Assign another collection variable directly.

```
PROCEDURE allocate_new_proj_list
   (p_dept_id NUMBER, p_name VARCHAR2, p_budget NUMBER)
 IS
   v_accounting_project typ_projectlist;
 BEGIN
 -- this example uses a constructor
   v_accounting_project :=
     typ_ProjectList
       (typ_Project (1, 'Dsgn New Expense Rpt', 3250),
        typ_Project (2, 'Outsource Payroll', 12350),
        typ_Project (3, 'Audit Accounts Payable',1425));
   INSERT INTO department
     VALUES(p_dept_id, p_name, p_budget, v_accounting_project);
 END allocate_new_proj_list;
```


Initializing 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 can use one of the following methods:

- Use a constructor, which is a system-defined function with the same name as the collection type. A constructor allows the creation of an object from an object type. Invoking a constructor is a way to instantiate (create) an object. This function "constructs" collections from the elements passed to it. In the example shown in the slide, you pass three elements to the `typ_ProjectList()` constructor, which returns a varray containing those elements.
- Read an entire collection from the database using a fetch.
- Assign another collection variable directly. You can copy the entire contents of one collection to another as long as both are built from the same data type.

Initializing Collections

```
FUNCTION get_dept_project (p_dept_id NUMBER)
   RETURN typ_projectlist
 IS
   v_accounting_project typ_projectlist;
 BEGIN  -- this example uses a fetch from the database
    SELECT  projects INTO  v_accounting_project
      FROM  department WHERE dept_id = p_dept_id;
    RETURN v_accounting_project;
 END get_dept_project;
```

1

```
FUNCTION manipulate_project (p_dept_id NUMBER)
   RETURN typ_projectlist
 IS
   v_accounting_project typ_projectlist;
   v_changed_list typ_projectlist;
 BEGIN
   SELECT  projects INTO  v_accounting_project
      FROM  department WHERE dept_id = p_dept_id;
 -- this example assigns one collection to another
   v_changed_list := v_accounting_project;
   RETURN v_changed_list;
 END manipulate_project;
```

2

Initializing Collections (continued)

In the first example shown in the slide, an entire collection from the database is fetched into the local PL/SQL collection variable.

In the second example in the slide, the entire content of one collection variable is assigned to another collection variable.

Referencing Collection Elements

```
-- sample caller program to the manipulate_project function
DECLARE
  v_result_list typ_projectlist;
BEGIN
  v_result_list := manage_dept_proj.manipulate_project(10);
  FOR i IN 1..v_result_list.COUNT LOOP
    dbms_output.put_line('Project #: '
                                ||v_result_list(i).project_no);
    dbms_output.put_line('Title: '||v_result_list(i).title);
    dbms_output.put_line('Cost: ' ||v_result_list(i).cost);
  END LOOP;

END;
```

```
Project #: 1001
Title: Travel Monitor
Cost: 400000
Project #: 1002
Title: Open World
Cost: 10000000
```


Referencing Collection Elements

In the example in the slide, the code calls the MANIPULATE PROJECT function in the MANAGE_DEPT_PROJ package. Department 10 is passed in as the parameter. The output shows the varray element values for the PROJECTS column in the DEPARTMENT table for department 10.

Whereas the value of 10 is hard-coded, you can have a form interface to query the user for a department value that can then be passed into the routine.

Using Collection Methods

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

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


Using Collection Methods

You can use collection methods from procedural statements but not from SQL statements.

Here is a list of some of the collection methods that you can use. You have already seen a few in the preceding examples.

Using Collection Methods (continued)

Function or Procedure	Description
`EXISTS`	Returns `TRUE` if the nth element in a collection exists; otherwise, `EXISTS(N)` returns `FALSE.`
`COUNT`	Returns the number of elements that a collection contains.
`LIMIT`	For nested tables that have no maximum size, `LIMIT` returns `NULL`; for varrays, `LIMIT` returns the maximum number of elements that a varray can contain.
`FIRST` and `LAST`	Returns the first and last (smallest and largest) index numbers in a collection, respectively.
`PRIOR` and `NEXT`	`PRIOR(n)` returns the index number that precedes index `n` in a collection; `NEXT(n)` returns the index number that follows index `n`.
`EXTEND`	Appends one null element. `EXTEND(n)` appends `n` elements; `EXTEND(n, i)` appends `n` copies of the `i`th element.
`TRIM`	Removes one element from the end; `TRIM(n)` removes n elements from the end of a collection
`DELETE`	Removes all elements from a nested or associative array table. `DELETE(n)` removes the `n`th element ; `DELETE(m, n)` removes a range. **Note:** Does not work on varrays.

Using Collection Methods

Traverse collections with the following methods:

```
FUNCTION check_costs (p_project_list typ_projectlist)
    RETURN boolean
  IS
    c_max_allowed        NUMBER := 10000000;
    i                    INTEGER;
    v_flag               BOOLEAN := FALSE;
  BEGIN
    i := p_project_list.FIRST ;
    WHILE i IS NOT NULL LOOP
      IF p_project_list(i).cost > c_max_allowed then
        v_flag := TRUE;
        dbms_output.put_line (p_project_list(i).title || '
                              exceeded allowable budget.');
        RETURN TRUE;
      END IF;
    i := p_project_list.NEXT(i);
    END LOOP;
    RETURN null;
  END check_costs;
```


Traversing Collections

In the example in the slide, the FIRST method finds the smallest index number, the NEXT method traverses the collection starting at the first index.

You can use the PRIOR and NEXT methods to traverse collections indexed by any series of subscripts. In the example shown, the NEXT method is used to traverse a varray.

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 is the inverse of NEXT.

PRIOR and NEXT do not wrap from one end of a collection to the other.

When traversing elements, PRIOR and NEXT ignore deleted elements.

Using Collection Methods

```
-- sample caller program to check_costs
set serverout on
DECLARE
  v_project_list typ_projectlist;
BEGIN
  v_project_list := typ_ProjectList(
    typ_Project (1,'Dsgn New Expense Rpt', 3250),
    typ_Project (2, 'Outsource Payroll', 120000),
    typ_Project (3, 'Audit Accounts Payable',14250000));
  IF manage_dept_proj.check_costs(v_project_list) THEN
    dbms_output.put_line('Project rejected: overbudget');
  ELSE
    dbms_output.put_line('Project accepted, fill out forms.');
  END IF;
END;
```

```
Audit Accounts Payable exceeded allowable budget.
Project rejected: overbudget
```

V_PROJECT_LIST variable:

PROJECT_NO	TITLE	COSTS
1	Dsgn New Expense Rpt	3250
2	Outsource Payroll	120000
3	Audit Accounts Payable	14250000

Traversing Collections (continued)

The code shown in the slide calls the CHECK_COSTS function (shown on the previous page). The CHECK_COSTS function accepts a varray parameter and returns a Boolean value. If it returns true, the costs for a project element are too high. The maximum budget allowed for a project element is defined by the C_MAX_ALLOWED constant in the function.

A project with three elements is constructed and passed to the CHECK_COSTS function. The CHECK_COSTS function returns true, because the third element of the varray exceeds the value of the maximum allowed costs.

Although the sample caller program has the varray values hard-coded, you could have some sort of form interface where the user enters the values for projects and the form calls the CHECK_COSTS function.

Manipulating Individual Elements

```
PROCEDURE update_a_project
    (p_deptno NUMBER, p_new_project typ_Project, p_position NUMBER)
  IS
     v_my_projects typ_ProjectList;
  BEGIN
    v_my_projects := get_dept_project (p_deptno);
    v_my_projects.EXTEND;     --make room for new project
    /* Move varray elements forward */
    FOR i IN REVERSE p_position..v_my_projects.LAST - 1 LOOP
      v_my_projects(i + 1) := v_my_projects(i);
    END LOOP;
    v_my_projects(p_position) := p_new_project; -- insert new one
   UPDATE department SET projects = v_my_projects
     WHERE dept_id = p_deptno;
  END update_a_project;
```


Manipulating Individual Elements

You must use PL/SQL procedural statements to reference the individual elements of a varray in an `INSERT`, `UPDATE`, or `DELETE` statement. In the example shown in the slide, the `UPDATE_A_PROJECT` procedure inserts a new project into a department's project list at a given position, and then updates the `PROJECTS` column with the newly entered value that is placed within the old collection values.

This code essentially shuffles the elements of a project so that you can insert a new element in a particular position.

Manipulating Individual Elements

```
-- check the table prior to the update:
SELECT d2.dept_id, d2.name, d1.*
FROM department d2, TABLE(d2.projects) d1;
```

```
DEPT_ID NAME                     PROJECT_NO TITLE                        COST
------- ------------------------ ---------- ---------------------------- --
     10 Executive Administration       1001 Travel Monitor             400000
     10 Executive Administration       1002 Open World               10000000
     20 Information Technology         2001 DB11gR2                    900000
```

```
-- caller program to update_a_project
BEGIN
  manage_dept_proj.update_a_project(20,
    typ_Project(2002, 'AQM', 80000), 2);
END;
```

```
-- check the table after the update:
SELECT d2.dept_id, d2.name, d1.*
FROM department d2, TABLE(d2.projects) d1;
```

```
DEPT_ID NAME                     PROJECT_NO TITLE                        COST
------- ------------------------ ---------- ---------------------------- --
     10 Executive Administration       1001 Travel Monitor             400000
     10 Executive Administration       1002 Open World               10000000
     20 Information Technology         2001 DB11gR2                    900000
     20 Information Technology         2002 AQM                         80000
```


Manipulating Individual Elements (continued)

To execute the procedure, pass the department number to which you want to add a project, the project information, and the position where the project information is to be inserted.

The third code box shown in the slide identifies that a project element should be added to the second position for project 2002 in department 20.

If you execute the following code, the AQM project element is shuffled to position 3 and the CQN project element is inserted at position 2. :

```
BEGIN
  manage_dept_proj.update_a_project(20,
    typ_Project(2003, 'CQN', 85000), 2);
END;
```

What happens if you request a project element to be inserted at position 5?

Lesson Agenda

- Understanding collections
- Using associative arrays
- Using nested tables
- Using varrays
- Working with collections
- Programming for collection exceptions
- Summarizing collections

Avoiding Collection Exceptions

Common exceptions with collections:

- COLLECTION_IS_NULL
- NO_DATA_FOUND
- SUBSCRIPT_BEYOND_COUNT
- SUBSCRIPT_OUTSIDE_LIMIT
- VALUE_ERROR

Avoiding Collection Exceptions

In most cases, if you reference a nonexistent collection element, PL/SQL raises a predefined exception.

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

Avoiding Collection Exceptions: Example

Common exceptions with collections:

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


Avoiding Collection Exceptions: Example

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 an element that was deleted.

Lesson Agenda

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Listing Characteristics for Collections

	PL/SQL Nested Tables	DB Nested Tables	PL/SQL Varrays	DB Varrays	PL/SQL Associative Arrays
Maximum size	No	No	Yes	Yes	Dynamic
Sparsity	Can be	No	Dense	Dense	Yes
Storage	N/A	Stored out-of-line	N/A	Stored inline (if < 4,000 bytes)	N/A
Ordering	Does not retain ordering and subscripts	Does not retain ordering and subscripts	Retains ordering and subscripts	Retains ordering and subscripts	Retains ordering and subscripts

Choosing Between Nested Tables and Associative Arrays

- Use associative arrays when:
  - You need to collect information of unknown volume.
  - You need flexible subscripts (negative, nonsequential, or string-based).
  - You need to pass the collection to and from the database server (use associative arrays with the bulk constructs).
- Use nested tables when:
  - You need persistence.
  - You need to pass the collection as a parameter.

Choosing Between Nested Tables and Varrays

- Use varrays when:
  - The number of elements is known in advance.
  - The elements are usually all accessed in sequence.
- Use nested tables when:
  - The index values are not consecutive.
  - There is no predefined upper bound for the index values.
  - You need to delete or update some, not all, elements simultaneously.
  - You would usually create a separate lookup table with multiple entries for each row of the main table and access it through join queries.

Guidelines for Using Collections Effectively

- Varrays involve fewer disk accesses and are more efficient.
- Use nested tables for storing large amounts of data.
- Use varrays to preserve the order of elements in the collection column.
- If you do not have a requirement to delete elements in the middle of a collection, favor varrays.
- Varrays do not allow piecewise updates.
- After deleting the elements, release the unused memory with `DBMS_SESSION.FREE_UNUSED_USER_MEMORY`

Guidelines for Using Collections Effectively

- Because varray data is stored inline (in the same tablespace), retrieving and storing varrays involves fewer disk accesses. Varrays are thus more efficient than nested tables.
- To store large amounts of persistent data in a column collection, use nested tables. Thus, the Oracle server can use a separate table to hold the collection data, which can grow over time. For example, when a collection for a particular row could contain 1 to 1,000,000 elements, a nested table is simpler to use.
- If your data set is not very large and it is important to preserve the order of elements in a collection column, use varrays. For example, if you know that the collection will not contain more than 10 elements in each row, you can use a varray with a limit of 10.
- If you do not want to deal with deletions in the middle of the data set, use varrays.
- If you expect to retrieve the entire collection simultaneously, use varrays.
- Varrays do not allow piecewise updates.
- After deleting the elements, you can release the unused memory with the `DBMS_SESSION.FREE_UNUSED_USER_MEMORY` procedure.

Note: If your application requires negative subscripts, you can use only associative arrays.

Summary

In this lesson, you should have learned how to:
- Identify types of collections
  - Nested tables
  - Varrays
  - Associative arrays
- Define nested tables and varrays in the database
- Define nested tables, varrays, and associative arrays in PL/SQL
  - Access collection elements
  - Use collection methods in PL/SQL
  - Identify raised exceptions with collections
  - Decide which collection type is appropriate for each scenario

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Summary

Collections are a grouping of elements, all of the same type. The types of collections are nested tables, varrays, and associative arrays. You can define nested tables and varrays in the database. Nested tables, varrays, and associative arrays can be used in a PL/SQL program.

When using collections in PL/SQL programs, you can access the collection elements, use predefined collection methods, and use the exceptions that are commonly encountered with collections.

There are guidelines for using collections effectively and for determining which collection type is appropriate under specific circumstances.

Practice 4: Overview

This practice covers the following topics:
- Analyzing collections
- Using collections

Practice 4: Overview

In this practice, you analyze collections for common errors, create a collection, and then write a PL/SQL package to manipulate the collection.

Use the `OE` schema for this practice.

For detailed instructions on performing this practice, see Appendix A, "Practice Solutions."

Practice 4

In this practice, you create a nested table collection and use PL/SQL code to manipulate the collection.

Analyzing Collections

1. Examine the following definitions. Run the `lab_04_01.sql` script to create these objects.

```
CREATE TYPE typ_item AS OBJECT  --create object
 (prodid  NUMBER(5),
  price   NUMBER(7,2) )
/
CREATE TYPE typ_item_nst -- define nested table type
  AS TABLE OF typ_item
/
CREATE TABLE pOrder (  -- create database table
     ordid  NUMBER(5),
     supplier    NUMBER(5),
     requester   NUMBER(4),
     ordered     DATE,
     items  typ_item_nst)
     NESTED TABLE items STORE AS item_stor_tab
/
```

2. The following code generates an error. Run the `lab_04_02.sql` script to generate and view the error.

```
BEGIN
  -- Insert an order
  INSERT INTO pOrder
    (ordid, supplier, requester, ordered, items)
    VALUES (1000, 12345, 9876, SYSDATE, NULL);
  -- insert the items for the order created
  INSERT INTO TABLE (SELECT items
                    FROM   pOrder
                    WHERE  ordid = 1000)
    VALUES(typ_item(99, 129.00));
END;
/
```

   a. Why does the error occur?

   b. How can you fix the error?

Practice 4 (continued)

Collection Analysis (continued)

3. Examine the following code, which produces an error. Which line causes the error, and how do you fix it?
   (**Note:** You can run the `lab_04_03.sql` script to view the error output).

```
DECLARE
  TYPE credit_card_typ
  IS VARRAY(100) OF VARCHAR2(30);

  v_mc   credit_card_typ := credit_card_typ();
  v_visa credit_card_typ := credit_card_typ();
  v_am   credit_card_typ;
  v_disc credit_card_typ := credit_card_typ();
  v_dc   credit_card_typ := credit_card_typ();

BEGIN
  v_mc.EXTEND;
  v_visa.EXTEND;
  v_am.EXTEND;
  v_disc.EXTEND;
  v_dc.EXTEND;
END;
/
```

Practice 4 (continued)

Using Collections

In the following practice exercises, you implement a nested table column in the `CUSTOMERS` table and write PL/SQL code to manipulate the nested table.

4. Create a nested table to hold credit card information.
   a. Create an object type called `typ_cr_card`. It should have the following specification:
      ```
      card_type   VARCHAR2(25)
      card_num    NUMBER
      ```
   b. Create a nested table type called `typ_cr_card_nst` that is a table of `typ_cr_card`.
   c. Add a column to the `CUSTOMERS` table called `credit_cards`. Make this column a nested table of type `typ_cr_card_nst`. You can use the following syntax:
      ```
      ALTER TABLE customers ADD
      (credit_cards typ_cr_card_nst)
         NESTED TABLE credit_cards STORE AD c_c_store_tab;
      ```

5. Create a PL/SQL package that manipulates the `credit_cards` column in the `CUSTOMERS` table.
   a. Open the `lab_04_05.sql` file. It contains the package specification and part of the package body.
   b. Complete the code so that the package:
      - Inserts credit card information (the credit card name and number for a specific customer)
      - Displays credit card information in an unnested format

      ```
      CREATE OR REPLACE PACKAGE credit_card_pkg
      IS
        PROCEDURE update_card_info
          (p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no
       VARCHAR2);
        PROCEDURE display_card_info
          (p_cust_id NUMBER);
      END credit_card_pkg;  -- package spec
      /
      ```

Practice 4 (continued)

Using Collections (continued)

```
CREATE OR REPLACE PACKAGE BODY credit_card_pkg
IS

  PROCEDURE update_card_info
    (p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no
VARCHAR2)
  IS
    v_card_info typ_cr_card_nst;
    i INTEGER;
  BEGIN
    SELECT credit_cards
      INTO v_card_info
      FROM customers
      WHERE customer_id = p_cust_id;
    IF v_card_info.EXISTS(1) THEN
 -- cards exist, add more

 -- fill in code here

    ELSE -- no cards for this customer, construct one

 -- fill in code here

    END IF;
  END update_card_info;


  PROCEDURE display_card_info
    (p_cust_id NUMBER)
  IS
    v_card_info typ_cr_card_nst;
    i INTEGER;
  BEGIN
    SELECT credit_cards
      INTO v_card_info
      FROM customers
      WHERE customer_id = p_cust_id;

 -- fill in code here to display the nested table
 -- contents

  END display_card_info;
END credit_card_pkg;  -- package body
/
```

Practice 4 (continued)

Using Collections (continued)

6. Test your package with the following statements and compare the output:

```
EXECUTE credit_card_pkg.display_card_info(120)
Customer has no credit cards.
PL/SQL procedure successfully completed.

EXECUTE credit_card_pkg.update_card_info -
    (120, 'Visa', 11111111)
PL/SQL procedure successfully completed.

SELECT credit_cards
FROM   customers
WHERE  customer_id = 120;

CREDIT_CARDS(CARD_TYPE, CARD_NUM)
-------------------------------------------------
  TYP_CR_CARD_NST(TYP_CR_CARD('Visa', 11111111))

EXECUTE credit_card_pkg.display_card_info(120)
Card Type: Visa / Card No: 11111111
PL/SQL procedure successfully completed.

EXECUTE credit_card_pkg.update_card_info -
    (120, 'MC', 2323232323)
PL/SQL procedure successfully completed.

EXECUTE credit_card_pkg.update_card_info -
    (120, 'DC', 4444444)
PL/SQL procedure successfully completed.

EXECUTE credit_card_pkg.display_card_info(120)
Card Type: Visa / Card No: 11111111
Card Type: MC / Card No: 2323232323
Card Type: DC / Card No: 4444444
PL/SQL procedure successfully completed.
```

Practice 4 (continued)

Using Collections (continued)

7. Write a `SELECT` statement against the `credit_cards` column to unnest the data. Use the `TABLE` expression. Use SQL*Plus.

   For example, if the `SELECT` statement returns:

```
SELECT credit_cards
FROM   customers
WHERE  customer_id = 120;

CREDIT_CARDS(CARD_TYPE, CARD_NUM)
--------------------------------------------------------
TYP_CR_CARD_NST(TYP_CR_CARD('Visa', 11111111),
  TYP_CR_CARD('MC', 2323232323), TYP_CR_CARD('DC',
  4444444))
```

   rewrite it using the `TABLE` expression so that the results look like this:

```
-- Use the table expression so that the result is:
CUSTOMER_ID CUST_LAST_NAME  CARD_TYPE       CARD_NUM
----------- --------------- ------------- -----------
        120 Higgins         Visa            11111111
        120 Higgins         MC            2323232323
        120 Higgins         DC               4444444
```

5

Using Advanced Interface Methods

Objectives

After completing this lesson, you should be able to do the following:

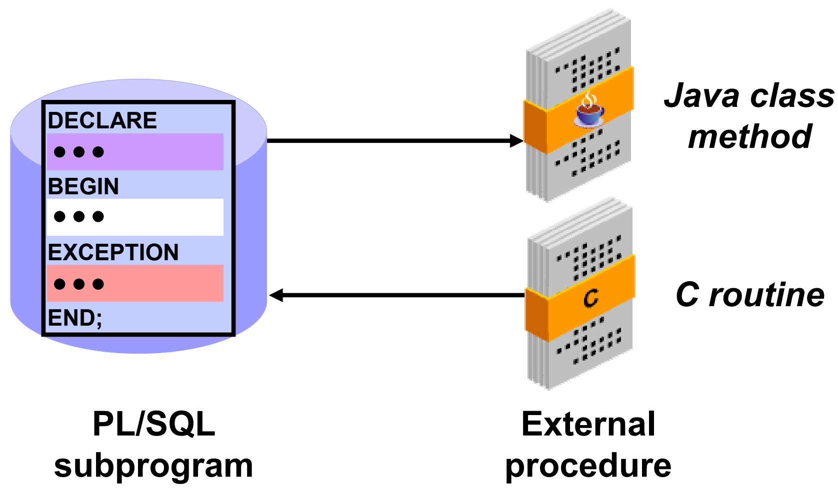
- Execute external C programs from PL/SQL
- Execute Java programs from PL/SQL

Objectives

In this lesson, you learn how to implement an external C routine from PL/SQL code and how to incorporate Java code into your PL/SQL programs.

Calling External Procedures from PL/SQL

With external procedures, you can make “callouts” and, optionally, “callbacks” through PL/SQL.



External Procedures: Overview

An *external procedure* (also called an *external routine*) is a routine stored in a dynamic link library (DLL), shared object (`.so` file in UNIX), or libunit in the case of a Java class method that can perform special purpose processing. You publish the routine with the base language, and then call it to perform special-purpose processing. You call the external routine from within PL/SQL or SQL. With C, you publish the routine through a library schema object, which is called from PL/SQL, that contains the compiled library file name that is stored on the operating system. With Java, publishing the routine is accomplished through creating a class libunit.

A *callout* is a call to the external procedure from your PL/SQL code.

A *callback* occurs when the external procedure calls back to the database to perform SQL operations. If the external procedure is to execute SQL or PL/SQL, it must “call back” to the database server process to get this work done.

An external procedure enables you to:

- Move computation-bound programs from the client to the server where they execute faster (because they avoid the round trips entailed in across-network communication)
- Interface the database server with external systems and data sources
- Extend the functionality of the database itself

Benefits of External Procedures

- External procedures integrate the strength and capability of different languages to give transparent access to these routines within the database.
- Extensibility: External procedures provide functionality in the database that is specific to a particular application, company, or technological area.
- Reusability: External procedures can be shared by all users on a database, and they can be moved to other databases or computers, thereby providing standard functionality with limited cost in development, maintenance, and deployment.

Benefits of External Procedures

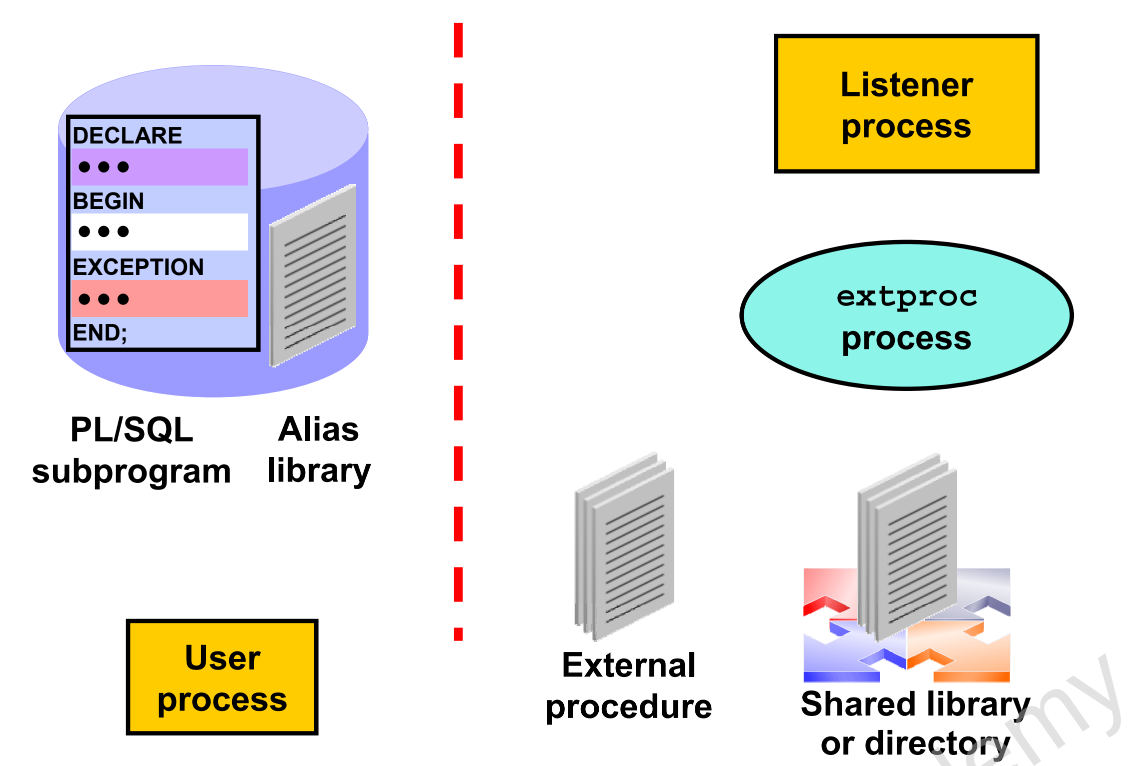
If you use the external procedure call, you can invoke an external routine by using a PL/SQL program unit. Additionally, you can integrate the powerful programming features of 3GLs with the ease of data access of SQL and PL/SQL commands.

You can extend the database and provide backward compatibility. For example, you can invoke different index or sorting mechanisms as an external procedure to implement data cartridges.

Example

A company has very complicated statistics programs written in C. The customer wants to access the data stored in an Oracle database and pass the data into the C programs. After execution of the C programs, depending on the result of the evaluations, data is inserted into the appropriate Oracle database tables.

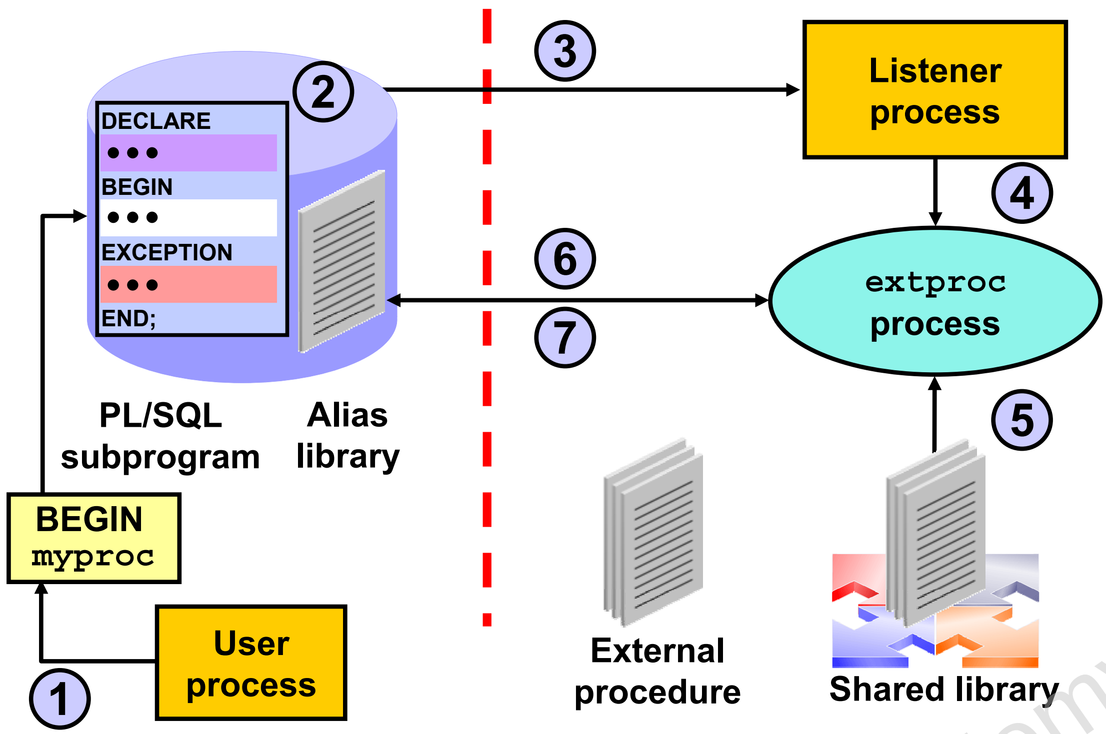
External C Procedure Components



External C Procedure Components

- **External procedure:** A unit of code written in C
- **Shared library:** An operating system file that stores the external procedure
- **Alias library:** A schema object that represents the operating system shared library
- **PL/SQL subprograms:** Packages, procedures, or functions that define the program unit specification and mapping to the PL/SQL library
- **`extproc` process:** A session-specific process that executes external procedures
- **Listener process:** A process that starts the `extproc` process and assigns it to the process executing the PL/SQL subprogram

How PL/SQL Calls a C External Procedure



How PL/SQL Calls a C External Procedure

1. The user process invokes a PL/SQL program.
2. The server process executes a PL/SQL subprogram, which looks up the alias library.
3. The PL/SQL subprogram passes the request to the listener.
4. The listener process spawns the `extproc` process. The `extproc` process remains active throughout your Oracle session until you log off.
5. The `extproc` process loads the shared library.
6. The `extproc` process links the server to the external file and executes the external procedure.
7. The data and status are returned to the server.

The `extproc` Process

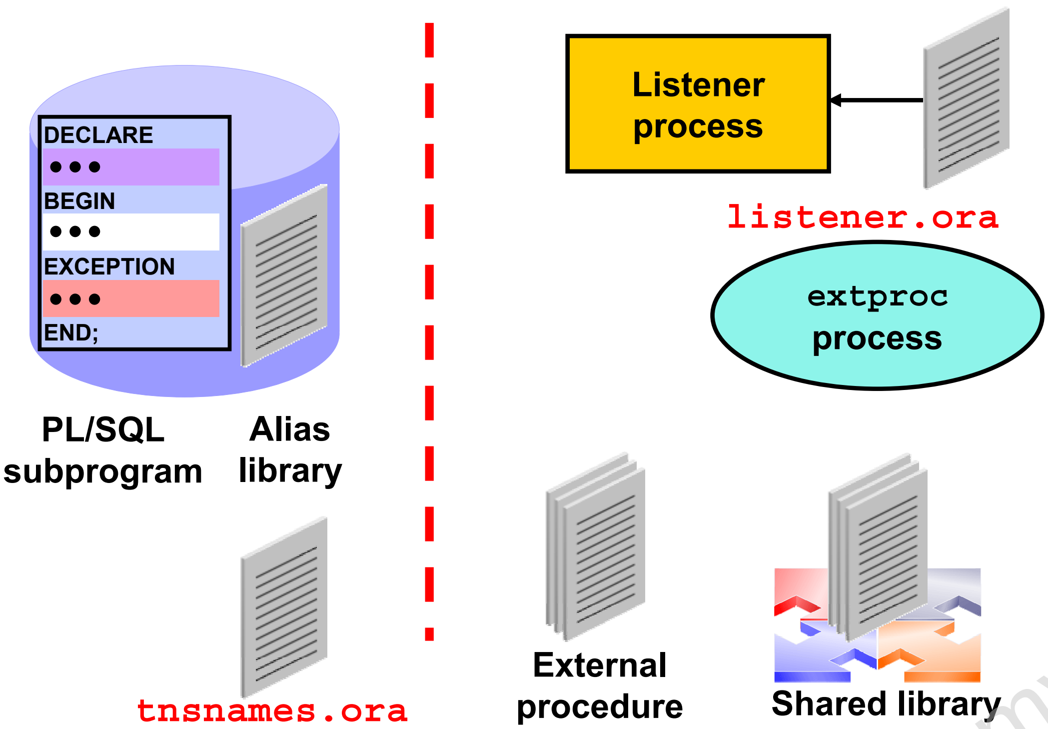
- The `extproc` process services the execution of external procedures for the duration of the session until the user logs off.
- Each session uses a different `extproc` process to execute external procedures.
- The listener must be configured to allow the server to be associated with the `extproc` process.
- The listener must be on the same machine as the server.

The `extproc` Process

The `extproc` process performs the following actions:

- **Converts PL/SQL calls to C calls:**
  - Loads the dynamic library
- **Executes the external procedures:**
  - Raises exceptions if necessary
  - Converts C back to PL/SQL
  - Sends arguments or exceptions back to the server process

The Listener Process



The Listener Process

When the Oracle server executes the external procedure, the request is passed to the listener process, which spawns an `extproc` process that executes the call to the external procedure.

This listener returns the information to the server process. A single `extproc` process is created for each session. The listener process starts the `extproc` process. The external procedure resides in a dynamic library. The Oracle Database Server runs the `extproc` process to load the dynamic library and to execute the external procedure.

3GL Call Dependencies: Example

Libraries are objects with the following dependencies:

Given library L1 and procedure P1, which depends on L1, when the procedure P1 is executed, library L1 is loaded, and the corresponding external library is dynamically loaded. P1 can now use the external library handle and call the appropriate external functions.

If L1 is dropped, P1 is invalidated and needs to be recompiled.

Development Steps for External C Procedures

1. Create and compile the external procedure in 3GL.
2. Link the external procedure with the shared library at the operating system level.
3. Create an alias library schema object to map to the operating system's shared library.
4. Grant execute privileges on the library.
5. Publish the external C procedure by creating the PL/SQL subprogram unit specification, which references the alias library.
6. Execute the PL/SQL subprogram that invokes the external procedure.

Development Steps for External C Procedures

Steps 1 and 2 vary according to the operating system. Consult your operating system or the compiler documentation. After these steps are completed, you create an alias library schema object that identifies the operating system's shared library within the server. Any user who needs to execute the C procedure requires execute privileges on the library. Within your PL/SQL code, you map the C arguments to the PL/SQL parameters, and execute the PL/SQL subprogram that invokes the external routine.

Development Steps for External C Procedures

1, 2. *Varies for each operating system; consult documentation.*

3. Use the `CREATE LIBRARY` statement to create an alias library object.

```
CREATE OR REPLACE LIBRARY library_name IS|AS
'file_path';
```

4. Grant the `EXECUTE` privilege on the alias library.

```
GRANT EXECUTE ON library_name TO user|ROLE|PUBLIC;
```


Creating the Alias Library

An alias library is a database object that is used to map to an external shared library. An external procedure that you want to use needs to be stored in a DLL or a shared object library (SO) operating system file. The DBA controls access to the DLL or SO files by using the `CREATE LIBRARY` statement to create a schema object called an alias library that represents the external file. The DBA must give you `EXECUTE` privileges on the library object so that you can publish the external procedure, and then call it from a PL/SQL program.

Steps

1, 2. Steps 1 and 2 vary for each operating system. Consult your operating system or the compiler documentation.

3. Create an alias library object by using the `CREATE LIBRARY` command:

```
CONNECT /as sysdba

CREATE OR REPLACE LIBRARY c_utility
 AS 'd:\labs\labs\calc_tax.dll';
```

The example shows the creation of a database object called `c_utility`, which references the location of the file and the name of the operating system file, `calc_tax.dll`.

Creating the Alias Library (continued)

4. Grant `EXECUTE` privilege on the library object:
```
GRANT EXECUTE ON c_utility TO OE;
```
5. Publish the external C routine.
6. Call the external C routine from PL/SQL.

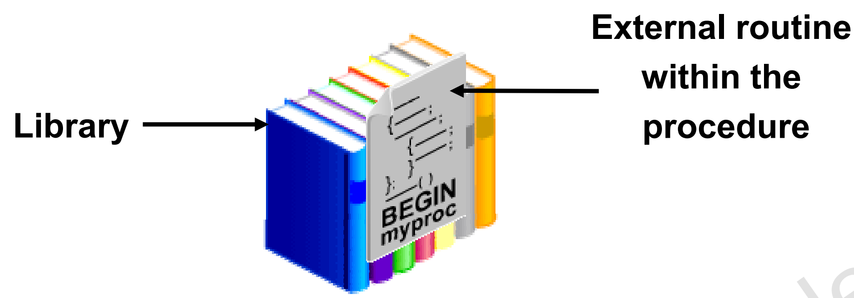
Dictionary Information

The alias library definitions are stored in the `USER_LIBRARIES` and `ALL_LIBRARIES` data dictionary views.

Development Steps for External C Procedures

Publish the external procedure in PL/SQL through call specifications:

- The body of the subprogram contains the external routine registration.
- The external procedure runs on the same machine.
- Access is controlled through the alias library.



Method to Access a Shared Library Through PL/SQL

You can access a shared library by specifying the alias library in a PL/SQL subprogram. The PL/SQL subprogram then calls the alias library.

- The body of the subprogram contains the external procedure registration.
- The external procedure runs on the same machine.
- Access is controlled through the alias library.

You can publish the external procedure in PL/SQL by:

- Identifying the characteristics of the C procedure to the PL/SQL program
- Accessing the library through PL/SQL

The package specification does not require changes. You do not need definitions for the external procedure.

The Call Specification

Call specifications enable:

- Dispatching the appropriate C or Java target procedure
- Data type conversions
- Parameter mode mappings
- Automatic memory allocation and cleanup
- Purity constraints to be specified, where necessary, for packaged functions that are called from SQL
- Calling Java methods or C procedures from database triggers
- Location flexibility

The Call Specification

The current way to publish external procedures is through call specifications. Call specifications enable you to call external routines from other languages. Although the specification is designed for intercommunication between SQL, PL/SQL, C, and Java, it is accessible from any base language that can call these languages.

To use an existing program as an external procedure, load, publish, and then call it.

Call specifications can be specified in any of the following locations:

- Stand-alone PL/SQL procedures and functions
- PL/SQL package specifications
- PL/SQL package bodies
- Object type specifications
- Object type bodies

Note: For functions that have the `RESTRICT_REFERENCES` pragma, use the `TRUST` option. The SQL engine cannot analyze those functions to determine whether they are free from side effects. The `TRUST` option makes it easier to call the Java and C procedures.

The Call Specification

- Identify the external body within a PL/SQL program to publish the external C procedure.

```
CREATE OR REPLACE FUNCTION function_name
(parameter_list)
RETURN datatype
  regularbody | externalbody
END;
```

- The external body contains the external C procedure information.

```
IS|AS LANGUAGE C
LIBRARY libname
[NAME C_function_name]
[CALLING STANDARD C | PASCAL]
[WITH CONTEXT]
[PARAMETERS (param_1, [param_n]);
```


Publishing an External C Routine

You create the PL/SQL procedure or function and use the `IS|AS LANGUAGE C` to publish the external C procedure. The external body contains the external routine information.

Syntax Definitions

where:	`LANGUAGE`	Is the language in which the external routine was written (defaults to C)
	`LIBRARY` *`libname`*	Is the name of the library database object
	`NAME` *`"C_function_name"`*	Represents the name of the C function; if omitted, the external procedure name must match the name of the PL/SQL subprogram
	`CALLING STANDARD`	Specifies the Windows NT calling standard (C or Pascal) under which the external routine was compiled (defaults to C)
	`WITH CONTEXT`	Specifies that a context pointer is passed to the external routine for callbacks
	`parameters`	Identifies arguments passed to the external routine

The Call Specification

- The parameter list:

```
parameter_list_element
[ , parameter_list_element ]
```

- The parameter list element:

```
{ formal_parameter_name [indicator]
| RETURN INDICATOR
| CONTEXT }
[BY REFERENCE]
[external_datatype]
```


The `PARAMETER` Clause

The foreign parameter list can be used to specify the position and the types of arguments, as well as to indicate whether they should be passed by value or by reference.

Syntax Definitions

where:		
	`formal_parameter_name [INDICATOR]`	Is the name of the PL/SQL parameter that is being passed to the external routine; the `INDICATOR` keyword is used to map a C parameter whose value indicates whether the PL/SQL parameter is null
	`RETURN INDICATOR`	Corresponds to the C parameter that returns a null indicator for the function
	`CONTEXT`	Specifies that a context pointer will be passed to the external routine
	`BY REFERENCE`	In C, you can pass `IN` scalar parameters by value (the value is passed) or by reference (a pointer to the value is passed). Use `BY REFERENCE` to pass the parameter by reference.
	`External_datatype`	Is the external data type that maps to a C data type

Note: The `PARAMETER` clause is optional if the mapping of the parameters is done on a positional basis, and indicators, reference, and context are not needed.

Publishing an External C Routine

Example

- Publish a C function called `calc_tax` from a PL/SQL function.

```
CREATE FUNCTION tax_amt (
 x BINARY_INTEGER)
 RETURN BINARY_INTEGER
  AS LANGUAGE C
  LIBRARY sys.c_utility
  NAME "calc_tax";
/
```

- The C prototype:

```
int calc_tax (n);
```


Example

You have an external C function called `calc_tax` that takes in one argument, the total sales amount. The function returns the tax amount calculated at 8%. The prototype for your `calc_tax` function is as follows:

```
int calc_tax (n);
```

To publish the `calc_tax` function in a stored PL/SQL function, use the `AS LANGUAGE C` clause within the function definition. The `NAME` identifies the name of the C function. Double quotation marks are used to preserve the case of the function defined in the C program. The `LIBRARY` identifies the library object that locates the C file. The `PARAMETERS` clause is not needed in this example, because the mapping of the parameters is done on a positional basis.

Executing the External Procedure

1. Create and compile the external procedure in 3GL.
2. Link the external procedure with the shared library at the operating system level.
3. Create an alias library schema object to map to the operating system's shared library.
4. Grant execute privileges on the library.
5. Publish the external C procedure by creating the PL/SQL subprogram unit specification, which references the alias library.
6. Execute the PL/SQL subprogram that invokes the external procedure.

Executing the External Procedure: Example

Here is a simple example of invoking the external routine:

```
BEGIN
  DBMS_OUTPUT.PUT_LINE(tax_amt(100));
END;
```

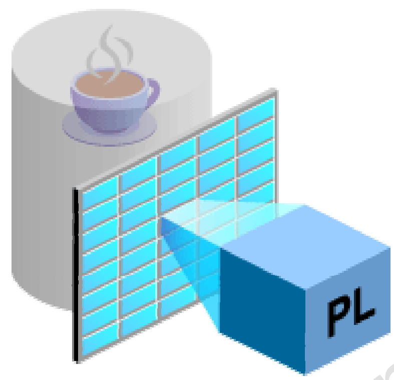
You can call the function in a cursor FOR loop or in any location where a PL/SQL function call is allowed:

```
DECLARE
  CURSOR cur_orders IS
    SELECT order_id, order_total
    FROM   orders;
  v_tax  NUMBER(8,2);
BEGIN
  FOR order_record IN cur_orders
  LOOP
    v_tax := tax_amt(order_record.order_total);
    DBMS_OUTPUT.PUT_LINE('Total tax: ' || v_tax);
  END LOOP;
END;
```

Java: Overview

The Oracle database can store Java classes and Java source, which:

- Are stored in the database as procedures, functions, or triggers
- Run inside the database
- Manipulate data

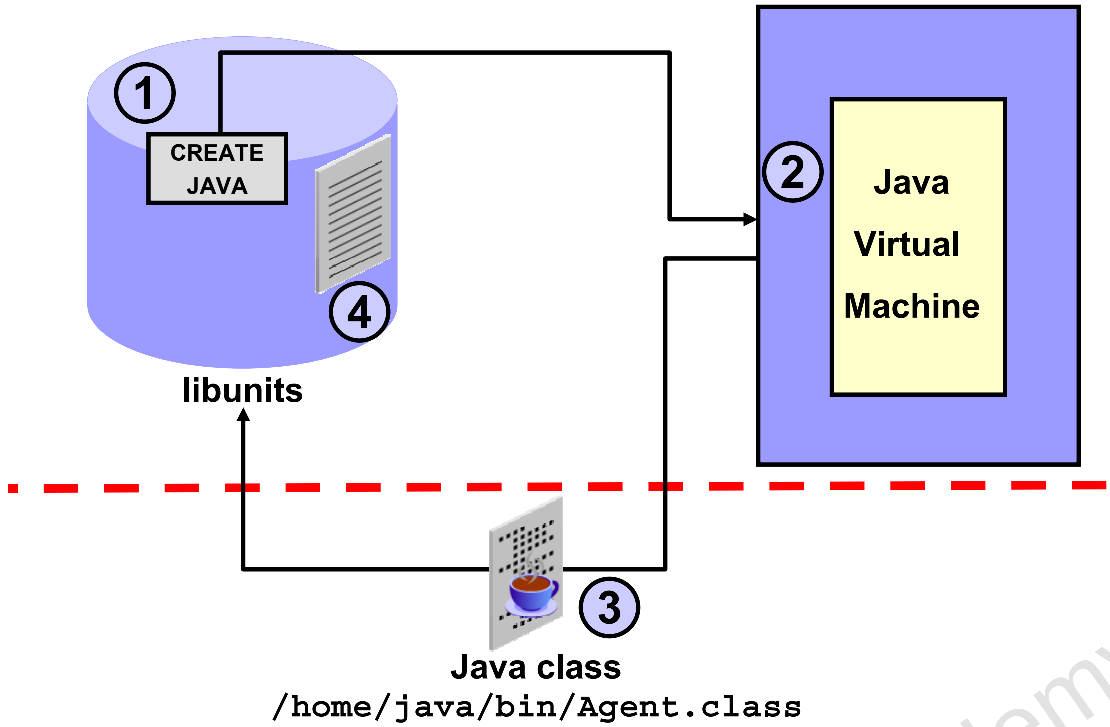


Java: Overview

The Oracle database can store Java classes (`.class` files) and Java source code (`.java` files), which are stored in the database as procedures, functions, or triggers. These classes can manipulate data but cannot display graphical user interface (GUI) elements such as Abstract Window Toolkit (AWT) or Swing components. Running Java inside the database helps these Java classes to be called many times and manipulate large amounts of data without the processing and network overhead that comes with running on the client machine.

You must write these named blocks, and then define them by using the `loadjava` command or the SQL `CREATE FUNCTION`, `CREATE PROCEDURE`, `CREATE TRIGGER`, or `CREATE PACKAGE` statements.

Calling a Java Class Method by Using PL/SQL



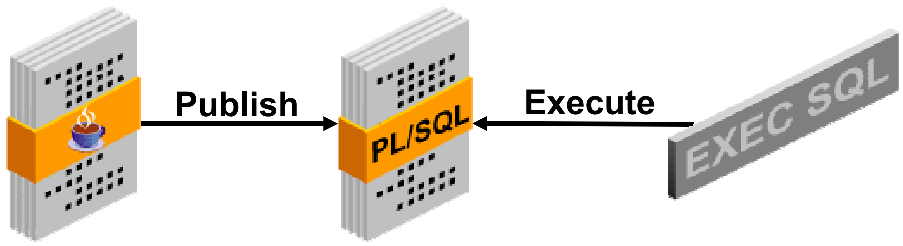
Calling a Java Class Method by Using PL/SQL

The `loadjava` command-line utility uploads the Java binaries and resources into a system-generated database table. It then uses the `CREATE JAVA` statement to load the Java files into the RDBMS libunits. You can upload the Java files from file systems, Java IDEs, intranets, or the Internet.

When the `CREATE JAVA` statement is invoked, the Java Virtual Machine library manager on the server loads the Java binaries and resources from the local `BFILE`s or `LOB` columns into the RDBMS libunits. Libunits can be considered analogous to the DLLs written in C, although they map one-to-one with Java classes, whereas DLLs can contain multiple routines.

Development Steps for Java Class Methods

1. Upload the Java file.
2. Publish the Java class method by creating the PL/SQL subprogram unit specification that references the Java class methods.
3. Execute the PL/SQL subprogram that invokes the Java class method.



Steps for Using Java Class Methods

Similar to using external C routines, the following steps are required to complete the setup before executing the Java class method from PL/SQL:

1. Upload the Java file. This takes an external Java binary file and stores the Java code in the database.
2. Publish the Java class method by creating the PL/SQL subprogram unit specification that references the Java class methods.
3. Execute the PL/SQL subprogram that invokes the Java class method.

Loading Java Class Methods

1. Upload the Java file.
   – At the operating system, use the `loadjava` command-line utility to load either the Java class file or the Java source file.

• To load the Java source file, use:

```
>loadjava -user oe/oe Factorial.java
```

• To load the Java class file, use:

```
>loadjava -user oe/oe Factorial.class
```

   – If you load the Java source file, you do not need to load the Java class file.

Loading Java Class Methods

Java classes and their methods are stored in RDBMS libunits where the Java sources, binaries, and resources can be loaded.

Use the `loadjava` command-line utility to load and resolve the Java classes. Using the `loadjava` utility, you can upload the Java source, class, or resource files into an Oracle database, where they are stored as Java schema objects. You can run `loadjava` from the command line or from an application.

After the file is loaded, it is visible in the data dictionary views.

```
SELECT object_name, object_type FROM   user_objects
WHERE  object_type like 'J%';
OBJECT_NAME                     OBJECT_TYPE
------------------------------- ------------------------
Factorial                       JAVA CLASS
Factorial                       JAVA SOURCE

SELECT text FROM   user_source WHERE name = 'Factorial';
TEXT
-------------------------------------------------------
public class Factorial {
  public static int calcFactorial (int n) {
    if (n == 1) return 1;
    else return n * calcFactorial (n - 1) ;   }}
```

Publishing a Java Class Method

2. Publish the Java class method by creating the PL/SQL subprogram unit specification that references the Java class methods.
   – Identify the external body within a PL/SQL program to publish the Java class method.
   – The external body contains the name of the Java class method.

```
CREATE OR REPLACE
{  PROCEDURE procedure_name [(parameter_list)]
 | FUNCTION function_name [(parameter_list]...)]
   RETURN datatype}
   regularbody | externalbody
END;
```

```
{IS | AS} LANGUAGE JAVA
  NAME 'method_fullname (java_type_fullname
     [, java_type_fullname]...)
     [return java_type_fullname]';
```


Publishing a Java Class Method

The publishing of Java class methods is specified in the AS LANGUAGE clause. This call specification identifies the appropriate Java target routine, data type conversions, parameter mode mappings, and purity constraints. You can publish value-returning Java methods as functions and void Java methods as procedures.

Publishing a Java Class Method

- Example:

```
CREATE OR REPLACE FUNCTION plstojavafac_fun
  (N NUMBER)
  RETURN NUMBER
  AS
    LANGUAGE JAVA
    NAME 'Factorial.calcFactorial
      (int) return int';
```

- Java method definition:

```
public class Factorial {
  public static int calcFactorial (int n) {
    if (n == 1) return 1;
    else return n * calcFactorial (n - 1) ;
  }
}
```


Example

You want to publish a Java method named `calcFactorial` that returns the factorial of its argument, as shown above:

- The PL/SQL function `plstojavafac_fun` is created to identify the parameters and the Java characteristics.
- The `NAME` clause string uniquely identifies the Java method
- The parameter named `N` corresponds to the `int` argument

Executing the Java Routine

1. Upload the Java file.
2. Publish the Java class method by creating the PL/SQL subprogram unit specification that references the Java class methods.
3. Execute the PL/SQL subprogram that invokes the Java class method.

Example (continued)

You can call the `calcFactorial` class method by using the following command:

```
EXECUTE DBMS_OUTPUT.PUT_LINE(plstojavafac_fun (5));

Anonymous block completed
120
```

Alternatively, to execute a `SELECT` statement from the `DUAL` table:

```
SELECT plstojavafac_fun (5)
FROM dual;

PLSTOJAVAFAC_FUN(5)
-------------------
                120
```

Creating Packages for Java Class Methods

```
CREATE OR REPLACE PACKAGE Demo_pack
AUTHID DEFINER
AS
  PROCEDURE plsToJ_InSpec_proc
   (x BINARY_INTEGER, y VARCHAR2, z DATE)
END;
```

```
CREATE OR REPLACE PACKAGE BODY Demo_pack
AS
  PROCEDURE plsToJ_InSpec_proc
   (x BINARY_INTEGER, y VARCHAR2, z DATE)
  IS LANGUAGE JAVA
  NAME 'pkg1.class4.J_InSpec_meth
         (int, java.lang.String, java.sql.Date)';
```


Creating Packages for Java Class Methods

The examples in the slide create a package specification and body named `Demo_pack`.

The package is a container structure. It defines the specification of the PL/SQL procedure named `plsToJ_InSpec_proc`.

Note that you cannot tell whether this procedure is implemented by PL/SQL or by way of an external procedure. The details of the implementation appear only in the package body in the declaration of the procedure body.

Summary

In this lesson, you should have learned how to:

- Use external C routines and call them from your PL/SQL programs
- Use Java methods and call them from your PL/SQL programs

Summary

You can embed calls to external C programs from your PL/SQL programs by publishing the external routines in a PL/SQL block. You can take external Java programs and store them in the database to be called from PL/SQL functions, procedures, and triggers.

Practice 5: Overview

This practice covers the following topics:

- Writing programs to interact with C routines
- Writing programs to interact with Java code

Practice 5: Overview

In this practice, you write two PL/SQL programs: One program calls an external C routine and the second program calls a Java routine.

Use the `OE` schema for this practice.

For detailed instructions about performing this practice, see Appendix A, "Practice Solutions."

Practice 5

Using External C Routines

An external C routine definition is created for you. The .c file is stored in the D:\labs\labs directory. This function returns the tax amount based on the total sales figure that is passed to the function as a parameter. The .c file is named calc_tax.c. The function is defined as:

```
__declspec(dllexport)
int calc_tax(n)
int n;
{
int tax;
tax = (n*8)/100;
return (tax);
}
```

1. A DLL file called calc_tax.dll was created for you. Copy the file from the D:\labs\labs directory into your D:\app\Administrator\product\11.1.0\db_1\BIN directory.

2. As the SYS user, create the alias library object. Name the library object c_code and define its path as:
   ```
   connect / as sysdba

   CREATE OR REPLACE LIBRARY c_code
     AS 'd:\app\Administrator\product\11.1.0\db_1\bin\calc_tax.dll';
     /
   ```

3. Grant execute privilege on the library to the OE user by executing the following command:
   ```
   GRANT EXECUTE ON c_code TO OE;
   ```

4. Publish the external C routine.
   As the OE user, create a function named call_c. This function has one numeric parameter and it returns a binary integer. Identify the AS LANGUAGE, LIBRARY, and NAME clauses of the function.

5. Create a procedure to call the call_c function that was created in the previous step. Name this procedure C_OUTPUT. It has one numeric parameter. Include a DBMS_OUTPUT.PUT_LINE statement so that you can view the results returned from your C function.

6. Set SERVEROUTPUT ON and execute the C_OUTPUT procedure.

Practice 5 (continued)

Calling Java from PL/SQL

A Java method definition is created for you. The method accepts a 16-digit credit card number as the argument and returns the formatted credit card number (4 digits followed by a space). The name of the `.class` file is `FormatCreditCardNo.class`. The method is defined as:

```
public class FormatCreditCardNo
{
public static final void formatCard(String[] cardno)
{
int count=0, space=0;
String oldcc=cardno[0];
String[] newcc= {""};
while (count<16)
{
newcc[0]+= oldcc.charAt(count);
space++;
if (space ==4)
{  newcc[0]+=" "; space=0;  }
count++;
}
cardno[0]=newcc [0];
}
}
```

7. Load the `.java` source file.

8. Publish the Java class method by defining a PL/SQL procedure named `CCFORMAT`. This procedure accepts one `IN OUT` parameter.

   Use the following definition for the `NAME` parameter:

   ```
   NAME 'FormatCreditCardNo.formatCard(java.lang.String[])';
   ```

9. Execute the Java class method. Define one SQL*Plus or SQL Developer variable, initialize it, and use the `EXECUTE` command to execute the `CCFORMAT` procedure. Your output should match the `PRINT` output as shown below.

```
EXECUTE ccformat(:x);


PRINT x
                   X
-------------------
1234 5678 1234 5678
```

Implementing Fine-Grained Access Control for VPD

Objectives

After completing this lesson, you should be able to do the following:

- Describe the process of fine-grained access control
- Implement and test fine-grained access control

Objectives

In this lesson, you learn about the security features in the Oracle Database from an application developer's standpoint.

For more information about these features, refer to *Oracle Supplied PL/SQL Packages and Types Reference, Oracle Label Security Administrator's Guide, Oracle Single Sign-On Application Developer's Guide,* and *Oracle Security Overview*.

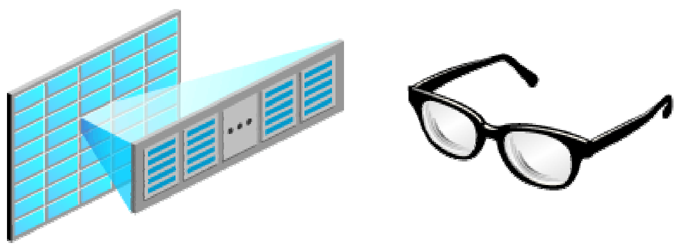
Lesson Agenda

- Describing the process of fine-grained access control
- Implementing and testing fine-grained access control

Fine-Grained Access Control: Overview

Fine-grained access control:

- Enables you to enforce security through a low level of granularity
- Restricts users to viewing only “their” information
- Is implemented through a security policy attached to tables
- Is implemented by highly privileged system DBAs, perhaps in coordination with developers
- Dynamically modifies user statements to fit the policy



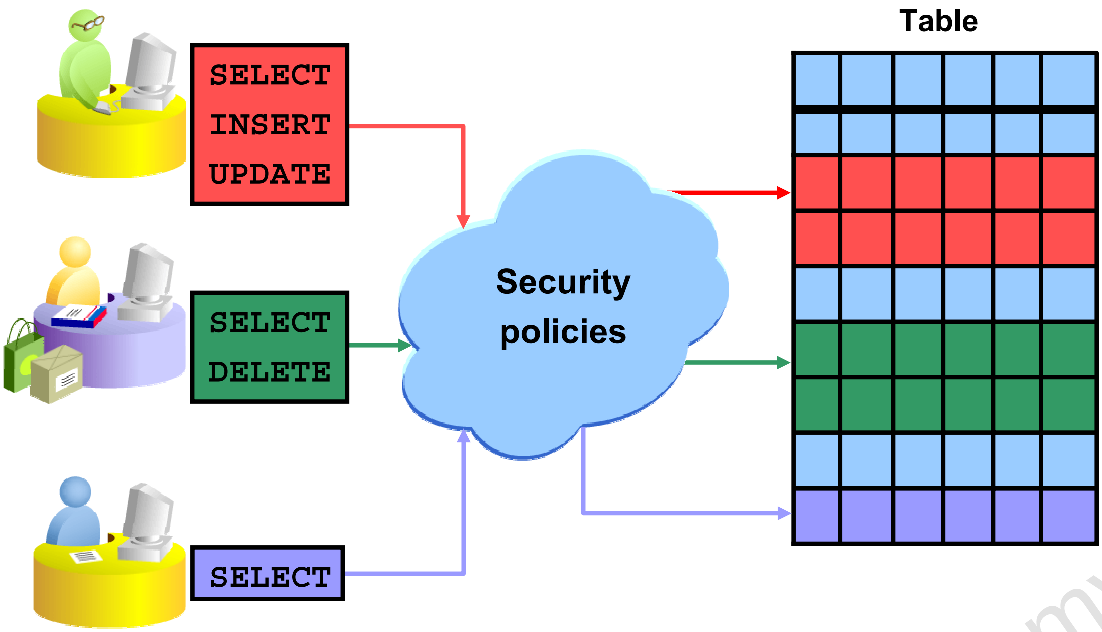
Fine-Grained Access Control: Overview

Fine-grained access control enables you to build applications that enforce security rules (or policies) at a low level of granularity. For example, you can use it to restrict customers who access the Oracle server to see only their own account, physicians to see only the records of their own patients, or managers to see only the records of employees who work for them.

When you use fine-grained access control, you create security policy functions attached to the table or view on which you based your application. When a user enters a data manipulation language (DML) statement on that object, the Oracle server dynamically modifies the user’s statement—transparently to the user—so that the statement implements the correct access control.

Fine-grained access is also known as a virtual private database (VPD), because it implements row-level security, essentially giving users access to their own private database. Fine-grained means at the individual row level.

Identifying Fine-Grained Access Features



Features

You can use fine-grained access control to implement security rules called policies with functions, and then associate those security policies with tables or views. The database server automatically enforces those security policies, no matter how the data is accessed.

A security policy is a collection of rules needed to enforce the appropriate privacy and security rules in the database itself, making it transparent to users of the data structure.

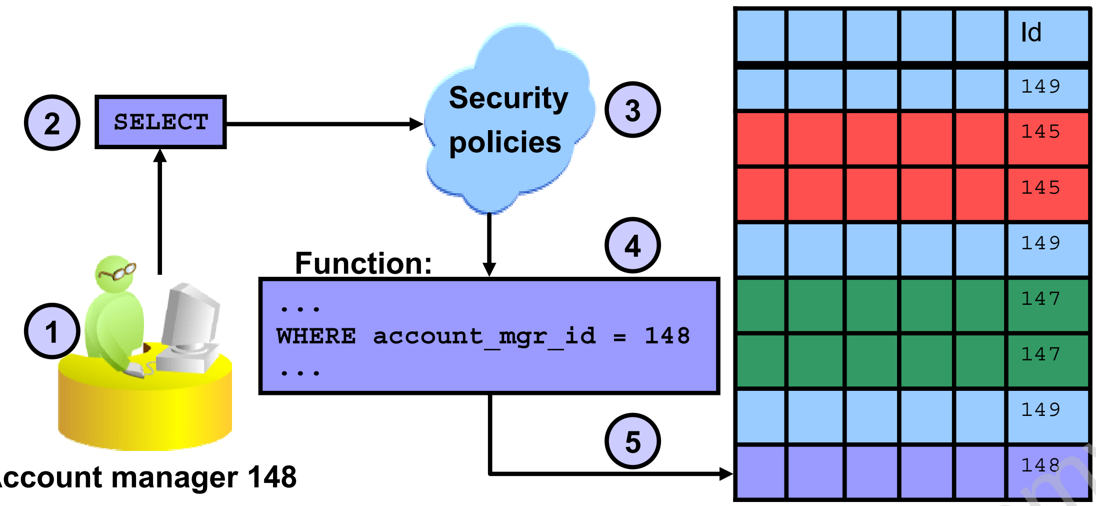
Attaching security policies to tables or views, rather than to applications, provides greater security, simplicity, and flexibility.

You can:

- Use different policies for `SELECT`, `INSERT`, `UPDATE`, and `DELETE` statements
- Use security policies only where you need them
- Use multiple policies for each table, including building on top of base policies in packaged applications
- Distinguish policies between different applications by using policy groups

How Fine-Grained Access Works

Implement the policy on the `CUSTOMERS` table:
"Account managers can see only their own customers."



How Fine-Grained Access Works

To implement a virtual private database so that account managers can see only their own customers, you must do the following:

1. Create a function to add a `WHERE` clause identifying a selection criterion to a user's SQL statement.
2. Have the user (the account manager) enter a SQL statement.
3. Implement the security policy through the function that you created. The Oracle server calls the function automatically.
4. Dynamically modify the user's statement through the function.
5. Execute the dynamically modified statement.

How Fine-Grained Access Works

- You write a function to return the account manager ID:

```
account_mgr_id := (SELECT account_mgr_id
                   FROM   customers
                   WHERE  account_mgr_id =
                   SYS_CONTEXT ('userenv','session_user'));
```

- The account manager user enters a query:

```
SELECT customer_id, cust_last_name, cust_email
FROM   customers;
```

- The query is modified with the function results:

```
SELECT customer_id, cust_last_name, cust_email
FROM   orders
WHERE  account_mgr_id = (SELECT account_mgr_id
                   FROM   customers
                   WHERE  account_mgr_id =
                   SYS_CONTEXT ('userenv','session_user'));
```


How Fine-Grained Access Works (continued)

Fine-grained access control is based on a dynamically modified statement. In the example in the slide, the user enters a broad query against the CUSTOMERS table that retrieves customer names and email names for a specific account manager. The Oracle server calls the function to implement the security policy. This modification is transparent to the user. It results in successfully restricting access to other customers' information, displaying only the information relevant to the account manager.

Note: The SYS_CONTEXT function returns a value for an attribute, in this case, connection attributes. This is explained in detail in the following pages.

Why Use Fine-Grained Access?

To implement the business rule “Account managers can see only their own customers,” you have three options:

Option	Comment
Modify all existing application code to include a predicate (a `WHERE` clause) for all SQL statements.	Does not ensure privacy enforcement outside the application. Also, all application code may need to be modified in the future as business rules change.
Create views with the necessary Predicates, and then create synonyms with the same name as the table names for these views.	This can be difficult to administer, especially if there are a large number of views to track and manage.
Create a VPD for each of the account managers by creating policy functions to generate dynamic predicates. These predicates can then be applied across all objects.	This option offers the best security without major administrative overheads and it also ensures complete privacy of information.

Why Use Fine-Grained Access?

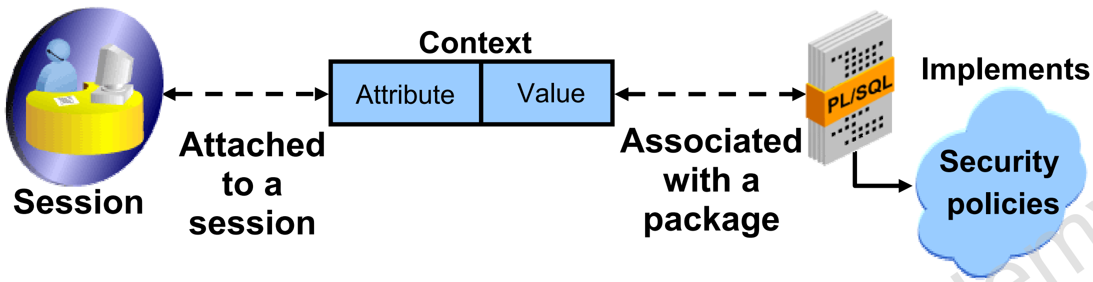
There are other methods by which you can implement the business rule “Account managers can see only their own customers.” The options are listed above. However, by using fine-grained access, you implement security without major overheads.

Lesson Agenda

- Describing the process of fine-grained access control
- Implementing and testing fine-grained access control

Using an Application Context

- An application context is used to facilitate the implementation of fine-grained access control.
- It is a named set of attribute/value pairs associated with a PL/SQL package.
- Applications can have their own application-specific contexts.
- Users cannot change their application's context.



Using an Application Context

An application context:

- Is a named set of attribute/value pairs associated with a PL/SQL package
- Is attached to a session
- Enables you to implement security policies with functions, and then associate them with applications

A context is a named set of attribute/value pairs that are global to your session. You can define an application context, name it, and associate a value with that context with a PL/SQL package. An application context enables you to write applications that draw upon certain aspects of a user's session information. It provides a way to define, set, and access attributes that an application can use to enforce access control—specifically, fine-grained access control.

Most applications contain information about the basis on which access is to be limited. In an order entry application, for example, you limit the customers' access their own orders (`ORDER_ID`) and customer number (`CUSTOMER_ID`). Or, you may limit account managers (`ACCOUNT_MGR_ID`) to view only their own customers. These values can be used as security attributes. Your application can use a context to set values that are accessed within your code and used to generate `WHERE` clause predicates for fine-grained access control.

An application context is owned by `SYS`.

Using an Application Context

System predefined

USERENV Context

Attribute	Value
IP_ADDRESS	139.185.35.118
SESSION_USER	oe
CURRENT_SCHEMA	oe
DB_NAME	orcl

Application defined

YOUR_DEFINED Context

Attribute	Value
customer_info	cus_1000
account_mgr	AM145

The function SYS_CONTEXT returns a value of an attribute of a context.

```
SELECT SYS_CONTEXT ('USERENV', 'SESSION_USER')
FROM DUAL;

SYS_CONTEXT ('USERENV', 'SESSION_USER')
------------------------------------------------------
 OE
```


Using an Application Context (continued)

A predefined application context named USERENV has a predefined list of attributes. Predefined attributes can be very useful for access control. You find the values of the attributes in a context by using the SYS_CONTEXT function. Although the predefined attributes in the USERENV application context are accessed with the SYS_CONTEXT function, you cannot change them.

With the SYS_CONTEXT function, you pass the context name and the attribute name. The attribute value is returned.

The following statement returns the name of the database that is being accessed:

```
SELECT SYS_CONTEXT ('USERENV', 'DB_NAME')
FROM DUAL;

SYS_CONTEXT('USERENV','DB_NAME')
-----------------------------------------------
ORCL
```

Creating an Application Context

```
CREATE [OR REPLACE] CONTEXT namespace
USING  [schema.]plsql_package
```

- Requires the `CREATE ANY CONTEXT` system privilege
- Parameters:
  - `namespace` is the name of the context.
  - `schema` is the name of the schema owning the PL/SQL package.
  - `plsql_package` is the name of the package used to set or modify the attributes of the context. (It does not need to exist at the time of context creation.)

```
CREATE CONTEXT order_ctx USING oe.orders_app_pkg;

Context created.
```


Creating an Application Context

For fine-grained access where you want account manager to view only their customers, customers to view only their information, and sales representatives to view only their orders, you can create a context called `ORDER_CTX` and define for it the `ACCOUNT_MGR`, `CUST_ID` and `SALE_REP` attributes.

Because a context is associated with a PL/SQL package, you need to name the package that you are associating with the context. This package does not need to exist at the time of context creation.

Setting a Context

- Use the supplied package procedure `DBMS_SESSION.SET_CONTEXT` to set a value for an attribute within a context.

```
DBMS_SESSION.SET_CONTEXT('context_name',
                         'attribute_name',
                         'attribute_value')
```

- Set the attribute value in the package that is associated with the context.

```
CREATE OR REPLACE PACKAGE orders_app_pkg
...
BEGIN
    DBMS_SESSION.SET_CONTEXT('ORDER_CTX',
                             'ACCOUNT_MGR',
                              v_user)
...
```


Setting a Context

When a context is defined, you can use the `DBMS_SESSION.SET_CONTEXT` procedure to set a value for an attribute within a context. The attribute is set in the package that is associated with the context.

```
CREATE OR REPLACE PACKAGE orders_app_pkg
IS
 PROCEDURE set_app_context;
END;
/
CREATE OR REPLACE PACKAGE BODY orders_app_pkg
IS
 c_context CONSTANT VARCHAR2(30) := 'ORDER_CTX';
 PROCEDURE set_app_context
 IS
    v_user VARCHAR2(30);
 BEGIN
  SELECT user INTO v_user FROM dual;
  DBMS_SESSION.SET_CONTEXT
    (c_context, 'ACCOUNT_MGR', v_user);
 END;
END;
/
```

Setting a Context (continued)

In the example on the previous page, the ORDER_CTX context has the ACCOUNT_MGR attribute set to the current user logged (determined by the USER function).

For this example, assume that users AM145, AM147, AM148, and AM149 exist. As each user logs on and the DBMS_SESSION.SET_CONTEXT is invoked, the attribute value for that ACCOUNT_MGR is set to the user ID.

```
GRANT EXECUTE ON oe.orders_app_pkg
  TO AM145, AM147, AM148, AM149;

CONNECT AM145/oracle
Connected.

EXECUTE oe.orders_app_pkg.set_app_context

SELECT SYS_CONTEXT('ORDER_CTX', 'ACCOUNT_MGR') FROM dual;

SYS_CONTEXT('ORDER_CTX', 'ACCOUNT_MGR')
---------------------------------------------------------
AM145
```

If you switch the user ID, the attribute value is also changed to reflect the current user.

```
CONNECT AM147/oracle
Connected.

EXECUTE oe.orders_app_pkg.set_app_context

SELECT SYS_CONTEXT('ORDER_CTX', 'ACCOUNT_MGR') FROM dual;

SYS_CONTEXT('ORDER_CTX', 'ACCOUNT_MGR')
---------------------------------------------------------
AM147
```

Implementing a Policy

Follow these steps:

1. Set up a driving context.

```
CREATE OR REPLACE CONTEXT order_ctx
  USING orders_app_pkg;
```

2. Create the package associated with the context that you defined in step 1. In the package:
   a. Set the context.
   b. Define the predicate.
3. Define the policy.
4. Set up a logon trigger to call the package at logon time and set the context.
5. Test the policy.

Implementing a Policy

In this example, assume that the users AM145, AM147, AM148, and AM149 exist. Next, create a context and a package associated with the context. The package will be owned by OE.

Step 1: Set Up a Driving Context

Use the CREATE CONTEXT syntax to create a context.

```
CONNECT /AS sysdba

CREATE CONTEXT order_ctx USING oe.orders_app_pkg;
```

Step 2: Creating the Package

```
CREATE OR REPLACE PACKAGE orders_app_pkg
IS
 PROCEDURE show_app_context;
 PROCEDURE set_app_context;
 FUNCTION the_predicate
  (p_schema VARCHAR2, p_name VARCHAR2)
   RETURN VARCHAR2;
END orders_app_pkg;     -- package spec
/
```


Implementing a Policy (continued)

Step 2: Create a Package

In the OE schema, the ORDERS_APP_PKG is created. This package contains three routines:

- **show_app_context:** For learning and testing purposes, this procedure displays a context attribute and value.
- **set_app_context:** This procedure sets a context attribute to a specific value.
- **the_predicate:** This function builds the predicate (the WHERE clause) that controls the rows visible in the CUSTOMERS table to a user. (Note that this function requires two input parameters. An error occurs when the policy is implemented if you exclude these two parameters.)

Implementing a Policy (continued)

Step 2: Create a Package (continued)

```
CREATE OR REPLACE PACKAGE BODY orders_app_pkg
IS
  c_context CONSTANT VARCHAR2(30) := 'ORDER_CTX';
  c_attrib  CONSTANT VARCHAR2(30) := 'ACCOUNT_MGR';

PROCEDURE show_app_context
IS
BEGIN
  DBMS_OUTPUT.PUT_LINE('Type: ' || c_attrib ||
   ' - ' || SYS_CONTEXT(c_context, c_attrib));
END show_app_context;

PROCEDURE set_app_context
  IS
    v_user VARCHAR2(30);
BEGIN
  SELECT user INTO v_user FROM dual;
  DBMS_SESSION.SET_CONTEXT
    (c_context, c_attrib, v_user);
END set_app_context;

FUNCTION the_predicate
(p_schema VARCHAR2, p_name VARCHAR2)
RETURN VARCHAR2
IS
  v_context_value VARCHAR2(100) :=
     SYS_CONTEXT(c_context, c_attrib);
  v_restriction VARCHAR2(2000);
BEGIN
  IF v_context_value LIKE 'AM%'  THEN
    v_restriction :=
     'ACCOUNT_MGR_ID =
      SUBSTR(''' || v_context_value || ''', 3, 3)';
  ELSE
    v_restriction := null;
  END IF;
  RETURN v_restriction;
END the_predicate;

END orders_app_pkg; -- package body
/
```

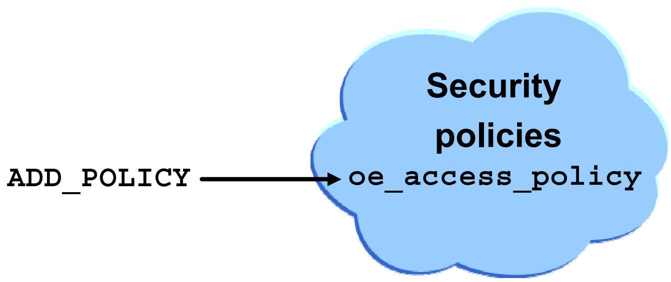
Note that the `THE_PREDICATE` function builds the `WHERE` clause and stores it in the `V_RESTRICTION` variable. If the `SYS_CONTEXT` function returns an attribute value that starts with `AM`, the `WHERE` clause is built with `ACCOUNT_MGR_ID =` *the last three characters of the attribute value*. If the user is `AM145`, the `WHERE` clause will be:

```
WHERE account_mgr_id = 145
```

Step 3: Defining the Policy

Use the DBMS_RLS package:

- It contains the fine-grained access administrative interface.
- It adds a fine-grained access control policy to a table or view.
- You use the ADD_POLICY procedure to add a fine-grained access control policy to a table or view.



Implementing a Policy (continued)

The DBMS_RLS package contains the fine-grained access control administrative interface. The package holds several procedures. But the package by itself does nothing until you add a policy. To add a policy, you use the ADD_POLICY procedure within the DBMS_RLS package.

Note: DBMS_RLS is available only with the Enterprise Edition.

Step 3: Define the Policy

The DBMS_RLS.ADD_POLICY procedure adds a fine-grained access control policy to a table or view. The procedure causes the current transaction, if any, to commit before the operation is carried out. However, this does not cause a commit first if it is inside a DDL event trigger. These are the parameters for the ADD_POLICY procedure:

```
DBMS_RLS.ADD_POLICY (
  object_schema    IN VARCHAR2  := NULL,
  object_name      IN VARCHAR2,
  policy_name      IN VARCHAR2,
  function_schema  IN VARCHAR2  := NULL,
  policy_function  IN VARCHAR2,
  statement_types  IN VARCHAR2  := NULL,
  update_check     IN BOOLEAN  := FALSE,
  enable           IN BOOLEAN  := TRUE);
```

Implementing a Policy (continued)

Step 3: Define the Policy (continued)

Parameter	Description
OBJECT_SCHEMA	Schema containing the table or view (logon user, if NULL).
OBJECT_NAME	Name of the table or view to which the policy is added.
POLICY_NAME	Name of the policy to be added. For any table of view, each POLICY_NAME must be unique.
FUNCTION_SCHEMA	Schema of the policy function (logon user, if NULL).
POLICY_FUNCTION	Name of the function that generates a predicate for the policy. If the function is defined within a package, the name of the package must be present.
STATEMENT_TYPES	Statement types that the policy will apply. It can be any combination of SELECT, INSERT, UPDATE, and DELETE. The default is to apply all these statement types to the policy.
UPDATE_CHECK	Optional argument for the INSERT or UPDATE statement types. The default is FALSE. Setting update_check to TRUE causes the server to also check the policy against the value after INSERT or UPDATE.
ENABLE	Indicates whether the policy is enabled when it is added. The default is TRUE.

The following is a list of the procedures contained in the DBMS_RLS package. For detailed information, refer to the *PL/SQL Packages and Types Reference 11g Release 1 (11.1)*.

Procedure	Description
ADD_POLICY	Adds a fine-grained access control policy to a table or view
DROP_POLICY	Drops a fine-grained access control policy from a table or view
REFRESH_POLICY	Causes all the cached statements associated with the policy to be reparsed
ENABLE_POLICY	Enables or disables a fine-grained access control policy
CREATE_POLICY_GROUP	Creates a policy group
ADD_GROUPED_POLICY	Adds a policy associated with a policy group
ADD_POLICY_CONTEXT	Adds the context for the active application
DELETE_POLICY_GROUP	Deletes a policy group
DROP_GROUPED_POLICY	Drops a policy associated with a policy group
DROP_POLICY_CONTEXT	Drops a driving context from the object so that it has one less driving context
ENABLE_GROUPED_POLICY	Enables or disables a row-level group security policy
REFRESH_GROUPED_POLICY	Reparses the SQL statements associated with a refreshed policy

Step 3: Defining the Policy

```
CONNECT /as sysdba

DECLARE
BEGIN
  DBMS_RLS.ADD_POLICY (
   'OE',                             ← Object schema
   'CUSTOMERS',                      ← Table name
   'OE_ACCESS_POLICY',               ← Policy name
   'OE',                             ← Function schema
   'ORDERS_APP_PKG.THE_PREDICATE',   ← Policy function
   'SELECT, UPDATE, DELETE',         ← Statement types
   FALSE,                            ← Update check
   TRUE);                            ← Enabled
END;
/
```


Implementing a Policy (continued)

Step 3: Define the Policy (continued)

The security policy `OE_ACCESS_POLICY` is created and added with the `DBMS_RLS.ADD_POLICY` procedure. The predicate function that defines how the policy is to be implemented is associated with the policy being added.

This example specifies that whenever a `SELECT`, `UPDATE`, or `DELETE` statement on the `OE.CUSTOMERS` table is executed, the predicate function return result is appended to the `WHERE` clause.

Step 4: Setting Up a Logon Trigger

Create a database trigger that executes whenever anyone logs on to the database:

```
CONNECT /as sysdba

CREATE OR REPLACE TRIGGER set_id_on_logon
AFTER logon on DATABASE
BEGIN
  oe.orders_app_pkg.set_app_context;
END;
/
```


Implementing a Policy (continued)

Step 4: Set Up a Logon Trigger

After the context is created, the security package is defined, the predicate is defined, and the policy is defined, you create a logon trigger to implement fine-grained access control. This trigger causes the context to be set as each user is logged on.

Example Results

Data in the CUSTOMERS table:

```
CONNECT as OE
SELECT   COUNT(*), account_mgr_id
FROM     customers
GROUP BY account_mgr_id;

  COUNT(*) ACCOUNT_MGR_ID
---------- --------------
       111 145
        76 147
        58 148
        74 149
         1
```

```
CONNECT AM148/oracle
SELECT   customer_id, customer_last_name
FROM     oe.customers;

CUSTOMER_ID CUSTOMER_LAST_NAME
----------- -----------------
...
58 rows selected.
```


Example Results

The AM148 user who logs on sees only those rows in the CUSTOMERS table that are defined by the predicate function. The user can issue SELECT, UPDATE, and DELETE statements against the CUSTOMERS table, but only the rows defined by the predicate function can be manipulated.

```
UPDATE oe.customers
SET credit_limit = credit_limit + 5000
WHERE customer_id = 101;

0 rows updated.
```

The AM148 user does not have access to customer ID 101. Customer ID 101 has the account manager of 145. Any updates, deletes, or selects attempted by user AM148 on customers that do not have him or her as an account manager are not performed. It is as though these customers do not exist.

Data Dictionary Views

- USER_POLICIES
- ALL_POLICIES
- DBA_POLICIES
- ALL_CONTEXT
- DBA_CONTEXT

Data Dictionary Views

You can query the data dictionary views to find information about the policies available in your schema.

View	Description
USER_POLICIES	All policies owned by the current schema
ALL_POLICIES	All policies owned or accessible by the current schema
DBA_POLICIES	All policies in the database (its columns are the same as those in ALL_POLICIES)
ALL_CONTEXT	All active context namespaces defined in the session
DBA_CONTEXT	All context namespace information (active and inactive)

Using the ALL_CONTEXT Dictionary View

Use ALL_CONTEXT to see the active context namespaces defined in your session:

```
CONNECT AS AM148

SELECT *
FROM   all_context;

NAMESPACE        SCHEMA     PACKAGE
---------------- ---------- ----------
ORDER_CTX        OE         ORDERS_APP_PKG
```


Using the ALL_CONTEXT Dictionary View

You can use the ALL_CONTEXT dictionary view to view information about the contexts to which you have access. In the slide, the NAMESPACE column is equivalent to the context name.

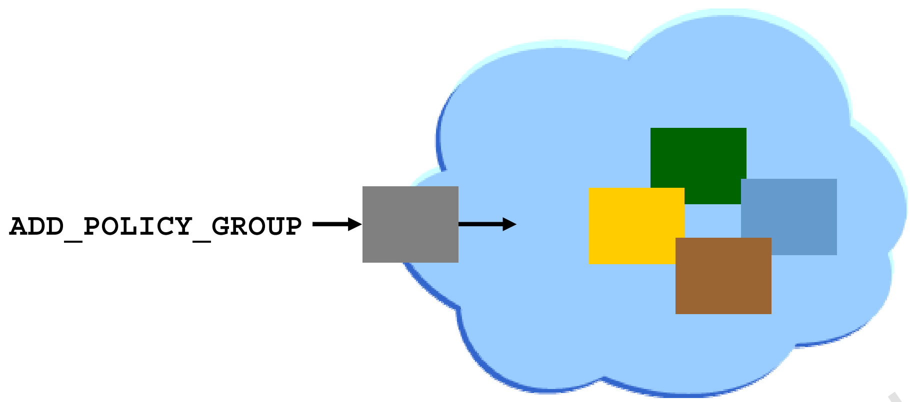
You can use the ALL_POLICIES dictionary view to view information about the policies to which you have access. In the following example, information is shown about the OE_ACCESS_POLICY policy.

```
SELECT object_name, policy_name, pf_owner, package,
       function, sel, ins, upd, del
FROM all_policies;

OBJECT_NAME                    POLICY_NAME
------------------------------ ------------------------------
PF_OWNER                       PACKAGE
------------------------------ ------------------------------
FUNCTION                       SEL INS UPD DEL
------------------------------ --- --- --- ---
CUSTOMERS                      OE_ACCESS_POLICY
OE                             ORDERS_APP_PKG
THE_PREDICATE                  YES NO  YES YES
```

Policy Groups

- Indicate a set of policies that belong to an application
- Are set up by a DBA through an application context called a driving context
- Use the `DBMS_RLS` package to administer the security policies



Policy Groups

Policy groups were introduced in Oracle9*i*, release 1 (9.0.1). The DBA designates an application context, called a driving context, to indicate the policy group in effect. When tables or views are accessed, the fine-grained access control engine looks up the driving context to determine the policy group in effect and enforces all associated policies that belong to that policy group.

The PL/SQL `DBMS_RLS` package enables you to administer your security policies and groups. Using this package, you can add, drop, enable, disable, and refresh the policy groups that you create.

More About Policies

- SYS_DEFAULT is the default policy group:
  - The SYS_DEFAULT group may or may not contain policies.
  - All policies belong to SYS_DEFAULT by default.
  - You cannot drop the SYS_DEFAULT policy group.
- Use DBMS_RLS.CREATE_POLICY_GROUP to create a new group.
- Use DBMS_RLS.ADD_GROUPED_POLICY to add a policy associated with a policy group.
- You can apply multiple driving contexts to the same table or view.

More About Policies

A policy group is a set of security policies that belong to an application. You can designate an application context (known as a driving context) to indicate the policy group in effect. When the tables or views are accessed, the server looks up the driving context to determine the policy group in effect. It enforces all associated policies that belong to that policy group.

By default, all policies belong to the SYS_DEFAULT policy group. The policies defined in this group for a particular table or view are always executed along with the policy group specified by the driving context. The SYS_DEFAULT policy group may or may not contain policies. If you attempt to drop the SYS_DEFAULT policy group, an error is raised. If you add policies associated with two or more objects to the SYS_DEFAULT policy group, each such object has a separate SYS_DEFAULT policy group associated with it.

For example, the CUSTOMERS table in the OE schema has one SYS_DEFAULT policy group, and the ORDERS table in the OE schema has a different SYS_DEFAULT policy group associated with it.

```
SYS_DEFAULT
 - policy1 (OE/CUSTOMERS)
 - policy3 (OE/CUSTOMERS)
SYS_DEFAULT
 - policy2 (OE/ORDERS)
```

More About Policies (continued)

When adding a policy to a table or view, you can use the `DBMS_RLS.ADD_GROUPED_POLICY` interface to specify the group to which the policy belongs. To specify which policies are effective, you can add a driving context using the `DBMS_RLS.ADD_POLICY_CONTEXT` interface. If the driving context returns an unknown policy group, an error is returned.

If the driving context is not defined, all policies are executed. Likewise, if the driving context is `NULL`, the policies from all policy groups are enforced. Thus, an application that accesses the data cannot bypass the security setup module (that sets up the application context) to avoid applicable policies.

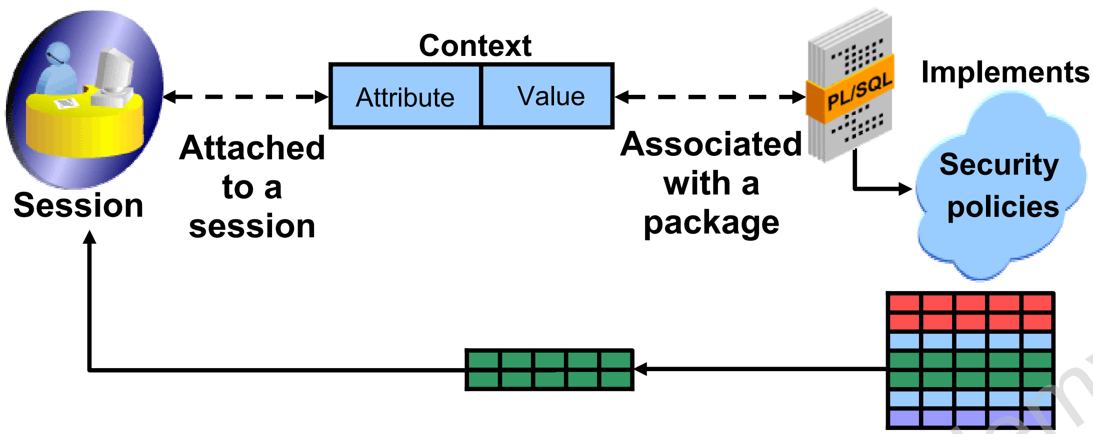
You can apply multiple driving contexts to the same table or view, and each of them are processed individually. Thus, you can configure multiple active sets of policies to be enforced.

You can create a new policy by using the `DBMS_RLS` package either from the command line or programmatically, or you can access the Oracle Policy Manager graphical user interface in Oracle Enterprise Manager.

Summary

In this lesson, you should have learned how to:

- Describe the process of fine-grained access control
- Implement and test fine-grained access control



Summary

In this lesson, you should have learned about fine-grained access control and the steps required to implement a virtual private database.

Practice 6: Overview

This practice covers the following topics:
- Creating an application context
- Creating a policy
- Creating a logon trigger
- Implementing a virtual private database
- Testing the virtual private database

Practice 6: Overview

In this practice, you implement and test fine-grained access control.

Practice 6: Implementing Fine-Grained Access Control for VPD

In this practice, you define an application context and security policy to implement the policy: "Sales Representatives can see only their own order information in the ORDERS table." You create sales representative IDs to test the success of your implementation.

Examine the definition of the ORDERS table and the ORDER count for each sales representative:

```
DESCRIBE orders
Name                Null?    Type
------------------ -------- --------------------------------
ORDER_ID           NOT NULL NUMBER(12)
ORDER_DATE         NOT NULL TIMESTAMP(6) WITH LOCAL TIME ZONE
ORDER_MODE                  VARCHAR2(8)
CUSTOMER_ID        NOT NULL NUMBER(6)
ORDER_STATUS                NUMBER(2)
ORDER_TOTAL                 NUMBER(8,2)
SALES_REP_ID                NUMBER(6)
PROMOTION_ID                NUMBER(6)

SELECT sales_rep_id, count(*)
FROM   orders
GROUP BY sales_rep_id;

SALES_REP_ID   COUNT(*)
------------ ----------
         153          5
         154         10
         155          5
         156          5
         158          7
         159          7
         160          6
         161         13
         163         12
                     35
10 rows selected.
```

1. Use your OE connection. Examine and then run the `lab_06_01.sql` script. This script creates the sales representative ID accounts with appropriate privileges to access the database.

2. Set up an application context:
   a. Connect to the database as SYSDBA before creating this context.
   b. Create an application context named `sales_orders_ctx`.
   c. Associate this context to the `oe.sales_orders_pkg`.

Practice 6 (continued)

3. Connect as OE.
   a. Examine this package specification:
```
CREATE OR REPLACE PACKAGE sales_orders_pkg
IS
 PROCEDURE set_app_context;
 FUNCTION the_predicate
  (p_schema VARCHAR2, p_name VARCHAR2)
   RETURN VARCHAR2;
END sales_orders_pkg;    -- package spec
/
```
   b. Create this package specification and the package body in the OE schema.
   c. When you create the package body, set up two constants as follows:
```
c_context CONSTANT VARCHAR2(30) := 'SALES_ORDERS_CTX';
c_attrib  CONSTANT VARCHAR2(30) := 'SALES_REP';
```
   d. Use these constants in the SET_APP_CONTEXT procedure to set the application context to the current user.

4. Connect as SYSDBA and define the policy.
   a. Use DBMS_RLS.ADD_POLICY to define the policy.
   b. Use these specifications for the parameter values:
```
object_schema   OE
object_name     ORDERS
policy_name     OE_ORDERS_ACCESS_POLICY
function_schema OE
policy_function SALES_ORDERS_PKG.THE_PREDICATE
statement_types SELECT, INSERT, UPDATE, DELETE
update_check    FALSE,
enable          TRUE);
```

5. Connect as SYSDBA and create a logon trigger to implement fine-grained access control. You can call the trigger SET_ID_ON_LOGON. This trigger causes the context to be set as each user is logged on.

Practice 6 (continued)

6. Test the fine-grained access implementation. Connect as your SR user and query the ORDERS table. For example, your results should match:

```
CONNECT sr153/oracle

SELECT sales_rep_id, COUNT(*)
FROM   orders
GROUP BY sales_rep_id;

SALES_REP_ID   COUNT(*)
------------ ----------
         153          5

CONNECT sr154/oracle

SELECT sales_rep_id, COUNT(*)
FROM   orders
GROUP BY sales_rep_id;

SALES_REP_ID   COUNT(*)
------------ ----------
         154         10
```

Note

During debugging, you may need to disable or remove some of the objects created for this lesson.

- If you need to disable the logon trigger, issue this command:
  ```
  ALTER TRIGGER set_id_on_logon DISABLE;
  ```
- If you need to remove the policy that you created, issue this command:
  ```
  EXECUTE DBMS_RLS.DROP_POLICY('OE', 'ORDERS', -
  'OE_ORDERS_ACCESS_POLICY')
  ```

Manipulating Large Objects

Objectives

After completing this lesson, you should be able to do the following:

- Compare and contrast `LONG` and large object (`LOB`) data types
- Create and maintain `LOB` data types
- Differentiate between internal and external `LOB`s
- Use the `DBMS_LOB` PL/SQL package
- Describe the use of temporary `LOB`s

Objectives

Databases have long been used to store large objects. However, the mechanisms built into databases have never been as useful as the large object (`LOB`) data types that have been provided since Oracle8. This lesson describes the characteristics of the new data types, comparing and contrasting them with the earlier data types. Examples, syntax, and issues regarding the `LOB` types are also presented.

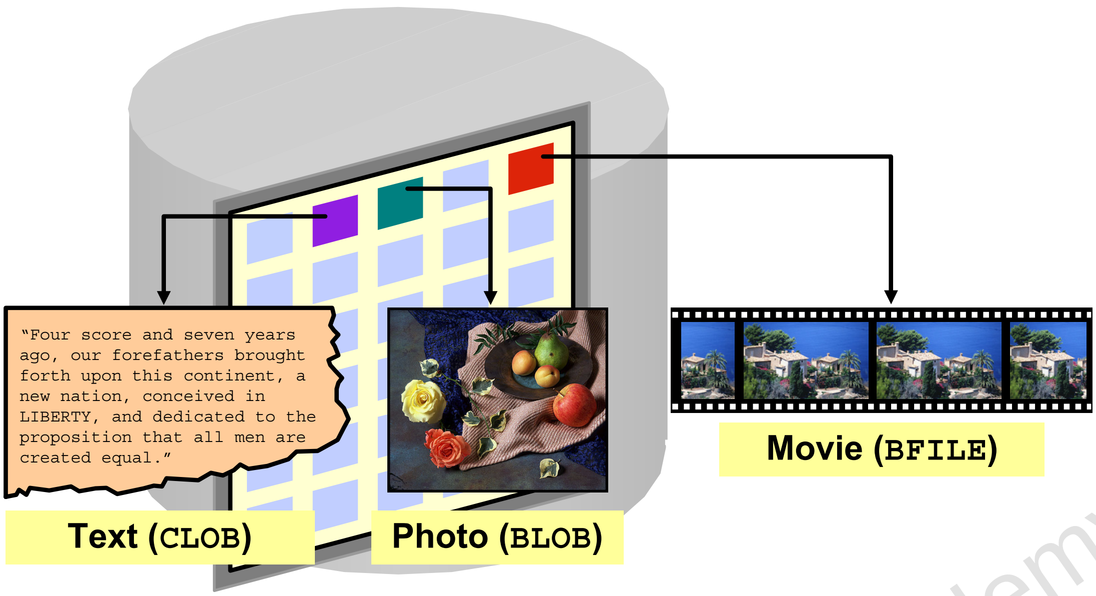
Note: A `LOB` is a data type and should not be confused with an object type.

Lesson Agenda

- Introduction to LOBs
- Managing BFILEs by using the DBMS_LOB package
- Migrating LONG data types to LOBs
- Manipulating LOB data
- Using temporary LOBs

What Is a LOB?

LOBs are used to store large, unstructured data such as text, graphic images, films, and sound waveforms.



LOB: Overview

A LOB is a data type that is used to store large, unstructured data such as text, graphic images, video clippings, and so on. Structured data, such as a customer record, may be a few hundred bytes large, but even small amounts of multimedia data can be thousands of times larger. Also, multimedia data may reside in operating system (OS) files, which may need to be accessed from a database.

There are four large object data types:

- BLOB represents a binary large object, such as a video clip.
- CLOB represents a character large object.
- NCLOB represents a multiple-byte character large object.
- BFILE represents a binary file stored in an OS binary file outside the database. The BFILE column or attribute stores a file locator that points to the external file.

LOBs are characterized in two ways, according to their interpretations by the Oracle server (binary or character) and their storage aspects. LOBs can be stored internally (inside the database) or in host files. There are two categories of LOBs:

- **Internal LOBs (CLOB, NCLOB, BLOB):** Stored in the database
- **External files (BFILE):** Stored outside the database

LOB: Overview (continued)

Oracle Database 10*g* performs implicit conversion between CLOB and VARCHAR2 data types. The other implicit conversions between LOBs are not possible. For example, if the user creates a table T with a CLOB column and a table S with a BLOB column, the data is not directly transferable between these two columns.

BFILEs can be accessed only in read-only mode from an Oracle server.

Contrasting LONG and LOB Data Types

LONG and LONG RAW	LOB
Single LONG column per table	Multiple LOB columns per table
Up to 2 GB	Up to 4 GB
SELECT returns data	SELECT returns locator
Data stored inline	Data stored inline or out-of-line
Sequential access to data	Random access to data

LONG and LOB Data Types

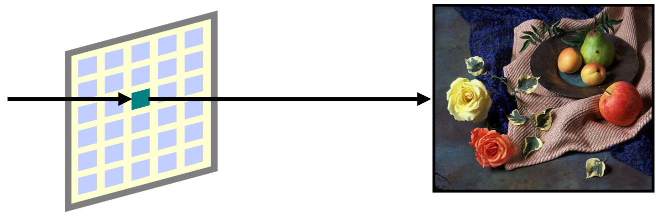
The LONG and LONG RAW data types were previously used for unstructured data, such as binary images, documents, or geographical information. These data types are superseded by the LOB data types. Oracle Database 10*g* provides a LONG-to-LOB API to migrate from LONG columns to LOB columns. The following bulleted list compares the LOB functionality with the older types, where LONGs refer to LONG and LONG RAW, and LOBs refer to all LOB data types:

- A table can have multiple LOB columns and object type attributes. A table can have only one LONG column.
- The maximum size of LONGs is 2 GB; LOBs can be up to 4 GB.
- LOBs return the locator; LONGs return the data.
- LOBs store a locator in the table and the data in a different segment, unless the data is less than 4,000 bytes; LONGs store all data in the same data block. In addition, LOBs allow data to be stored in a separate segment and tablespace, or in a host file.
- LOBs can be object type attributes; LONGs cannot be object type attributes.
- LOBs support random piecewise access to the data through a file-like interface; LONGs are restricted to sequential piecewise access.

The TO_LOB function can be used to convert LONG and LONG RAW values in a column to LOB values. You use this in the SELECT list of a subquery in an INSERT statement.

Components of a LOB

The LOB column stores a locator to the LOB's value.



Components of a LOB

There are two parts to a LOB:

- **LOB value:** The data that constitutes the real object being stored
- **LOB locator:** A pointer to the location of the LOB value that is stored in the database

Regardless of where the LOB value is stored, a locator is stored in the row. You can think of a LOB locator as a pointer to the actual location of the LOB value.

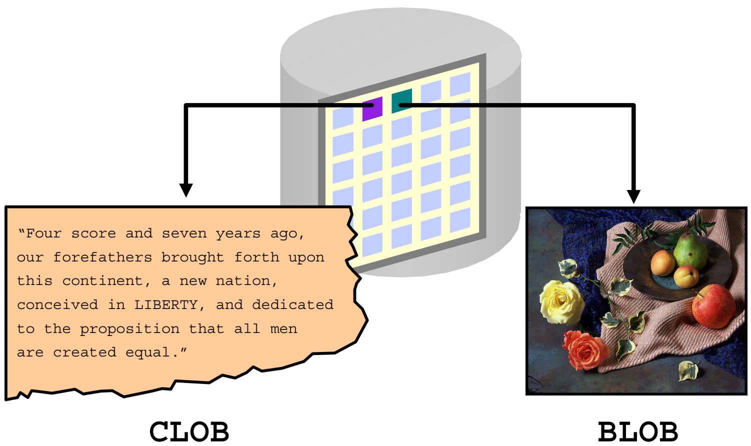
A LOB column does not contain the data; it contains the locator of the LOB value.

When a user creates an internal LOB, the value is stored in the LOB segment and a locator to the out-of-line LOB value is placed in the LOB column of the corresponding row in the table. External LOBs store the data outside the database, so only a locator to the LOB value is stored in the table.

To access and manipulate LOBs without SQL data manipulation language (DML), you must create a LOB locator. The programmatic interfaces operate on the LOB values by using these locators in a manner similar to OS file handles.

Internal LOBs

The LOB value is stored in the database.



Internal LOBs

An internal LOB is stored in the Oracle server. A BLOB, NCLOB, or CLOB can be one of the following:

- An attribute of a user-defined type
- A column in a table
- A bind or host variable
- A PL/SQL variable, parameter, or result

Internal LOBs can take advantage of Oracle features, such as:

- Concurrency mechanisms
- Redo logging and recovery mechanisms
- Transactions with COMMIT or ROLLBACK

The BLOB data type is interpreted by the Oracle server as a bitstream, similar to the LONG RAW data type.

The CLOB data type is interpreted as a single-byte character stream.

The NCLOB data type is interpreted as a multiple-byte character stream, based on the byte length of the database national character set.

Managing Internal LOBs

- To interact fully with LOB, file-like interfaces are provided in:
  – PL/SQL package DBMS_LOB
  – Oracle Call Interface (OCI)
  – Oracle Objects for object linking and embedding (OLE)
  – Pro*C/C++ and Pro*COBOL precompilers
  – Java Database Connectivity (JDBC)
- The Oracle server provides some support for LOB management through SQL.

Managing Internal LOBs

To manage an internal LOB, perform the following steps:

1. Create and populate the table containing the LOB data type.
2. Declare and initialize the LOB locator in the program.
3. Use SELECT FOR UPDATE to lock the row containing the LOB into the LOB locator.
4. Manipulate the LOB with DBMS_LOB package procedures, OCI calls, Oracle Objects for OLE, Oracle precompilers, or JDBC by using the LOB locator as a reference to the LOB value. You can also manage LOBs through SQL.
5. Use the COMMIT command to make any changes permanent.

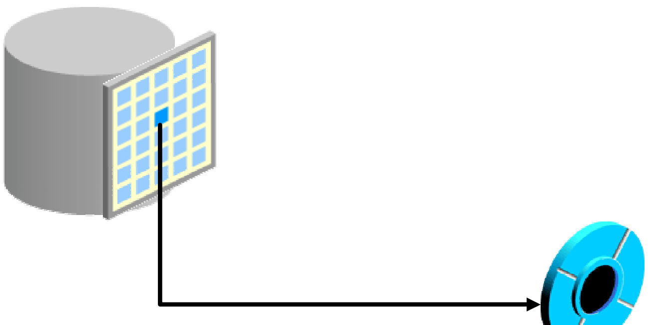
Lesson Agenda

- Introduction to LOBs
- Managing BFILEs by using the DBMS_LOB package
- Migrating LONG data types to LOBs
- Manipulating LOB data
- Using temporary LOBs

What Are BFILEs?

The BFILE data type supports an external or file-based large object as:

- Attributes in an object type
- Column values in a table



What Are BFILEs?

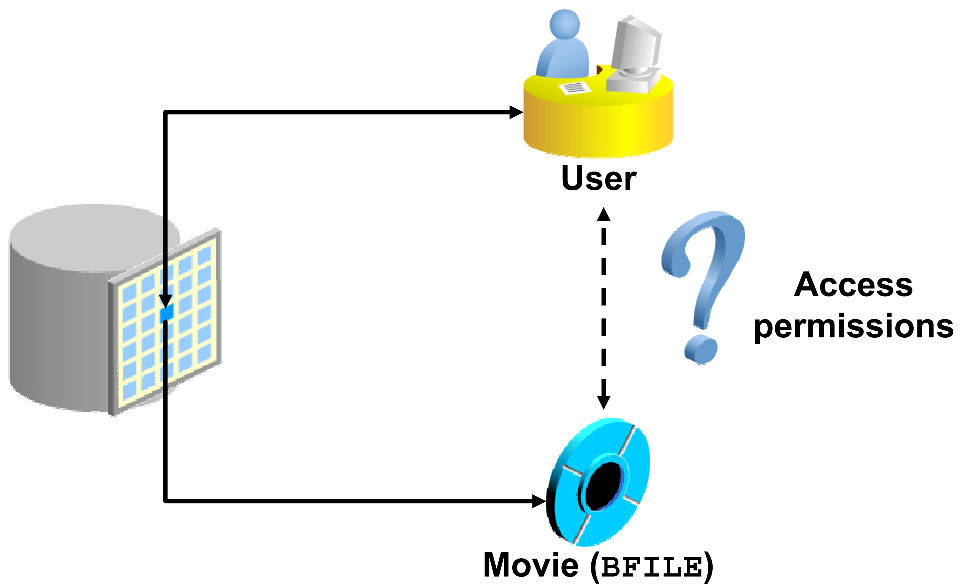
BFILEs are external large objects (LOBs) stored in OS files that are external to database tables. The BFILE data type stores a locator to the physical file. A BFILE can be in GIF, JPEG, MPEG, MPEG2, text, or other formats. The external LOBs may be located on hard disks, CD-ROMs, photo CDs, or other media, but a single LOB cannot extend from one medium or device to another. The BFILE data type is available so that database users can access the external file system. Oracle Database 10*g* provides:

- Definition of BFILE objects
- Association of BFILE objects with the corresponding external files
- Security for BFILEs

The remaining operations that are required for using BFILEs are possible through the DBMS_LOB package and OCI. BFILEs are read-only; they do not participate in transactions. Support for integrity and durability must be provided by the operating system. The file must be created and placed in the appropriate directory, giving the Oracle process privileges to read the file. When the LOB is deleted, the Oracle server does not delete the file. Administration of the files and the OS directory structures can be managed by the DBA, system administrator, or user. The maximum size of an external large object depends on the operating system but cannot exceed 4 GB.

Note: BFILEs are available with the Oracle8 database and later releases.

Securing BFILEs



Securing BFILEs

Unauthenticated access to files on a server presents a security risk. Oracle Database 10*g* can act as a security mechanism to shield the operating system from unsecured access while removing the need to manage additional user accounts on an enterprise computer system.

File Location and Access Privileges

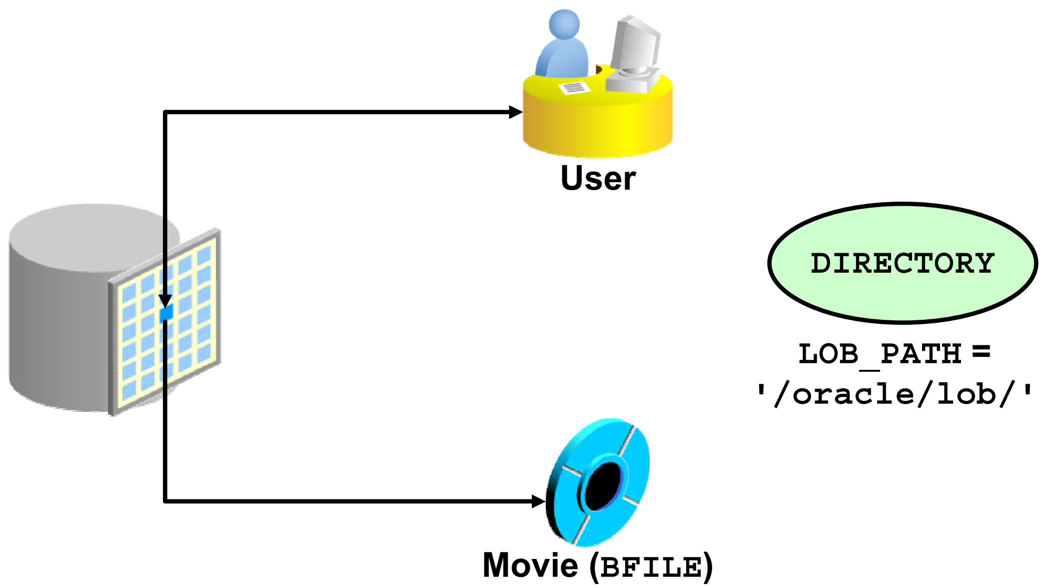
The file must reside on the machine where the database exists. A timeout to read a nonexistent `BFILE` is based on the OS value.

You can read a `BFILE` in the same way that you read an internal `LOB`. However, there could be restrictions related to the file itself, such as:

- Access permissions
- File system space limits
- Non-Oracle manipulations of files
- OS maximum file size

Oracle Database 10*g* does not provide transactional support on `BFILE`s. Any support for integrity and durability must be provided by the underlying file system and the OS. Oracle backup and recovery methods support only the `LOB` locators, not the physical `BFILE`s.

What Is a DIRECTORY?



What Is a DIRECTORY?

A DIRECTORY is a nonschema database object that enables the administration of access and usage of BFILEs in Oracle Database 10*g*.

A DIRECTORY specifies an alias for a directory on the file system of the server under which a BFILE is located. By granting users suitable privileges for these items, you can provide secure access to files in the corresponding directories on a user-by-user basis (certain directories can be made read-only, inaccessible, and so on).

Furthermore, these directory aliases can be used while referring to files (open, close, read, and so on) in PL/SQL and OCI. This provides application abstraction from hard-coded path names and gives flexibility in portably managing file locations.

The DIRECTORY object is owned by SYS and created by the DBA (or a user with the CREATE ANY DIRECTORY privilege). The directory objects have object privileges, unlike other nonschema objects. Privileges to the DIRECTORY object can be granted and revoked. Logical path names are not supported.

The permissions for the actual directory depend on the operating system. They may differ from those defined for the DIRECTORY object and could change after creation of the DIRECTORY object.

Guidelines for Creating DIRECTORY Objects

- Do not create DIRECTORY objects on paths with database files.
- Limit the number of people who are given the following system privileges:
  - CREATE ANY DIRECTORY
  - DROP ANY DIRECTORY
- All DIRECTORY objects are owned by SYS.
- Create directory paths and properly set permissions before using the DIRECTORY object so that the Oracle server can read the file.

Guidelines for Creating DIRECTORY Objects

To associate an OS file with a BFILE, you should first create a DIRECTORY object that is an alias for the full path name to the OS file.

Create DIRECTORY objects by using the following guidelines:

- Directories should point to paths that do not contain database files, because tampering with these files could corrupt the database. Currently, only the READ privilege can be given for a DIRECTORY object.
- The CREATE ANY DIRECTORY and DROP ANY DIRECTORY system privileges should be used carefully and not granted to users indiscriminately.
- DIRECTORY objects are not schema objects; all are owned by SYS.
- Create the directory paths with appropriate permissions on the OS before creating the DIRECTORY object. Oracle does not create the OS path.

If you migrate the database to a different OS, you may need to change the path value of the DIRECTORY object.

Information about the DIRECTORY object that you create by using the CREATE DIRECTORY command is stored in the DBA_DIRECTORIES and ALL_DIRECTORIES data dictionary views.

Using the DBMS_LOB Package

- Working with LOBs often requires the use of the Oracle-supplied DBMS_LOB package.
- DBMS_LOB provides routines to access and manipulate internal and external LOBs.
- LOB data can be retrieved directly using SQL.
- In PL/SQL, you can define a VARCHAR2 for a CLOB and a RAW for a BLOB.

Using the DBMS_LOB Package

To work with LOBs, you may need to use the DBMS_LOB package. The package does not support any concurrency control mechanism for BFILE operations. The user is responsible for locking the row containing the destination internal LOB before calling subprograms that involve writing to the LOB value. These DBMS_LOB routines do not implicitly lock the row containing the LOB.

The two constants, LOBMAXSIZE and FILE_READONLY, that are defined in the package specification are also used in the procedures and functions of DBMS_LOB; for example, use them to achieve the maximum level of purity in SQL expressions.

The DBMS_LOB functions and procedures can be broadly classified into two types: mutators and observers.

- The mutators can modify LOB values: APPEND, COPY, ERASE, TRIM, WRITE, FILECLOSE, FILECLOSEALL, and FILEOPEN.
- The observers can read LOB values: COMPARE, FILEGETNAME, INSTR, GETLENGTH, READ, SUBSTR, FILEEXISTS, and FILEISOPEN.

Using the `DBMS_LOB` Package

- Modify `LOB` values:
  `APPEND`, `COPY`, `ERASE`, `TRIM`, `WRITE`, `LOADFROMFILE`
- Read or examine `LOB` values:
  `GETLENGTH`, `INSTR`, `READ`, `SUBSTR`
- Specific to `BFILE`s:
  `FILECLOSE`, `FILECLOSEALL`, `FILEEXISTS`, `FILEGETNAME`, `FILEISOPEN`, `FILEOPEN`

ORACLE

Using the `DBMS_LOB` Package (continued)

APPEND	Appends the contents of the source LOB to the destination LOB
COPY	Copies all or part of the source LOB to the destination LOB
ERASE	Erases all or part of a LOB
LOADFROMFILE	Loads BFILE data into an internal LOB
TRIM	Trims the LOB value to a specified shorter length
WRITE	Writes data to the LOB from a specified offset
GETLENGTH	Gets the length of the LOB value
INSTR	Returns the matching position of the *n*th occurrence of the pattern in the LOB
READ	Reads data from the LOB starting at the specified offset
SUBSTR	Returns part of the LOB value starting at the specified offset
FILECLOSE	Closes the file
FILECLOSEALL	Closes all previously opened files
FILEEXISTS	Checks whether the file exists on the server
FILEGETNAME	Gets the directory alias and the file name
FILEISOPEN	Checks whether the file was opened using the input BFILE locators
FILEOPEN	Opens a file

DBMS_LOB Package

- NULL parameters get NULL returns.
- Offsets:
  - BLOB, BFILE: Measured in bytes
  - CLOB, NCLOB: Measured in characters
- There are no negative values for parameters.

Using the DBMS_LOB Routines

All functions in the DBMS_LOB package return NULL if any input parameters are NULL. All mutator procedures in the DBMS_LOB package raise an exception if the destination LOB/BFILE is input as NULL.

Only positive, absolute offsets are allowed. They represent the number of bytes or characters from the beginning of the LOB data from which to start the operation. The negative offsets and ranges that are observed in SQL string functions and operators are not allowed. Corresponding exceptions are raised upon violation. The default value for an offset is 1, which indicates the first byte or character in the LOB value.

Similarly, only natural number values are allowed for the amount (BUFSIZ) parameter. Negative values are not allowed.

DBMS_LOB.READ and DBMS_LOB.WRITE

```
PROCEDURE READ (
  lobsrc IN BFILE|BLOB|CLOB ,
  amount IN OUT BINARY_INTEGER,
  offset IN INTEGER,
  buffer OUT RAW|VARCHAR2 )
```

```
PROCEDURE WRITE (
  lobdst IN OUT BLOB|CLOB,
  amount IN OUT BINARY_INTEGER,
  offset IN INTEGER := 1,
  buffer IN RAW|VARCHAR2 )  -- RAW for BLOB
```


DBMS_LOB.READ

Call the READ procedure to read and return piecewise a specified AMOUNT of data from a given LOB, starting from OFFSET. An exception is raised when no more data remains to be read from the source LOB. The value returned in AMOUNT is less than the one specified if the end of the LOB is reached before the specified number of bytes or characters can be read. In the case of CLOBs, the character set of data in BUFFER is the same as that in the LOB.

PL/SQL allows a maximum length of 32,767 for RAW and VARCHAR2 parameters. Ensure that the allocated system resources are adequate to support buffer sizes for the given number of user sessions. Otherwise, the Oracle server raises the appropriate memory exceptions.

Note: BLOB and BFILE return RAW; the others return VARCHAR2.

DBMS_LOB.WRITE

Call the WRITE procedure to write piecewise a specified AMOUNT of data into a given LOB, from the user-specified BUFFER, starting from an absolute OFFSET from the beginning of the LOB value.

Make sure (especially with multiple-byte characters) that the amount in bytes corresponds to the amount of buffer data. WRITE has no means of checking whether they match, and it will write AMOUNT bytes of the buffer contents into the LOB.

Managing BFILEs

The DBA or the system administrator:

1. Creates an OS directory and supplies files
2. Creates a DIRECTORY object in the database
3. Grants the READ privilege on the DIRECTORY object to the appropriate database users

The developer or the user:

4. Creates an Oracle table with a column that is defined as a BFILE data type
5. Inserts rows into the table by using the BFILENAME function to populate the BFILE column
6. Writes a PL/SQL subprogram that declares and initializes a LOB locator, and reads BFILE

Managing BFILEs

Managing BFILEs requires cooperation between the database administrator and the system administrator, and then between the developer and the user of the files.

The database or system administrator must perform the following privileged tasks:

1. Create the operating system (OS) directory (as an Oracle user), and set permissions so that the Oracle server can read the contents of the OS directory. Load files into the OS directory.
2. Create a database DIRECTORY object that references the OS directory.
3. Grant the READ privilege on the database DIRECTORY object to the database users that require access to it.

The designer, application developer, or user must perform the following tasks:

4. Create a database table containing a column that is defined as the BFILE data type.
5. Insert rows into the table by using the BFILENAME function to populate the BFILE column, associating the field to an OS file in the named DIRECTORY.
6. Write PL/SQL subprograms that:
   a. Declare and initialize the BFILE LOB locator
   b. Select the row and column containing the BFILE into the LOB locator
   c. Read the BFILE with a DBMS_LOB function, by using the locator file reference

Preparing to Use BFILEs

1. Create an OS directory to store the physical data files:

```
md D:\Labs\DATA_FILES\MEDIA_FILES
```

2. Create a DIRECTORY object by using the CREATE DIRECTORY command:

```
CREATE DIRECTORY data_files
               AS 'D:\Labs\DATA_FILES\MEDIA_FILES;
```

3. Grant the READ privilege on the DIRECTORY object to the appropriate users:

```
GRANT READ ON DIRECTORY data_files TO OE;
```


Preparing to Use BFILEs

To use a BFILE within an Oracle table, you must have a table with a column of the BFILE data type. For the Oracle server to access an external file, the server needs to know the physical location of the file in the OS directory structure.

The database DIRECTORY object provides the means to specify the location of the BFILEs. Use the CREATE DIRECTORY command to specify the pointer to the location where your BFILEs are stored. You need the CREATE ANY DIRECTORY privilege.

Syntax definition: CREATE DIRECTORY *dir_name* AS *os_path*;

In this syntax, *dir_name* is the name of the directory database object, and *os_path* specifies the location of the BFILEs.

The slide examples show the commands to set up:

- The physical directory (for example, /temp/data_files) in the OS
- A named DIRECTORY object, called data_files, that points to the physical directory in the OS
- The READ access right on the directory to be granted to users in the database that provides the privilege to read the BFILEs from the directory

Note: The value of the SESSION_MAX_OPEN_FILES database initialization parameter, which is set to 10 by default, limits the number of BFILEs that can be opened in a session.

Populating BFILE Columns with SQL

- Use the BFILENAME function to initialize a BFILE column. The function syntax is:

```
FUNCTION BFILENAME(directory_alias IN VARCHAR2,
                   filename IN VARCHAR2)
RETURN BFILE;
```

- Example:
  - Add a BFILE column to a table:

```
ALTER TABLE customers ADD video BFILE;
```

  - Update the column using the BFILENAME function:

```
UPDATE customers
 SET video = BFILENAME('DATA_FILES', 'Winters.avi')
WHERE customer_id = 448;
```


Populating BFILE Columns with SQL

The BFILENAME function is a built-in function that you use to initialize a BFILE column, by using the following two parameters:

- *directory_alias* for the name of the database DIRECTORY object that references the OS directory containing the files
- *filename* for the name of the BFILE to be read

The BFILENAME function creates a pointer (or LOB locator) to the external file stored in a physical directory, which is assigned a directory alias name that is used in the first parameter of the function. Populate the BFILE column by using the BFILENAME function in either of the following:

- The VALUES clause of an INSERT statement
- The SET clause of an UPDATE statement

An UPDATE operation can be used to change the pointer reference target of the BFILE. A BFILE column can also be initialized to a NULL value and updated later with the BFILENAME function, as shown in the slide.

After the BFILE columns are associated with a file, subsequent read operations on the BFILE can be performed by using the PL/SQL DBMS_LOB package and OCI. However, these files are read-only when accessed through BFILEs. Therefore, they cannot be updated or deleted through BFILEs.

Populating a BFILE Column with PL/SQL

```
CREATE PROCEDURE set_video(
  dir_alias VARCHAR2, custid NUMBER) IS
  filename VARCHAR2(40);
  file_ptr BFILE;
  CURSOR cust_csr IS
    SELECT cust_first_name FROM customers
    WHERE customer_id = custid FOR UPDATE;
BEGIN
  FOR rec IN cust_csr LOOP
    filename := rec.cust_first_name || '.gif';
    file_ptr := BFILENAME(dir_alias, filename);
    DBMS_LOB.FILEOPEN(file_ptr);
    UPDATE customers SET video = file_ptr
      WHERE CURRENT OF cust_csr;
    DBMS_OUTPUT.PUT_LINE('FILE: ' || filename ||
     ' SIZE: ' || DBMS_LOB.GETLENGTH(file_ptr));
    DBMS_LOB.FILECLOSE(file_ptr);
  END LOOP;
END set_video;
```


Populating a BFILE Column with PL/SQL

The slide example shows a PL/SQL procedure called `set_video`, which accepts the name of the directory alias referencing the OS file system as a parameter, and a customer ID. The procedure performs the following tasks:

- Uses a cursor `FOR` loop to obtain each customer record
- Sets the `filename` by appending `.gif` to the customer's `first_name`
- Creates an in-memory `LOB` locator for the `BFILE` in the `file_ptr` variable
- Calls the `DBMS_LOB.FILEOPEN` procedure to verify whether the file exists, and to determine the size of the file by using the `DBMS_LOB.GETLENGTH` function
- Executes an `UPDATE` statement to write the `BFILE` locator value to the `video` `BFILE` column
- Displays the file size returned from the `DBMS_LOB.GETLENGTH` function
- Closes the file by using the `DBMS_LOB.FILECLOSE` procedure

Suppose that you execute the following call:

```
EXECUTE set_video('DATA_FILES', 844)
```

The sample result is:

```
FILE: Alice.gif SIZE: 2619802
```

Using DBMS_LOB Routines with BFILEs

The DBMS_LOB.FILEEXISTS function can check whether the file exists in the OS. The function:

- Returns 0 if the file does not exist
- Returns 1 if the file does exist

```
CREATE OR REPLACE FUNCTION get_filesize(p_file_ptr IN
OUT BFILE)
RETURN NUMBER IS
  v_file_exists BOOLEAN;
  v_length NUMBER:= -1;
BEGIN
  v_file_exists := DBMS_LOB.FILEEXISTS(p_file_ptr) = 1;
  IF v_file_exists THEN
    DBMS_LOB.FILEOPEN(p_file_ptr);
    v_length := DBMS_LOB.GETLENGTH(p_file_ptr);
    DBMS_LOB.FILECLOSE(p_file_ptr);
  END IF;
  RETURN v_length;
END;
/
```


Using DBMS_LOB Routines with BFILEs

The set_video procedure on the previous page terminates with an exception if a file does not exist. To prevent the loop from prematurely terminating, you could create a function, such as get_filesize, to determine whether a given BFILE locator references a file that actually exists on the server's file system. The DBMS_LOB.FILEEXISTS function accepts the BFILE locator as a parameter and returns an INTEGER with:

- A value 0 if the physical file does not exist
- A value 1 if the physical file exists

If the BFILE parameter is invalid, one of the following three exceptions may be raised:

- NOEXIST_DIRECTORY if the directory does not exist
- NOPRIV_DIRECTORY if the database processes do not have privileges for the directory
- INVALID_DIRECTORY if the directory was invalidated after the file was opened

In the get_filesize function, the output of the DBMS_LOB.FILEEXISTS function is compared with value 1 and the result of the condition sets the BOOLEAN variable file_exists. The DBMS_LOB.FILEOPEN call is performed only if the file exists, thereby preventing unwanted exceptions from occurring. The get_filesize function returns a value of –1 if a file does not exist; otherwise, it returns the size of the file in bytes. The caller can take appropriate action with this information.

Lesson Agenda

- Introduction to LOBs
- Managing BFILEs by using the DBMS_LOB package
- Migrating LONG data types to LOBs
- Manipulating LOB data
- Using temporary LOBs

Migrating from LONG to LOB

Oracle Database 10*g* enables the migration of LONG columns to LOB columns.

- Data migration consists of the procedure to move existing tables containing LONG columns to use LOBs:

```
ALTER TABLE [<schema>.] <table_name>
    MODIFY (<long_col_name> {CLOB | BLOB | NCLOB})
```

- Application migration consists of changing applications using LONG data types to use LOB data types instead.

Migrating from LONG to LOB

Oracle Database 10*g* supports LONG-to-LOB migration by using an API. In data migration, existing tables that contain LONG columns need to be moved to use LOB columns. This can be done by using the ALTER TABLE command. You can use the syntax shown to:

- Modify a LONG column to a CLOB or an NCLOB column
- Modify a LONG RAW column to a BLOB column

The constraints of the LONG column (NULL and NOT NULL are the only allowed constraints) are maintained for the new LOB columns. The default value specified for the LONG column is also copied to the new LOB column. For example, you have the following table:

```
CREATE TABLE long_tab (id NUMBER, long_col LONG);
```

To change the long_col column in the long_tab table to the CLOB data type, use:

```
ALTER TABLE long_tab MODIFY (long_col CLOB );
```

For information about the limitations on LONG-to-LOB migration, refer to *Oracle Database Application Developer's Guide - Large Objects*. In application migration, the existing LONG applications change to using LOBs. You can use SQL and PL/SQL to access LONGs and LOBs. The LONG-to-LOB migration API is provided for both OCI and PL/SQL.

Migrating from LONG to LOB

- Implicit conversion: From LONG (LONG RAW) or a VARCHAR2(RAW) variable to a CLOB (BLOB) variable, and vice versa.
- Explicit conversion:
  - TO_CLOB() converts LONG, VARCHAR2, and CHAR to CLOB.
  - TO_BLOB() converts LONG RAW and RAW to BLOB.
- Function and procedure parameter passing:
  - CLOBs and BLOBs are passed as actual parameters.
  - VARCHAR2, LONG, RAW, and LONG RAW are formal parameters, and vice versa.
- LOB data is acceptable in most of the SQL and PL/SQL operators and built-in functions.

Migrating from LONG to LOB (continued)

With the new LONG-to-LOB API introduced in Oracle Database 10*g*, data from CLOB and BLOB columns can be referenced by regular SQL and PL/SQL statements.

Implicit assignment and parameter passing: The LONG-to-LOB migration API supports assigning a CLOB (BLOB) variable to a LONG (LONG RAW) or a VARCHAR2(RAW) variable, and vice versa.

Explicit conversion functions: In PL/SQL, the following two new explicit conversion functions were added in Oracle Database 10*g* to convert other data types to CLOB and BLOB as part of the LONG-to-LOB migration:

- TO_CLOB() converts LONG, VARCHAR2, and CHAR to CLOB.
- TO_BLOB() converts LONG RAW and RAW to BLOB.

Note: TO_CHAR() is enabled to convert a CLOB to a CHAR type.

Function and procedure parameter passing: This enables the use of CLOBs and BLOBs as actual parameters where VARCHAR2, LONG, RAW, and LONG RAW are formal parameters, and vice versa. In SQL and PL/SQL built-in functions and operators, a CLOB can be passed to SQL and PL/SQL VARCHAR2 built-in functions, behaving exactly like a VARCHAR2. Or, the VARCHAR2 variable can be passed into DBMS_LOB APIs, acting like a LOB locator.

Lesson Agenda

- Introduction to LOBs
- Managing BFILEs by using the DBMS_LOB package
- Migrating LONG data types to LOBs
- Manipulating LOB data
- Using temporary LOBs

Initializing LOB Columns Added to a Table

- Add the LOB columns to an existing table by using ALTER TABLE.

```
ALTER TABLE customers
     ADD (resume CLOB, picture BLOB);
```

- Create a tablespace where you will put a new table with the LOB columns.

```
connect /as sysdba

CREATE TABLESPACE lob_tbs1
 DATAFILE 'lob_tbs1.dbf' SIZE 800M REUSE
EXTENT MANAGEMENT LOCAL
UNIFORM SIZE 64M
SEGMENT SPACE MANAGEMENT AUTO;
```


Initializing LOB Columns Added to a Table

The contents of a LOB column are stored in the LOB segment, whereas the column in the table contains only a reference to that specific storage area, called the LOB locator. In PL/SQL, you can define a variable of the LOB type, which contains only the value of the LOB locator. You can initialize the LOB locators by using the following functions:

- EMPTY_CLOB() function to a LOB locator for a CLOB column
- EMPTY_BLOB() function to a LOB locator for a BLOB column

Note: These functions create the LOB locator value and not the LOB content. In general, you use the DBMS_LOB package subroutines to populate the content. The functions are available in Oracle SQL DML, and are not part of the DBMS_LOB package.

LOB columns are defined by using SQL data definition language (DDL). You can add LOB columns to an existing table by using the ALTER TABLE statement.

You can also add LOB columns to a new table. It is recommended that you create a tablespace first, and then create the new table in that tablespace.

Initializing LOB Columns Added to a Table

Initialize the column LOB locator value with the DEFAULT option or the DML statements using:

- EMPTY_CLOB() function for a CLOB column
- EMPTY_BLOB() function for a BLOB column

```
connect oe

CREATE TABLE customer_profiles (
   id  NUMBER,
   full_name    VARCHAR2(45),
   resume       CLOB DEFAULT EMPTY_CLOB(),
   picture      BLOB DEFAULT EMPTY_BLOB())
   LOB(picture) STORE AS BASICFILE
     (TABLESPACE lob_tbs1);
```


Initializing LOB Columns Added to a Table (continued)

The slide example shows that you can use the EMPTY_CLOB() and EMPTY_BLOB() functions in the DEFAULT option in a CREATE TABLE statement. Thus, the LOB locator values are populated in their respective columns when a row is inserted into the table and the LOB columns were not specified in the INSERT statement.

The CUSTOMER_PROFILES table is created. The PICTURE column holds the LOB data in the BasicFile format, because the storage clause identifies the format. You learn about the SecureFile format in the lesson titled "Administering SecureFile LOBs."

You learn how to use these functions in INSERT and UPDATE statements to initialize the LOB locator values.

Populating LOB Columns

- Insert a row into a table with LOB columns:

```
INSERT INTO customer_profiles
  (id, full_name, resume, picture)
 VALUES (164, 'Charlotte Kazan', EMPTY_CLOB(), NULL);
```

- Initialize a LOB using the EMPTY_BLOB() function:

```
UPDATE customer_profiles
 SET resume = 'Date of Birth: 8 February 1951',
    picture = EMPTY_BLOB()
 WHERE id = 164;
```

- Update a CLOB column:

```
UPDATE customer_profiles
 SET resume = 'Date of Birth: 1 June 1956'
 WHERE id = 150;
```


Populating LOB Columns

You can insert a value directly into a LOB column by using host variables in SQL or PL/SQL, 3GL-embedded SQL, or OCI. You can use the special EMPTY_BLOB() and EMPTY_CLOB() functions in INSERT or UPDATE statements of SQL DML to initialize a NULL or non-NULL internal LOB to empty. To populate a LOB column, perform the following steps:

1. Initialize the LOB column to a non-NULL value—that is, set a LOB locator pointing to an empty or populated LOB value. This is done by using the EMPTY_BLOB() and EMPTY_CLOB() functions.
2. Populate the LOB contents by using the DBMS_LOB package routines.

However, as shown in the slide examples, the two UPDATE statements initialize the resume LOB locator value and populate its contents by supplying a literal value. This can also be done in an INSERT statement. A LOB column can be updated to:

- Another LOB value
- A NULL value
- A LOB locator with empty contents by using the EMPTY_*LOB() built-in function

You can update the LOB by using a bind variable in embedded SQL. When assigning one LOB to another, a new copy of the LOB value is created. Use a SELECT FOR UPDATE statement to lock the row containing the LOB column before updating a piece of the LOB contents.

Writing Data to a LOB

- Create the procedure to read the MS Word files and load them into the LOB column.
- Call this procedure from the WRITE_LOB procedure (shown on the next page).

```
CREATE OR REPLACE PROCEDURE loadLOBFromBFILE_proc
  (p_dest_loc IN OUT BLOB, p_file_name IN VARCHAR2,
   p_file_dir IN VARCHAR2)
IS
  v_src_loc  BFILE := BFILENAME(p_file_dir, p_file_name);
  v_amount   INTEGER := 4000;
BEGIN
  DBMS_LOB.OPEN(v_src_loc, DBMS_LOB.LOB_READONLY);
  v_amount := DBMS_LOB.GETLENGTH(v_src_loc);
  DBMS_LOB.LOADFROMFILE(p_dest_loc, v_src_loc, v_amount);
  DBMS_LOB.CLOSE(v_src_loc);
END loadLOBFromBFILE_proc;
```


Writing Data to a LOB

The procedure shown in the slide is used to load data into the LOB column.

Before running the LOADLOBFROMBFILE_PROC procedure, you must set a directory object that identifies where the LOB files are stored externally. In this example, the Microsoft Word documents are stored in the DATA_FILES directory that was created earlier in this lesson.

The LOADLOBFROMBFILE_PROC procedure is used to read the LOB data into the PICTURE column in the CUSTOMER_PROFILES table.

In this example:

- DBMS_LOB.OPEN is used to open an external LOB in read-only mode.
- DBMS_LOB.GETLENGTH is used to find the length of the LOB value.
- DBMS_LOB.LOADFROMFILE is used to load the BFILE data into an internal LOB.
- DBMS_LOB.CLOSE is used to close the external LOB.

Note: The LOADLOBFROMBFILE_PROC procedure shown in the slide can be used to read both SecureFile and BasicFile formats. SecureFile LOBs is discussed in the lesson titled "Administering SecureFile LOBs."

Writing Data to a LOB

Create the procedure to insert LOBs into the table:

```
CREATE OR REPLACE PROCEDURE write_lob
  (p_file IN VARCHAR2, p_dir IN VARCHAR2)
IS
 i     NUMBER;          v_fn VARCHAR2(15);
 v_ln VARCHAR2(40);     v_b  BLOB;
BEGIN
  DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE('Begin inserting rows...');
  FOR i IN 1 .. 30 LOOP
    v_fn:=SUBSTR(p_file,1,INSTR(p_file,'.')-1);
    v_ln:=SUBSTR(p_file,INSTR(p_file,'.')+1,LENGTH(p_file)-
                 INSTR(p_file,'.')-4);
    INSERT INTO customer_profiles
      VALUES (i, v_fn, v_ln, EMPTY_BLOB())
      RETURNING picture INTO v_b;
    loadLOBFromBFILE_proc(v_b,p_file, p_dir);
    DBMS_OUTPUT.PUT_LINE('Row '|| i ||' inserted.');
  END LOOP;
  COMMIT;
END write_lob;
```

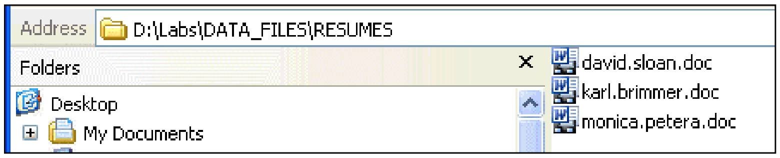

Writing Data to a LOB (continued)

Before you write data to the LOB column, you must make the LOB column non-NULL. The LOB column must contain a locator that points to an empty or populated LOB value. You can initialize a BLOB column value by using the EMPTY_BLOB() function as a default predicate.

The code shown in the slide uses the INSERT statement to initialize the locator. The LOADLOBFROMBFILE routine is then called and the LOB column value is inserted.

The write and read performance statistics for LOB storage is captured through output messages.

Writing Data to a LOB



1

```
CREATE DIRECTORY resume_files
  AS 'D:\Labs\DATA_FILES\RESUMES';
```

```
set serveroutput on
set verify on
set term on
set linesize 200

timing start load_data
execute write_lob('karl.brimmer.doc',   'RESUME_FILES')
execute write_lob('monica.petera.doc', 'RESUME_FILES')
execute write_lob('david.sloan.doc',   'RESUME_FILES')
timing stop
```

2

Writing Data to a LOB (continued)

1. The Microsoft Word files are stored in the `D:\Labs|DATA_FILES\RESUMES` directory.
2. To read them into the `PICTURE` column in the `CUSTOMER_PROFILES` table, the `WRITE_LOB` procedure is called and the name of the `.doc` files is passed as a parameter.

Note: This script is run in SQL*Plus, because `TIMING` is a SQL*Plus option and is not available in SQL Developer.

Writing Data to a LOB (continued)

The output is similar to the following:

```
timing start load_data
execute write_lob('karl.brimmer.doc', 'RESUME_FILES');
Begin inserting rows...
Row 1 inserted.
...
PL/SQL procedure successfully completed.

execute write_lob('monica.petera.doc', 'RESUME_FILES');
Begin inserting rows...
Row 1 inserted.
...
PL/SQL procedure successfully completed.

execute write_lob('david.sloan.doc', 'RESUME_FILES');
Begin inserting rows...
Row 1 inserted.
...
PL/SQL procedure successfully completed.

timing stop
timing for: load_data
Elapsed: 00:00:00.96
```

Reading `LOB`s from the Table

```
CREATE OR REPLACE PROCEDURE read_lob
IS
  v_lob_loc         BLOB;
  CURSOR profiles_cur IS
    SELECT id, full_name, resume, picture
      FROM customer_profiles;
  v_profiles_rec    customer_profiles%ROWTYPE;
BEGIN
  OPEN profiles_cur;
  LOOP
    FETCH profiles_cur INTO v_profiles_rec;
     v_lob_loc := v_profiles_rec.picture;
     DBMS_OUTPUT.PUT_LINE('The length is: '||
                          DBMS_LOB.GETLENGTH(v_lob_loc));
     DBMS_OUTPUT.PUT_LINE('The ID is: '|| v_profiles_rec.id);
     DBMS_OUTPUT.PUT_LINE('The blob is read: '||
     UTL_RAW.CAST_TO_VARCHAR2(DBMS_LOB.SUBSTR(v_lob_loc,200,1)));
    EXIT WHEN profiles_cur%NOTFOUND;
  END LOOP;
  CLOSE profiles_cur;
END;
```


Reading LOBs from the Table

To retrieve the records that were inserted, you can call the `READ_LOB` procedure:

```
set serveroutput on
set verify on
set term on
set linesize 200

timing start read_data
execute read_lob;
timing stop
```

The commands shown in the slide read back the 90 records from the `CUSTOMER_PROFILES` table. For each record, the size of the `LOB` value plus the first 200 characters of the `LOB` are displayed on the screen. A SQL*Plus timer is started to capture the total elapsed time for the retrieval.

Reading LOBs from the Table (continued)

The output is similar to the following:

```
The ID is: 1
The blob is read: ¿□¿□¿              > □ ¿¿   □           □
x        □  z    □   ¿¿¿¿    w
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿
The length is: 64000
The ID is: 2
The blob is read: ¿□¿□¿              > □ ¿¿   □           □
x        □  z    □   ¿¿¿¿    w
...
The length is: 37376
The ID is: 30
The blob is read: ¿□¿□¿              > □ ¿¿   □           □
D        □  F    □   ¿¿¿¿    C
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿
The length is: 37376
The ID is: 30
The blob is read: ¿□¿□¿              > □ ¿¿   □           □
D        □  F    □   ¿¿¿¿    C
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿
¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿¿

…

PL/SQL procedure successfully completed.

timing stop
timing for: read_data
Elapsed: 00:00:01.09
```

Note: The text shown on this page is intentional. The text appears as gibberish, because it is a binary file.

Updating LOB by Using DBMS_LOB in PL/SQL

```
DECLARE
  v_lobloc CLOB;     -- serves as the LOB locator
  v_text   VARCHAR2(50) := 'Resigned = 5 June 2000';
  v_amount NUMBER ; -- amount to be written
  v_offset INTEGER; -- where to start writing
BEGIN
  SELECT resume INTO v_lobloc FROM customer_profiles
  WHERE id = 164 FOR UPDATE;
  v_offset := DBMS_LOB.GETLENGTH(v_lobloc) + 2;
  v_amount := length(v_text);
  DBMS_LOB.WRITE (v_lobloc, v_amount, v_offset, v_text);
  v_text := ' Resigned = 30 September 2000';
  SELECT resume INTO v_lobloc FROM customer_profiles
  WHERE id = 150 FOR UPDATE;
  v_amount := length(v_text);
  DBMS_LOB.WRITEAPPEND(v_lobloc, v_amount, v_text);
  COMMIT;
END;
```


Updating LOB by Using DBMS_LOB in PL/SQL

In the example in the slide, the LOBLOC variable serves as the LOB locator, and the AMOUNT variable is set to the length of the text that you want to add. The SELECT FOR UPDATE statement locks the row and returns the LOB locator for the RESUME LOB column. Finally, the PL/SQL WRITE package procedure is called to write the text into the LOB value at the specified offset. WRITEAPPEND appends to the existing LOB value.

The example shows how to fetch a CLOB column in releases before Oracle9*i*. In those releases, it was not possible to fetch a CLOB column directly into a character column. The column value must be bound to a LOB locator, which is accessed by the DBMS_LOB package. An example later in this lesson shows that you can directly fetch a CLOB column by binding it to a character variable.

Checking the Space Usage of a LOB Table

```
CREATE OR REPLACE PROCEDURE check_space
IS
  l_fs1_bytes NUMBER;
  l_fs2_bytes NUMBER; ...
BEGIN
  DBMS_SPACE.SPACE_USAGE(
    segment_owner       => 'OE',
    segment_name        => 'CUSTOMER_PROFILES',
    segment_type        => 'TABLE',
    fs1_bytes           => l_fs1_bytes,
    fs1_blocks          => l_fs1_blocks,
    fs2_bytes           => l_fs2_bytes,
    fs2_blocks          => l_fs2_blocks, ...
  );
  DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE(' FS1 Blocks = '||l_fs1_blocks||'
     Bytes = '||l_fs1_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS2 Blocks = '||l_fs2_blocks||'
     Bytes = '||l_fs2_bytes); …
  DBMS_OUTPUT.PUT_LINE('=======================================');
  DBMS_OUTPUT.PUT_LINE('Total Blocks =
     '||to_char(l_fs1_blocks + l_fs2_blocks …));
END;
/
```


Checking the Space Usage of a LOB Table

To check the space usage in the disk blocks allocated to the LOB segment in the CUSTOMER_PROFILES table, use the CHECK_SPACE, as shown above. This procedure calls the DBMS_SPACE package.

To execute the procedure, run the following command:

```
EXECUTE check_space
```

The output is as follows:

```
FS1 Blocks = 1      Bytes = 8192
FS2 Blocks = 0      Bytes = 0
FS3 Blocks = 1      Bytes = 8192
FS4 Blocks = 3      Bytes = 24576
Full Blocks = 0     Bytes = 0
=========================
Total Blocks =      5 ||
Total Bytes = 40960
PL/SQL procedure successfully completed.
```

Checking Space Usage of a LOB Table (continued)

Complete Code of the CHECK_SPACE Procedure

```
CREATE OR REPLACE PROCEDURE check_space
IS
  l_fs1_bytes NUMBER;   l_fs2_bytes NUMBER;
  l_fs3_bytes NUMBER;   l_fs4_bytes NUMBER;
  l_fs1_blocks NUMBER;  l_fs2_blocks NUMBER;
  l_fs3_blocks NUMBER;  l_fs4_blocks NUMBER;
  l_full_bytes NUMBER;  l_full_blocks NUMBER;
  l_unformatted_bytes NUMBER;
  l_unformatted_blocks NUMBER;
BEGIN
  DBMS_SPACE.SPACE_USAGE(
    segment_owner      => 'OE',
    segment_name       => 'CUSTOMER_PROFILES',
    segment_type       => 'TABLE',
    fs1_bytes          => l_fs1_bytes,
    fs1_blocks         => l_fs1_blocks,
    fs2_bytes          => l_fs2_bytes,
    fs2_blocks         => l_fs2_blocks,
    fs3_bytes          => l_fs3_bytes,
    fs3_blocks         => l_fs3_blocks,
    fs4_bytes          => l_fs4_bytes,
    fs4_blocks         => l_fs4_blocks,
    full_bytes         => l_full_bytes,
    full_blocks        => l_full_blocks,
    unformatted_blocks => l_unformatted_blocks,
    unformatted_bytes  => l_unformatted_bytes
   );
DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE(' FS1 Blocks = '||l_fs1_blocks||'
     Bytes = '||l_fs1_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS2 Blocks = '||l_fs2_blocks||'
     Bytes = '||l_fs2_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS3 Blocks = '||l_fs3_blocks||'
     Bytes = '||l_fs3_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS4 Blocks = '||l_fs4_blocks||'
     Bytes = '||l_fs4_bytes);
  DBMS_OUTPUT.PUT_LINE('Full Blocks = '||l_full_blocks||'
     Bytes = '||l_full_bytes);
  DBMS_OUTPUT.PUT_LINE('====================================
      ========');
  DBMS_OUTPUT.PUT_LINE('Total Blocks =
     '||to_char(l_fs1_blocks + l_fs2_blocks +
     l_fs3_blocks + l_fs4_blocks + l_full_blocks)||  ' ||
     Total Bytes = '|| to_char(l_fs1_bytes + l_fs2_bytes
     + l_fs3_bytes + l_fs4_bytes + l_full_bytes));
END;
```

Selecting `CLOB` Values by Using SQL

- Query:

```
SELECT id, full_name , resume -- CLOB
FROM customer_profiles
WHERE id IN (164, 150);
```

- Output in SQL*Plus:

```
 ID         FULL_NAME           RESUME
---------- ----------------- ---------------------------
       164 Charlotte Kazan   Date of Birth: 8 Februa
ry 1951 Resigned = 5 June 2000
       150 Harry Dean Fonda  Date of Birth: 1 June 1
956 Resigned = 30 September 2000
```

- Output in SQL Developer:

	ID	FULL_NAME	RESUME
1	164	Charlotte Kazan	(CLOB) Resigned ...
2	150	Harry Dean Fo...	(CLOB) Date of Bi...

Selecting `CLOB` Values by Using SQL

It is possible to see the data in a `CLOB` column by using a `SELECT` statement. It is not possible to see the data in a `BLOB` or `BFILE` column by using a `SELECT` statement in SQL*Plus. You must use a tool that can display the binary information for a `BLOB`, as well as the relevant software for a `BFILE`—for example, you can use Oracle Forms.

Selecting CLOB Values by Using DBMS_LOB

- DBMS_LOB.SUBSTR (lob, amount, start_pos)
- DBMS_LOB.INSTR (lob, pattern)

```
SELECT DBMS_LOB.SUBSTR (resume, 5, 18),
       DBMS_LOB.INSTR (resume,' = ')
FROM   customer_profiles
WHERE  id IN (150, 164);
```

SQL*Plus

```
DBMS_LOB.SUBSTR(RESUME,5,18)
-----------------------------------------------
-----------------------------------------------
DBMS_LOB.INSTR(RESUME,'=')
--------------------------
Febru
                        40
June
                        36
```

SQL Developer

	DBMS_LOB.SUBSTR(RESUME,5,18)	DBMS_LOB.INSTR(RESUME,'=')
1	Febru	40
2	June	36

Selecting CLOB Values by Using DBMS_LOB

DBMS_LOB.SUBSTR

Use DBMS_LOB.SUBSTR to display a part of a LOB. It is similar in functionality to the SUBSTR SQL function.

DBMS_LOB.INSTR

Use DBMS_LOB.INSTR to search for information within the LOB. This function returns the numerical position of the information.

Selecting CLOB Values in PL/SQL

```
SET LINESIZE 50 SERVEROUTPUT ON FORMAT WORD_WRAP

DECLARE
  text VARCHAR2(4001);
BEGIN
 SELECT resume INTO text
 FROM customer_profiles
 WHERE id = 150;
 DBMS_OUTPUT.PUT_LINE('text is: '|| text);
END;
/
```

```
anonymous block completed
text is: Date of Birth: 1 June 1956 Resigned = 30
September 2000
```


Selecting CLOB Values in PL/SQL

The slide shows the code for accessing CLOB values that can be implicitly converted to VARCHAR2. When selected, the RESUME column value is implicitly converted from a CLOB to a VARCHAR2 to be stored in the TEXT variable.

Removing LOBs

- Delete a row containing LOBs:

```
DELETE
FROM  customer_profiles
WHERE id = 164;
```

- Disassociate a LOB value from a row:

```
UPDATE customer_profiles
SET resume = EMPTY_CLOB()
WHERE id = 150;
```


Removing LOBs

A LOB instance can be deleted (destroyed) by using the appropriate SQL DML statements. The SQL statement DELETE deletes a row and its associated internal LOB value. To preserve the row and destroy only the reference to the LOB, you must update the row by replacing the LOB column value with NULL or an empty string, or by using the EMPTY_B/CLOB() function.

Note: Replacing a column value with NULL and using EMPTY_B/CLOB are not the same. Using NULL sets the value to null; using EMPTY_B/CLOB ensures that nothing is in the column.

A LOB is destroyed when the row containing the LOB column is deleted, when the table is dropped or truncated, or when all LOB data is updated.

You must explicitly remove the file associated with a BFILE by using the OS commands.

To erase part of an internal LOB, you can use DBMS_LOB.ERASE.

Lesson Agenda

- Introduction to LOBs
- Managing BFILEs by using the DBMS_LOB package
- Migrating LONG data types to LOBs
- Manipulating LOB data
- Using temporary LOBs

Temporary LOBs

- Temporary LOBs:
  - Provide an interface to support creation of LOBs that act like local variables
  - Can be BLOBs, CLOBs, or NCLOBs
  - Are not associated with a specific table
  - Are created by using the DBMS_LOB.CREATETEMPORARY procedure
  - Use DBMS_LOB routines
- The lifetime of a temporary LOB is a session.
- Temporary LOBs are useful for transforming data in permanent internal LOBs.

Temporary LOBs

Temporary LOBs provide an interface to support the creation and deletion of LOBs that act like local variables. Temporary LOBs can be BLOBs, CLOBs, or NCLOBs.

The following are the features of temporary LOBs:

- Data is stored in your temporary tablespace, not in tables.
- Temporary LOBs are faster than persistent LOBs, because they do not generate redo or rollback information.
- Temporary LOBs lookup is localized to each user's own session. Only the user who creates a temporary LOB can access it, and all temporary LOBs are deleted at the end of the session in which they were created.
- You can create a temporary LOB by using DBMS_LOB.CREATETEMPORARY.

Temporary LOBs are useful when you want to perform a transformational operation on a LOB (for example, changing an image type from GIF to JPEG). A temporary LOB is empty when created and does not support the EMPTY_B/CLOB functions.

Use the DBMS_LOB package to use and manipulate temporary LOBs.

Creating a Temporary LOB

The PL/SQL procedure to create and test a temporary LOB:

```
CREATE OR REPLACE PROCEDURE is_templob_open(
  p_lob IN OUT BLOB, p_retval OUT INTEGER) IS
BEGIN
  -- create a temporary LOB
  DBMS_LOB.CREATETEMPORARY (p_lob, TRUE);
  -- see if the LOB is open: returns 1 if open
  p_retval := DBMS_LOB.ISOPEN (p_lob);
  DBMS_OUTPUT.PUT_LINE (
    'The file returned a value...' || p_retval);
  -- free the temporary LOB
  DBMS_LOB.FREETEMPORARY (p_lob);
END;
/
```


Creating a Temporary LOB

The example in the slide shows a user-defined PL/SQL procedure, is_templob_open, which creates a temporary LOB. This procedure accepts a LOB locator as input, creates a temporary LOB, opens it, and tests whether the LOB is open.

The is_templob_open procedure uses the procedures and functions from the DBMS_LOB package as follows:

- The CREATETEMPORARY procedure is used to create the temporary LOB.
- The ISOPEN function is used to test whether a LOB is open: This function returns the value 1 if the LOB is open.
- The FREETEMPORARY procedure is used to free the temporary LOB. Memory increases incrementally as the number of temporary LOBs grows, and you can reuse the temporary LOB space in your session by explicitly freeing temporary LOBs.

Summary

In this lesson, you should have learned how to:
- Identify four built-in types for large objects: BLOB, CLOB, NCLOB, and BFILE
- Describe how LOBs replace LONG and LONG RAW
- Describe two storage options for LOBs:
  - Oracle server (internal LOBs)
  - External host files (external LOBs)
- Use the DBMS_LOB PL/SQL package to provide routines for LOB management
- Use temporary LOBs in a session

Summary

There are four LOB data types:
- A BLOB is a binary large object.
- A CLOB is a character large object.
- An NCLOB stores multiple-byte national character set data.
- A BFILE is a large object stored in a binary file outside the database.

LOBs can be stored internally (in the database) or externally (in an OS file). You can manage LOBs by using the DBMS_LOB package and its procedure.

Temporary LOBs provide an interface to support the creation and deletion of LOBs that act like local variables.

Practice 7: Overview

This practice covers the following topics:

- Creating object types by using the `CLOB` and `BLOB` data types
- Creating a table with the `LOB` data types as columns
- Using the `DBMS_LOB` package to populate and interact with the `LOB` data

Practice 7: Overview

In this practice, you create a table with both `BLOB` and `CLOB` columns. Then, you use the `DBMS_LOB` package to populate the table and manipulate the data.

Use the `OE` schema for this practice.

For detailed instructions about performing this practice, see Appendix A, “Practice Solutions.”

Practice 7

In this practice, you create a table with both BLOB and CLOB columns. Then, you use the DBMS_LOB package to populate the table and manipulate the data.

Working with LOBs

1. Create a table called PERSONNEL by executing the D:\Labs\labs\lab_07_01.sql script file. The table contains the following attributes and data types:

Column Name	Data Type	Length
ID	NUMBER	6
last_name	VARCHAR2	35
review	CLOB	N/A
picture	BLOB	N/A

2. Insert two rows into the PERSONNEL table, one each for employee 2034 (whose last name is Allen) and employee 2035 (whose last name is Bond). Use the empty function for the CLOB, and provide NULL as the value for the BLOB.
3. Examine and execute the D:\labs\labs\lab_07_03.sql script. The script creates a table named REVIEW_TABLE. This table contains the annual review information for each employee. The script also contains two statements to insert review details about two employees.
4. Update the PERSONNEL table.
   a. Populate the CLOB for the first row by using this subquery in an UPDATE statement:
   ```
   SELECT ann_review
      FROM   review_table
   WHERE  employee_id = 2034;
   ```
   b. Populate the CLOB for the second row by using PL/SQL and the DBMS_LOB package. Use the following SELECT statement to provide a value for the LOB locator.
   ```
   SELECT ann_review
   FROM   review_table
   WHERE  employee_id = 2035;
   ```
5. Create a procedure that adds a locator to a binary file into the PICTURE column of the PRODUCT_INFORMATION table. The binary file is a picture of the product. The image files are named after the product IDs. You must load an image file locator into all rows in the Printers category (CATEGORY_ID = 12) in the PRODUCT_INFORMATION table.
   a. Create a DIRECTORY object called PRODUCT_PIC that references the location of the binary. These files are available in the D:\Labs\DATA_FILES\PRODUCT_PIC folder.
   ```
   CREATE DIRECTORY product_pic AS
   'D:\Labs\DATA_FILES\PRODUCT_PIC';
   ```
   (Alternatively, use the D:\labs\labs\lab_07_05a.sql script.)

   b. Add the image column to the PRODUCT_INFORMATION table by using:
   ```
   ALTER TABLE product_information ADD (picture BFILE);
   ```
   (Alternatively, use the D:\labs\labs\lab_07_05_b.sql file.)

Practice 7 (continued)

c. Create a PL/SQL procedure called `load_product_image` that uses `DBMS_LOB.FILEEXISTS` to test whether the product picture file exists. If the file exists, set the `BFILE` locator for the file in the `PICTURE` column; otherwise, display a message that the file does not exist. Use the `DBMS_OUTPUT` package to report file size information about each image associated with the `PICTURE` column. (Alternatively, use the `D:\labs\labs\lab_07_05_c.sql` file.)

d. Invoke the procedure by passing the name of the `PRODUCT_PIC` directory object as a string literal parameter value.

e. Check the `LOB` space usage of the `PRODUCT_INFORMATION` table. Use the `D:\labs\labs\lab_07_05_e.sql` file to create the procedure and execute it.

8

Administering SecureFile LOBs

Objectives

After completing this lesson, you should be able to:

- Describe SecureFile `LOB` features
- Enable SecureFile `LOB` deduplication, compression, and encryption
- Migrate BasicFile `LOB`s to the SecureFile `LOB` format
- Analyze the performance of `LOB`s

Objectives

In this lesson, you learn to migrate the pre-Oracle Database 11*g* `LOB` storage format (called BasicFile `LOB` format) to the SecureFile `LOB` format. You also compare the performance of `LOB`s stored in the BasicFile format with the SecureFile format. Finally, you learn how to enable SecureFile `LOB` deduplication (storage sharing), compression, and encryption.

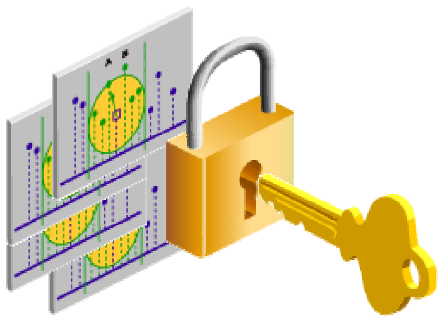
Lesson Agenda

- SecureFile LOB features
- Deduplication, compression, and encryption
- Migration of BasicFile LOBs to the SecureFile LOB format
- Performance of LOBs

SecureFile LOBs

Oracle Database 11*g* offers a reengineered large object (LOB) data type that:

- Improves performance
- Eases manageability
- Simplifies application development
- Offers advanced, next-generation functionality such as intelligent compression and transparent encryption



SecureFile LOBs

With SecureFile LOBs, the LOB data type is completely reengineered with dramatically improved performance, manageability, and ease of application development. This implementation, available with Oracle Database 11*g*, also offers advanced, next-generation functionality such as intelligent compression and transparent encryption. This feature significantly strengthens the native content management capabilities of Oracle Database.

SecureFile LOBs were introduced to supplement the implementation of original BasicFile LOBs that are identified by the BASICFILE SQL parameter.

Storage of SecureFile LOBs

Oracle Database 11*g* implements a new storage paradigm for LOB storage:

- If the SECUREFILE storage keyword appears in the CREATE TABLE statement, the new storage is used.
- If the BASICFILE storage keyword appears in the CREATE TABLE statement, the old storage paradigm is used.
- By default, the storage is BASICFILE, unless you modify the setting for the DB_SECUREFILE parameter in the init.ora file.

Storage of SecureFile LOBs

Starting with Oracle Database 11*g*, you have the option of using the new SecureFile storage paradigm for LOBs. You can specify to use the new paradigm by using the SECUREFILE keyword in the CREATE TABLE statement. If that keyword is left out, the old storage paradigm for basic file LOBs is used. This is the default behavior.

You can modify the init.ora file and change the default behavior for the storage of LOBs by setting the DB_SECUREFILE initialization parameter. The values allowed are:

- ALWAYS: Attempts to create all LOB files as SECUREFILES but creates any LOBs not in ASSM tablespaces as BASICFILE LOBs
- FORCE: All LOBs created in the system are created as SECUREFILE LOBs.
- PERMITTED: The default; allows SECUREFILES to be created when specified with the SECUREFILE keyword in the CREATE TABLE statement
- NEVER: Creates LOBs that are specified as SECUREFILE LOBs as BASICFILE LOBs
- IGNORE: Ignores the SECUREFILE keyword and all SECUREFILE options

Creating a SecureFile LOB

- Create a tablespace for the LOB data:

```
-- have your dba do this:
CREATE TABLESPACE sf_tbs1
 DATAFILE 'sf_tbs1.dbf' SIZE 1500M REUSE
 AUTOEXTEND ON NEXT 200M
 MAXSIZE 3000M
 SEGMENT SPACE MANAGEMENT AUTO;
```

1

- Create a table to hold the LOB data:

```
CONNECT oe
CREATE TABLE customer_profiles_sf
(id NUMBER,
 first_name VARCHAR2 (40),
 last_name  VARCHAR2 (80),
 profile_info  BLOB)
 LOB(profile_info) STORE AS SECUREFILE
 (TABLESPACE sf_tbs1);
```

2

Creating a SecureFile LOB

To create a column to hold a LOB that is a SecureFile, you:

- Create a tablespace to hold the data
- Define a table that contains a LOB column data type that is used to store the data in the SecureFile format

In the example shown in the slide:

1. The sf_tbs1 tablespace is defined. This tablespace stores the LOB data in the SecureFile format. When you define a column to hold SecureFile data, you must have Automatic Segment Space Management (ASSM) enabled for the tablespace in order to support SecureFiles.
2. The CUSTOMER_PROFILES_SF table is created. The PROFILE_INFO column holds the LOB data in the SecureFile format, because the storage clause identifies the format.

Writing Data to the SecureFile LOB

Writing data to a SECUREFILE LOB works in the same way as writing data to a BASICFILE LOB.

- Create the DIRECTORY object in the database that points to the location where the external documents are stored.
- Create a procedure to read the LOB data into the LOB column.
- Create a procedure to insert LOB data into the table (which references the procedure that reads the LOB data).
- Execute the insert procedure and specify the file that you want to insert.

Writing Data to the SecureFile LOB

In the previous lesson, you learned how to write data to a LOB. The same procedure is used when writing data to a SecureFile LOB.

Reading Data from the Table

Reading data from a SECUREFILE LOB works in the same way as reading data from a BASICFILE LOB.

- Create a procedure to specify the LOB data that you want to read from the table.
- Execute the procedure to read the table.

Reading Data From a SecureFile LOB

In the previous lesson, you learned how to read data from a LOB. The same procedure is used when reading data from a SecureFile LOB.

Lesson Agenda

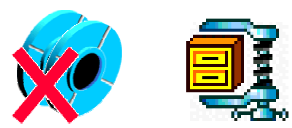
- SecureFile LOB features
- Deduplication, compression, and encryption
- Migration of BasicFile LOBs to the SecureFile LOB format
- Performance of LOBs

Enabling Deduplication and Compression

To enable deduplication and compression, use the ALTER TABLE statement with the DEDUPLICATE and COMPRESS options.

- By enabling deduplication with SecureFiles, duplicate LOB data is automatically detected and space is conserved by storing only one copy.
- Enabling compression turns on LOB compression.

```
ALTER TABLE tblname
MODIFY LOB lobcolname
(DEDUPLICATE option
 COMPRESS    option)
```



Enabling Deduplication and Compression with the ALTER TABLE Statement

You can enable deduplication and compression of SecureFiles with the ALTER TABLE statement and the DEDUPLICATE and COMPRESS options.

The DEDUPLICATE option enables you to specify that LOB data, which is identical in two or more rows in a LOB column, should share the same data blocks. The opposite of this option is KEEP_DUPLICATES. Using a secure hash index to detect duplication, the database combines LOBs with identical content into a single copy, thereby reducing storage and simplifying storage management. You can also use DBMS_LOB.SETOPTIONS to enable or disable deduplication on individual LOBs.

The options for the COMPRESS clause are:

- COMPRESS HIGH: Provides the best compression but incurs the most work
- COMPRESS MEDIUM: Is the default value
- NOCOMPRESS: Disables compression

You can also use DBMS_LOB.SETOPTIONS to enable or disable compression on individual LOBs.

Enabling Deduplication and Compression: Example

1. Check the space being used by the `CUSTOMER_PROFILES_SF` table.
2. Enable deduplication and compression on the `PROFILE_INFO` `LOB` column with the `ALTER TABLE` statement.
3. Recheck the space being used by the `CUSTOMER_PROFILES_SF` table.
4. Reclaim the space.

Deduplication and Compression: Example

To demonstrate how efficient deduplication and compression are on SecureFiles, the example follows the set of steps outlined in the slide.

In the first step, you see the space being used by the `CUSTOMER_PROFILES_SF` table.

In the second step, you enable deduplication and compression for the `PROFILE_INFO` `LOB` column in the `CUSTOMER_PROFILES_SF` table.

In the third step, you examine the space being used after deduplication and compression are enabled.

In the fourth step, you reclaim the space and examine the results.

Step 1: Checking Space Usage

```
CREATE OR REPLACE PROCEDURE check_sf_space
IS
  l_fs1_bytes NUMBER;
  l_fs2_bytes NUMBER;
  ...
BEGIN
  DBMS_SPACE.SPACE_USAGE(
    segment_owner       => 'OE',
    segment_name        => 'CUSTOMER_PROFILES_SF',
    segment_type        => 'TABLE',
    fs1_bytes           => l_fs1_bytes,
    fs1_blocks          => l_fs1_blocks,
    fs2_bytes           => l_fs2_bytes,
    fs2_blocks          => l_fs2_blocks, …
  );
  DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE(' FS1 Blocks = '||l_fs1_blocks||'
     Bytes = '||l_fs1_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS2 Blocks = '||l_fs2_blocks||'
     Bytes = '||l_fs2_bytes); …
  DBMS_OUTPUT.PUT_LINE('=======================================');
  DBMS_OUTPUT.PUT_LINE('Total Blocks =
     '||to_char(l_fs1_blocks + l_fs2_blocks));
...
END;
```


Checking Space Usage Before Deduplication and Compression

In the previous lesson, you checked the space usage of a BASICFILE LOB. Here, you create another procedure to check the SECUREFILE LOB space usage.

To execute the procedure, run the following command:

```
EXECUTE check_sf_space
```

Note: The full code for the CHECK_SF_SPACE procedure is shown on the next page.

Checking Space Usage Before Deduplication and Compression (continued)

```
CREATE OR REPLACE PROCEDURE check_sf_space
IS
  l_fs1_bytes NUMBER;   l_fs2_bytes NUMBER;
  l_fs3_bytes NUMBER;   l_fs4_bytes NUMBER;
  l_fs1_blocks NUMBER;  l_fs2_blocks NUMBER;
  l_fs3_blocks NUMBER;  l_fs4_blocks NUMBER;
  l_full_bytes NUMBER;  l_full_blocks NUMBER;
  l_unformatted_bytes NUMBER;
  l_unformatted_blocks NUMBER;
BEGIN
  DBMS_SPACE.SPACE_USAGE(
    segment_owner      => 'OE',
    segment_name       => 'CUSTOMER_PROFILES_SF',
    segment_type       => 'TABLE',
    fs1_bytes          => l_fs1_bytes,
    fs1_blocks         => l_fs1_blocks,
    fs2_bytes          => l_fs2_bytes,
    fs2_blocks         => l_fs2_blocks,
    fs3_bytes          => l_fs3_bytes,
    fs3_blocks         => l_fs3_blocks,
    fs4_bytes          => l_fs4_bytes,
    fs4_blocks         => l_fs4_blocks,
    full_bytes         => l_full_bytes,
    full_blocks        => l_full_blocks,
    unformatted_blocks => l_unformatted_blocks,
    unformatted_bytes  => l_unformatted_bytes
   );
DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE(' FS1 Blocks = '||l_fs1_blocks||'
     Bytes = '||l_fs1_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS2 Blocks = '||l_fs2_blocks||'
     Bytes = '||l_fs2_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS3 Blocks = '||l_fs3_blocks||'
     Bytes = '||l_fs3_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS4 Blocks = '||l_fs4_blocks||'
     Bytes = '||l_fs4_bytes);
  DBMS_OUTPUT.PUT_LINE('Full Blocks = '||l_full_blocks||'
     Bytes = '||l_full_bytes);
 DBMS_OUTPUT.PUT_LINE('================================
==============');
  DBMS_OUTPUT.PUT_LINE('Total Blocks =
     '||to_char(l_fs1_blocks + l_fs2_blocks +
     l_fs3_blocks + l_fs4_blocks + l_full_blocks)||  ' ||
     Total Bytes = '|| to_char(l_fs1_bytes + l_fs2_bytes
     + l_fs3_bytes + l_fs4_bytes + l_full_bytes));
END check_sf_space;
```

Step 1: Checking Space Usage

Execution Results:

```
EXECUTE check_sf_space

FS1 Blocks = 0     Bytes = 0
FS2 Blocks = 1     Bytes = 8192
FS3 Blocks = 0     Bytes = 0
FS4 Blocks = 4     Bytes = 32768
Full Blocks = 0    Bytes = 0
================================
Total Blocks = 5 ||
Total Bytes =  40960

PL/SQL procedure successfully completed.
```


Checking Space Usage Before Deduplication and Compression (continued)

You are shown the space usage before enabling deduplication and compression. The amount shown in the slide is used as a baseline for comparison over the next few steps.

Note: You can also compare the space usage with that of the `BASICFILE LOB` from the previous lesson.

Enabling Deduplication and Compression: Example

Step 2: Enabling deduplication and compression:

```
ALTER TABLE customer_profiles_sf
MODIFY LOB (profile_info)
(DEDUPLICATE LOB
 COMPRESS    HIGH);

Table altered.
```


Enabling Deduplication and Compression: Example

To enable deduplication and compression, run the ALTER TABLE statement with the appropriate options.

In this example, deduplication is turned on and the compression rate is set to HIGH.

Enabling Deduplication and Compression: Example

Step 3: Rechecking `LOB` space usage:

```
EXECUTE check_sf_space

FS1 Blocks = 0      Bytes = 0
FS2 Blocks = 0      Bytes = 0
FS3 Blocks = 0      Bytes = 0
FS4 Blocks = 4      Bytes = 32768
Full Blocks = 1      Bytes = 8192
================================
Total Blocks = 5 ||
Total Bytes =  40960

PL/SQL procedure successfully completed.
```


Rechecking LOB Space Usage

The amount of space used should be about 65% less than before deduplication and compression were enabled.

If the total space used appears to be the same as before deduplication and compression were enabled, you need to reclaim the free space before it is usable again.

Enabling Deduplication and Compression: Example

Step 4: Reclaiming the free space:

```
ALTER TABLE customer_profiles_sf ENABLE ROW MOVEMENT;   1
Table altered.

ALTER TABLE customer_profiles_sf SHRINK SPACE COMPACT   2
Table altered.

ALTER TABLE customer_profiles_sf SHRINK SPACE;          3
Table altered.
```


Reclaiming the Free Space

1. The first statement enables row movement so that the data can be shifted to save space. Compacting the segment requires row movement.
2. The second statement (`ALTER TABLE` resumes `SHRINK SPACE COMPACT`) redistributes the rows inside the blocks resulting in more free blocks under the High Water Mark (HWM)—but the HWM itself is not disturbed.
3. The third statement (`ALTER TABLE` resumes `SHRINK SPACE`) returns unused blocks to the database and resets the HWM, moving it to a lower position. Lowering the HWM should result in better full-table scan reads.

Rechecking LOB Space Usage

```
EXECUTE check_sf_space
FS1 Blocks = 0      Bytes = 0
FS2 Blocks = 1      Bytes = 8192
FS3 Blocks = 0      Bytes = 0
FS4 Blocks = 0      Bytes = 0
Full Blocks = 0      Bytes = 0
================================
Total Blocks = 1 ||
Total Bytes =  8192
```

Using Encryption

The encryption option enables you to turn the LOB encryption on or off, and optionally select an encryption algorithm.

- Encryption is performed at the block level.
- You can specify the encryption algorithm:
  - 3DES168
  - AES128
  - AES192 (default)
  - AES256

- The column encryption key is derived by using Transparent Data Encryption.
- All LOBs in the LOB column are encrypted.
- DECRYPT keeps the LOBs in cleartext.
- LOBs can be encrypted on a per-column or per-partition basis.

Using Encryption

You can create a table or alter a table with encryption enabled or disabled on a LOB column. The current Transparent Data Encryption (TDE) syntax is used for extending encryption to LOB data types.

Using Encryption

1. Create a directory to store the Transparent Data Encryption (TDE) wallet.

```
mkdir d:\etc\oracle\wallets
```

2. Edit the `<ORACLE_HOME>\network\admin\sqlnet.ora` file to indicate the location of the TDE wallet.

```
ENCRYPTION_WALLET_LOCATION=(SOURCE=(METHOD=FILE)
(METHOD_DATA= (DIRECTORY=d:\etc\oracle\wallets)))
```

3. Stop and start the listener for the change to take effect.

```
LSNRCTL RELOAD
```

4. To open the wallet, log in to SQL*Plus as `SYSDBA` and execute the following command:

```
ALTER system SET KEY IDENTIFIED BY "welcome1";
```


Using Encryption (continued)

TDE enables you to encrypt sensitive data in database columns as it is stored in the operating system files.

TDE is a key-based access control system that enforces authorization by encrypting data with a key that is kept secret. There can be only one key for each database table that contains encrypted columns, regardless of the number of encrypted columns in a given table. Each table's column encryption key is, in turn, encrypted with the database server's master key. No keys are stored in the database. Instead, they are stored in an Oracle wallet, which is part of the external security module.

To enable TDE, perform the following:

1. Create a directory to store the TDE wallet.
2. Modify the `sqlnet.ora` file to identify the location of the TDE wallet, as shown in the slide. Make sure that the wallet location is set to a location outside the Oracle installation to avoid ending up on a backup tape together with encrypted data.
3. Stop and start the listener to have the change take effect: `LSNRCTL RELOAD`
4. Open the wallet. Log in to SQL*Plus as the `SYS` user and execute the following command:

```
ALTER system SET KEY IDENTIFIED BY “welcome”;
```

Using Encryption: Example

- Enable encryption:

```
ALTER TABLE customer_profiles_sf
  MODIFY (profile_info ENCRYPT USING 'AES192');

Table altered.
```

- Verify that the LOB is encrypted:

```
SELECT *
FROM user_encrypted_columns;

TABLE_NAME        COLUMN_NAME       ENCRYPTION_ALG   SAL
----------------- ----------------- ---------------- ---
CUSTOMER_PROFILES PROFILE_INFO      AES 192 bits key YES
```


Using Encryption: Example

In the example shown in the slide, the CUSTOMER_PROFILES_SF table is modified so that the PROFILE_INFO column uses encryption.

You can query the USER_ENCRYPTED_COLUMNS dictionary view to see the status of the encrypted columns.

Lesson Agenda

- SecureFile `LOB` features
- Deduplication, compression, and encryption
- Migration of BasicFile `LOB`s to the SecureFile `LOB` format
- Performance of `LOB`s

Migrating from BasicFile to SecureFile Format

Check the LOB segment subtype name for the BasicFile format:

```
col segment_name format a30
col segment_type format a13

SELECT segment_name, segment_type, segment_subtype
FROM   dba_segments
WHERE  tablespace_name = 'LOB_TBS1'
AND    segment_type = 'LOBSEGMENT';

SEGMENT_NAME                   SEGMENT_TYPE       SEGME
------------------------------ ------------------ -----
SYS_LOB0000080068C00004$$      LOBSEGMENT         ASSM
```


LOB Segment Type for BasicFile Format

By querying the DBA_SEGMENTS view, you can see that the LOB segment subtype name for BasicFile LOB storage is ASSM.

Migrating from BasicFile to SecureFile Format

- The migration from BasicFile to SecureFiles LOB storage format is performed online.
- This means that the CUSTOMER_PROFILES table continues to be accessible during the migration.
- This type of operation is called online redefinition.

```
connect oe
CREATE TABLE customer_profiles_interim
(id NUMBER,
 full_name VARCHAR2 (45),
 resume CLOB,
 picture  BLOB)
 LOB(picture) STORE AS SECUREFILE
 (TABLESPACE lob_tbs1);
```


Creating an Interim Table

Online redefinition requires an interim table for data storage.

In this step, the interim table is defined with the SecureFiles LOB storage format, and the LOB is stored in the lob_tbs1 tablespace. After the migration is completed, the PICTURE LOB is stored in the lob_tbs1 tablespace.

Migrating from BasicFile to SecureFile Format

Call the DBMS_REDEFINITION package to perform the online redefinition operation:

```
connect /as sysdba
DECLARE
 error_count PLS_INTEGER := 0;
BEGIN
  DBMS_REDEFINITION.START_REDEF_TABLE
    ('OE', 'customer_profiles', 'customer_profiles_interim',
     'id id, full_name full_name,
      resume resume, picture picture',
      OPTIONS_FLAG => DBMS_REDEFINITION.CONS_USE_ROWID);
  DBMS_REDEFINITION.COPY_TABLE_DEPENDENTS
    ('OE', 'customer_profiles', 'customer_profiles_interim',
      1, true,true,true,false, error_count);
  DBMS_OUTPUT.PUT_LINE('Errors := ' || TO_CHAR(error_count));
  DBMS_REDEFINITION.FINISH_REDEF_TABLE
    ('OE', 'customer_profiles', 'customer_profiles_interim');
END;
```


Using DBMS_REDEFINITION to Perform Redefinition

After running the code shown in the slide and completing the redefinition operation, you can drop the interim table:

```
connect oe

DROP TABLE customer_profiles_interim;
```

Now, check the segment type of the migrated LOB. Note that the segment subtype for SecureFile LOB storage is SECUREFILE; for BasicFile format, it is ASSM.

```
SELECT segment_name, segment_type, segment_subtype
FROM dba_segments
WHERE tablespace_name = 'LOB_TBS1'
AND segment_type = 'LOBSEGMENT'
/

SEGMENT_NAME                    SEGMENT_TYPE        SEGMENT_SU
------------------------------ ------------------- ----------
SYS_LOB0000080071C00004$$       LOBSEGMENT          SECUREFILE
```

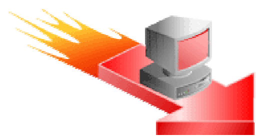
Lesson Agenda

- SecureFile `LOB` features
- Deduplication, compression, and encryption
- Migration of BasicFile `LOB`s to the SecureFile `LOB` format
- Performance of `LOB`s

Comparing Performance

Compare the performance on loading and reading LOB columns in the SecureFile and BasicFile formats:

Performance Comparison	Loading Data	Reading Data
SecureFile format	00:00:00.96	00:00:01.09
BasicFile format	00:00:01.68	00:00:01.15



Performance

In the examples shown in this lesson and the previous lesson, the performance on loading and reading data in the LOB column of the SecureFile format LOB is faster than that of the BasicFile format LOB.

Summary

In this lesson, you should have learned how to:

- Describe SecureFile `LOB` features
- Enable SecureFile `LOB` deduplication, compression, and encryption
- Migrate BasicFile `LOB`s to the SecureFile `LOB` format
- Analyze the performance of `LOB`s

Summary

In this lesson, you learned about the new SecureFile format for `LOB`s. You learned that the SecureFile format offers features such as deduplication, compression, and encryption. You learned how to migrate the older version BasicFile format to the SecureFile format, and also learned that the performance of SecureFile format `LOB`s is faster than the BasicFile format `LOB`s.

Practice 8 Overview: Using SecureFile Format LOBs

This practice covers the following topics:

- Setting up the environment for LOBs
- Migrating BasicFile LOBs to SecureFile LOBs
- Enabling deduplication and compression

Practice 8 Overview: Using SecureFile Format LOBs

In this lesson, you practice using the features of SecureFile format LOBs.

Use the OE schema for this practice.

For detailed instructions about performing this practice, see Appendix A, "Practice Solutions."

Practice 8

In this lesson, you practice using the features of SecureFile format LOBs.

Working with SecureFile LOBs

1. In this practice, you migrate a BasicFile format LOB to a SecureFile format LOB. You need to set up several supporting structures:
   a. As the OE user, drop your existing PRODUCT_DESCRIPTIONS table and create a new one:

```
DROP TABLE product_descriptions;

CREATE TABLE product_descriptions
  (product_id NUMBER);
```

   b. As the SYS user, create a new tablespace to store the LOB information.

```
CREATE TABLESPACE lob_tbs2
  DATAFILE 'lob_tbs2.dbf' SIZE 1500M REUSE
  AUTOEXTEND ON NEXT 200M
  MAXSIZE 3000M
  SEGMENT SPACE MANAGEMENT AUTO;
```

   c. Create a directory object that identifies the location of your LOBs. In the Oracle classroom, the location is in the Oracle D:\labs\DATA_FILES\PRODUCT_PIC folder. Then, grant read privileges on the directory to the OE user.

```
CREATE OR REPLACE DIRECTORY product_files
  AS 'd:\Labs\DATA_FILES\PRODUCT_PIC ';

GRANT READ ON DIRECTORY product_files TO oe;
```

   d. As the OE user, alter the table and add a BLOB column of the BASICFILE storage type.

```
ALTER TABLE product_descriptions ADD
 (detailed_product_info BLOB )
  LOB (detailed_product_info) STORE AS BASICFILE
   (tablespace lob_tbs2);
```

   e. Create the procedure to load the LOB data into the column (You can run the D:\Labs\labs\lab_08_01_e.sql script.):

```
CREATE OR REPLACE PROCEDURE loadLOBFromBFILE_proc (
  p_dest_loc IN OUT BLOB, p_file_name IN VARCHAR2)
IS
  v_src_loc  BFILE := BFILENAME('PRODUCT_FILES', p_file_name);
  v_amount   INTEGER := 4000;
BEGIN
  DBMS_LOB.OPEN(v_src_loc, DBMS_LOB.LOB_READONLY);
  v_amount := DBMS_LOB.GETLENGTH(v_src_loc);
  DBMS_LOB.LOADFROMFILE(p_dest_loc, v_src_loc, v_amount);
  DBMS_LOB.CLOSE(v_src_loc);
END loadLOBFromBFILE_proc;
/
```

Practice 8 (continued)

f. As the OE user, create the procedure to write the LOB data. (You can run the D:\Labs\lab\lab_08_01_f.sql script.)

```
CREATE OR REPLACE PROCEDURE write_lob (p_file IN
   VARCHAR2)
IS
  i    NUMBER;   v_id NUMBER;  v_b  BLOB;
BEGIN
  DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE('Begin inserting rows...');
  FOR i IN 1 .. 5 LOOP
    v_id:=SUBSTR(p_file, 1, 4);
    INSERT INTO product_descriptions
      VALUES (v_id, EMPTY_BLOB())
      RETURNING detailed_product_info INTO v_b;
    loadLOBFromBFILE_proc(v_b,p_file);
    DBMS_OUTPUT.PUT_LINE('Row '|| i ||' inserted.');
  END LOOP;
  COMMIT;
END write_lob;
/
```

g. As the OE user, execute the procedures to load the data. If you are using SQL*Plus, you can set the timing on to observe the time. (You can run the D:\Labs\lab\lab_08_01_g.sql script.)
Note: If you are using SQL Developer, issue only the EXECUTE statements listed as follows. In SQL Developer, some of the SQL*Plus commands are ignored. It is recommended that you use SQL*Plus for this exercise.

```
set serveroutput on
set verify on
set term on
set lines 200

timing start load_data
execute write_lob('1726_LCD.doc');
execute write_lob('1734_RS232.doc');
execute write_lob('1739_SDRAM.doc');
timing stop
```

h. As the SYSTEM user, check the segment type in the data dictionary.

```
SELECT segment_name, segment_type, segment_subtype
FROM   dba_segments
WHERE  tablespace_name = 'LOB_TBS2'
AND    segment_type = 'LOBSEGMENT';
```

Practice 8 (continued)

i. As the OE user, create an interim table.

```
CREATE TABLE product_descriptions_interim
(product_id NUMBER,
 detailed_product_info BLOB)
 LOB(detailed_product_info) STORE AS SECUREFILE
 (TABLESPACE lob_tbs2);
```

j. Connect as the SYSTEM user and run the redefinition script. (You can run the D:\Labs\lab\lab_08_01_j.sql script.)

```
DECLARE
 error_count PLS_INTEGER := 0;
BEGIN
  DBMS_REDEFINITION.START_REDEF_TABLE
    ('OE', 'product_descriptions',
   'product_descriptions_interim',
     'product_id product_id, detailed_product_info
   detailed_product_info',
      OPTIONS_FLAG => DBMS_REDEFINITION.CONS_USE_ROWID);
  DBMS_REDEFINITION.COPY_TABLE_DEPENDENTS
    ('OE', 'product_descriptions',
   'product_descriptions_interim',
      1, true,true,true,false, error_count);
  DBMS_OUTPUT.PUT_LINE('Errors := ' ||
   TO_CHAR(error_count));
  DBMS_REDEFINITION.FINISH_REDEF_TABLE
    ('OE', 'product_descriptions',
   'product_descriptions_interim');
END;
/
```

k. As the OE user, remove the interim table.

```
DROP TABLE product_descriptions_interim;
```

l. As the SYSTEM user, check the segment type in the data dictionary to make sure it is now set to SECUREFILE.

```
SELECT segment_name, segment_type, segment_subtype
FROM dba_segments
WHERE tablespace_name = 'LOB_TBS2'
AND segment_type = 'LOBSEGMENT';
```

Practice 8 (continued)

m. As the OE user, check the space of the table by executing the CHECK_SPACE procedure. (You can run the D:\Labs\labs\lab_08_01_m.sql script.)

```
CREATE OR REPLACE PROCEDURE check_space
IS
  l_fs1_bytes NUMBER;
  l_fs2_bytes NUMBER;
  l_fs3_bytes NUMBER;
  l_fs4_bytes NUMBER;
  l_fs1_blocks NUMBER;
  l_fs2_blocks NUMBER;
  l_fs3_blocks NUMBER;
  l_fs4_blocks NUMBER;
  l_full_bytes NUMBER;
  l_full_blocks NUMBER;
  l_unformatted_bytes NUMBER;
  l_unformatted_blocks NUMBER;
BEGIN
  DBMS_SPACE.SPACE_USAGE(
    segment_owner      => 'OE',
    segment_name       => 'PRODUCT_DESCRIPTIONS',
    segment_type       => 'TABLE',
    fs1_bytes          => l_fs1_bytes,
    fs1_blocks         => l_fs1_blocks,
    fs2_bytes          => l_fs2_bytes,
    fs2_blocks         => l_fs2_blocks,
    fs3_bytes          => l_fs3_bytes,
    fs3_blocks         => l_fs3_blocks,
    fs4_bytes          => l_fs4_bytes,
    fs4_blocks         => l_fs4_blocks,
    full_bytes         => l_full_bytes,
    full_blocks        => l_full_blocks,
    unformatted_blocks => l_unformatted_blocks,
    unformatted_bytes  => l_unformatted_bytes
   );
DBMS_OUTPUT.ENABLE;
  DBMS_OUTPUT.PUT_LINE(' FS1 Blocks = '||l_fs1_blocks||'
     Bytes = '||l_fs1_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS2 Blocks = '||l_fs2_blocks||'
     Bytes = '||l_fs2_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS3 Blocks = '||l_fs3_blocks||'
     Bytes = '||l_fs3_bytes);
  DBMS_OUTPUT.PUT_LINE(' FS4 Blocks = '||l_fs4_blocks||'
     Bytes = '||l_fs4_bytes);
  DBMS_OUTPUT.PUT_LINE('Full Blocks = '||l_full_blocks||'
     Bytes = '||l_full_bytes);
  DBMS_OUTPUT.PUT_LINE('====================================
      =========');
```

Practice 8 (continued)

```
DBMS_OUTPUT.PUT_LINE('Total Blocks =
     '||to_char(l_fs1_blocks + l_fs2_blocks +
     l_fs3_blocks + l_fs4_blocks + l_full_blocks)||  ' ||
     Total Bytes = '|| to_char(l_fs1_bytes + l_fs2_bytes
     + l_fs3_bytes + l_fs4_bytes + l_full_bytes));
END;
/

set serveroutput on
execute check_space;
```

9

Performance and Tuning

Objectives

After completing this lesson, you should be able to do the following:

- Understand and influence the compiler
- Tune PL/SQL code
- Enable intraunit inlining

Objectives

In this lesson, the performance and tuning topics are divided into three main groups:

- Native and interpreted compilation
- Tuning PL/SQL code
- Intraunit inlining

In the compilation section, you learn about native and interpreted compilation.

In the "Tuning PL/SQL Code" section, you learn why it is important to write smaller, executable sections of code, when to use SQL or PL/SQL, how bulk binds can improve performance, how to use the `FORALL` syntax, how to rephrase conditional statements, about data types and constraint issues.

With inlining, the compiler reviews code to see whether it can be inlined rather than referenced. You can influence the inlining process.

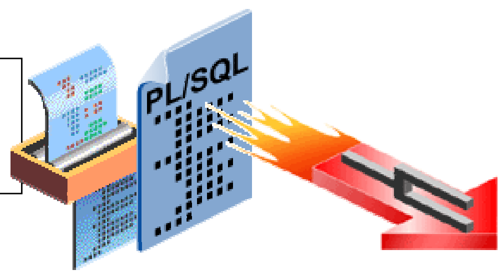
Lesson Agenda

- Using native and interpreted compilation methods
- Tuning PL/SQL code
- Enabling intraunit inlining

Native and Interpreted Compilation

Two compilation methods:

- Interpreted compilation
  - Default compilation method
  - Interpreted at run time
- Native compilation
  - Compiles into native code
  - Stored in the `SYSTEM` tablespace



Native and Interpreted Compilation

You can compile your PL/SQL code by using either native compilation or interpreted compilation.

With interpreted compilation, the PL/SQL statements in a PL/SQL program unit are compiled into an intermediate form, machine-readable code, which is stored in the database dictionary and interpreted at run time. You can use PL/SQL debugging tools on program units compiled for interpreted mode.

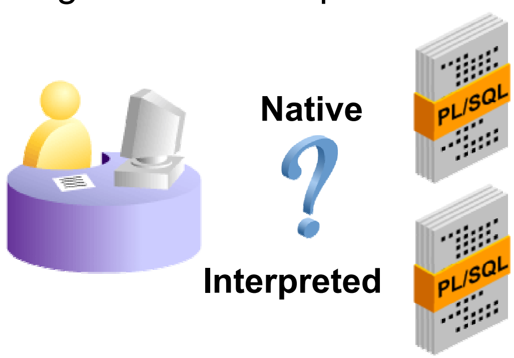
With PL/SQL native compilation, the PL/SQL statements in a PL/SQL program unit are compiled into native code and stored in the `SYSTEM` tablespace. Because the native code does not have to be interpreted at run time, it runs faster.

Native compilation applies only to PL/SQL statements. If your PL/SQL program contains only calls to SQL statements, it may not run faster when natively compiled, but it will run at least as fast as the corresponding interpreted code. The compiled code and the interpreted code make the same library calls, so their action is the same.

The first time a natively compiled PL/SQL program unit is executed, it is fetched from the `SYSTEM` tablespace into the shared memory. Regardless of how many sessions call the program unit, the shared memory has only one copy of it. If a program unit is not being used, the shared memory it is using might be freed, to reduce the memory load.

Deciding on a Compilation Method

- Use the interpreted mode when (typically during development):
  - You are using a debugging tool, such as SQL Developer
  - You need the code compiled quickly
- Use the native mode when (typically post development):
  - Your code is heavily PL/SQL based
  - You are looking for increased performance in production



Deciding on a Compilation Method

When deciding on a compilation method, you need to examine:

- Where you are in the development cycle
- What the program unit does

If you are debugging and recompiling program units frequently, the interpreted mode has these advantages:

- You can use PL/SQL debugging tools on program units compiled for interpreted mode (but not for those compiled for native mode).
- Compiling for interpreted mode is faster than compiling for native mode.

After completing the debugging phase of development, consider the following in determining whether to compile a PL/SQL program unit for native mode:

- The native mode provides the greatest performance gains for computation-intensive procedural operations. Examples are data warehouse applications and applications with extensive server-side transformations of data for display.
- The native mode provides the least performance gains for PL/SQL subprograms that spend most of their time executing SQL.
- When many program units (typically over 15,000) are compiled for native execution, and are simultaneously active, the large amount of shared memory required might affect system performance.

Setting the Compilation Method

- PLSQL_CODE_TYPE: Specifies the compilation mode for the PL/SQL library units

```
PLSQL_CODE_TYPE = { INTERPRETED | NATIVE }
```

- PLSQL_OPTIMIZE_LEVEL: Specifies the optimization level to be used to compile the PL/SQL library units

```
PLSQL_OPTIMIZE_LEVEL = { 0 | 1 | 2 | 3}
```

- In general, for fastest performance, use the following setting:

```
PLSQL_CODE_TYPE = NATIVE
PLSQL_OPTIMIZE_LEVEL = 2
```


Using the Initialization Parameters for PL/SQL Compilation

The PLSQL_CODE_TYPE Parameter

The PLSQL_CODE_TYPE compilation parameter determines whether the PL/SQL code is natively compiled or interpreted.

If you choose INTERPRETED:

- PL/SQL library units are compiled to PL/SQL bytecode format.
- These modules are executed by the PL/SQL interpreter engine.

If you choose NATIVE:

- PL/SQL library units (with the possible exception of top-level anonymous PL/SQL blocks) are compiled to native (machine) code.
- Such modules are executed natively without incurring interpreter overhead.

When the value of this parameter is changed, it has no effect on the PL/SQL library units that have already been compiled. The value of this parameter is stored persistently with each library unit. If a PL/SQL library unit is compiled natively, all subsequent automatic recompilations of that library unit use the native compilation. In Oracle Database 11*g*, native compilation is easier and more integrated, with fewer initialization parameters to set.

Using the PL/SQL Initialization Parameters (continued)

The `PLSQL_OPTIMIZE_LEVEL` Parameter

This parameter specifies the optimization level that is used to compile the PL/SQL library units. The higher the setting of this parameter, the more effort the compiler makes to optimize the PL/SQL library units. The available values are (0, 1, and 2 were available starting with Oracle 10*g*, release 2):

0: Maintains the evaluation order and hence the pattern of side effects, exceptions, and package initializations of Oracle9*i* and earlier releases. Also removes the new semantic identity of `BINARY_INTEGER` and `PLS_INTEGER`, and restores the earlier rules for the evaluation of integer expressions. Although the code runs somewhat faster than it did in Oracle9*i*, the use of level 0 forfeits most of the performance gains of PL/SQL starting with Oracle Database 10*g*.

1: Applies a wide range of optimizations to PL/SQL programs, including the elimination of unnecessary computations and exceptions, but generally does not move source code out of its original source order.

2: Applies a wide range of modern optimization techniques beyond those of level 1, including changes that may move source code relatively far from its original location.

3: This value is available in Oracle Database 11*g*. It applies a wide range of optimization techniques beyond those of level 2, automatically including techniques not specifically requested. This enables procedure inlining, which is an optimization process that replaces procedure calls with a copy of the body of the procedure to be called. The copied procedure almost always runs faster than the original call. To allow subprogram inlining, either accept the default value of the `PLSQL_OPTIMIZE_LEVEL` initialization parameter (which is 2) or set it to 3. With `PLSQL_OPTIMIZE_LEVEL` = 2, you must specify each subprogram to be inlined. With `PLSQL_OPTIMIZE_LEVEL` = 3, the PL/SQL compiler seeks opportunities to inline subprograms beyond those that you specify.

Generally, setting this parameter to 2 pays off in terms of better execution performance. If, however, the compiler runs slowly on a particular source module or if optimization does not make sense for some reason (for example, during rapid turnaround development), setting this parameter to 1 results in almost as good a compilation with less use of compile-time resources. The value of this parameter is stored persistently with the library unit.

Viewing the Compilation Settings

Use the USER|ALL|DBA_PLSQL_OBJECT_SETTINGS data dictionary views to display the settings for a PL/SQL object:

```
DESCRIBE ALL_PLSQL_OBJECT_SETTINGS
```

```
 Name                       Null?    Type
 ------------------------- -------- --------------------
 OWNER                      NOT NULL VARCHAR2(30)
 NAME                       NOT NULL VARCHAR2(30)
 TYPE                                VARCHAR2(12)
 PLSQL_OPTIMIZE_LEVEL                NUMBER
 PLSQL_CODE_TYPE                     VARCHAR2(4000)
 PLSQL_DEBUG                         VARCHAR2(4000)
 PLSQL_WARNINGS                      VARCHAR2(4000)
 NLS_LENGTH_SEMANTICS                VARCHAR2(4000)
 PLSQL_CCFLAGS                       VARCHAR2(4000)
 PLSCOPE_SETTINGS                    VARCHAR2(4000)
```


Displaying the PL/SQL Initialization Parameters

The columns of the USER_PLSQL_OBJECTS_SETTINGS data dictionary view include:

Owner: The owner of the object. This column is not displayed in the USER_PLSQL_OBJECTS_SETTINGS view.

Name: The name of the object

Type: The available choices are PROCEDURE, FUNCTION, PACKAGE, PACKAGE BODY, TRIGGER, TYPE, or TYPE BODY.

PLSQL_OPTIMIZE_LEVEL: The optimization level that was used to compile the object

PLSQL_CODE_TYPE: The compilation mode for the object

PLSQL_DEBUG: Specifies whether or not the object was compiled for debugging

PLSQL_WARNINGS: The compiler warning settings used to compile the object

NLS_LENGTH_SEMANTICS: The national language support (NLS) length semantics used to compile the object

PLSQL_CCFLAGS: The conditional compilation flag used to compile the object

PLSCOPE_SETTINGS: Controls the compile time collection, cross reference, and storage of PL/SQL source code identifier data (new in Oracle Database 11*g*)

Viewing the Compilation Settings

```
SELECT name, plsql_code_type, plsql_optimize_level
FROM   user_plsql_object_settings;
```

```
NAME                 PLSQL_CODE_TYP PLSQL_OPTIMIZE_LEVEL
-------------------- -------------- --------------------
ACTIONS_T              INTERPRETED                     2
ACTION_T               INTERPRETED                     2
ACTION_V               INTERPRETED                     2
ADD_ORDER_ITEMS        INTERPRETED                     2
CATALOG_TYP            INTERPRETED                     2
CATALOG_TYP            INTERPRETED                     2
CATALOG_TYP            INTERPRETED                     2
CATEGORY_TYP           INTERPRETED                     2
CATEGORY_TYP           INTERPRETED                     2
COMPOSITE_CATEGORY_TYP INTERPRETED                     2
...
```


Displaying the PL/SQL Initialization Parameters (continued)

Set the values of the compiler initialization parameters by using the `ALTER SYSTEM` or `ALTER SESSION` statements.

The parameters' values are accessed when the `CREATE OR REPLACE` or `ALTER` statements are executed.

Setting Up a Database for Native Compilation

- This requires DBA privileges.
- The PLSQL_CODE_TYPE compilation parameter must be set to NATIVE.
- The benefits apply to all the built-in PL/SQL packages that are used for many database operations.

```
ALTER SYSTEM SET PLSQL_CODE_TYPE = NATIVE;
```


Setting Up a Database for Native Compilation

If you have DBA privileges, you can set up a new database for PL/SQL native compilation by setting the PLSQL_CODE_TYPE compilation parameter to NATIVE. The performance benefits apply to all built-in PL/SQL packages that are used for many database operations.

Compiling a Program Unit for Native Compilation

```
SELECT name, plsql_code_type, plsql_optimize_level
FROM   user_plsql_object_settings
WHERE  name = 'ADD_ORDER_ITEMS';

NAME                    PLSQL_CODE_T PLSQL_OPTIMIZE_LEVEL
----------------------- ------------ --------------------
ADD_ORDER_ITEMS         INTERPRETED                     2
ALTER SESSION SET PLSQL_CODE_TYPE = 'NATIVE';

ALTER PROCEDURE add_order_items COMPILE;

SELECT name, plsql_code_type, plsql_optimize_level
FROM   user_plsql_object_settings
WHERE  name = 'ADD_ORDER_ITEMS';

NAME                    PLSQL_CODE_T PLSQL_OPTIMIZE_LEVEL
----------------------- ------------ --------------------
ADD_ORDER_ITEMS         NATIVE                          2
```

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Changing PL/SQL Initialization Parameters: Example

To change a compiled PL/SQL object from interpreted code type to native code type, you must set the `PLSQL_CODE_TYPE` parameter to `NATIVE` (optionally set the other parameters), and then recompile the program.

In the example shown above:

1. The compilation type is checked on the `ADD_ORDER_ITEMS` program unit.
2. The compilation method is set to `NATIVE` at the session level.
3. The `ADD_ORDER_ITEMS` program unit is recompiled.
4. The compilation type is checked again on the `ADD_ORDER_ITEMS` program unit to verify that it changed.

If you want to compile an entire database for native or interpreted compilation, scripts are provided to help you do so.

- You require DBA privileges.
- Set `PLSQL_CODE_TYPE` at the system level.
- Run the `dbmsupgnv.sql`-supplied script that is found in the `\Oraclehome\product\11.1.0\db_1\RDBMS\ADMIN` folder.

For detailed information, see the *Oracle® Database PL/SQL Language Reference 11g* reference manual.

Lesson Agenda

- Using native and interpreted compilation methods
- Tuning PL/SQL code
- Enabling intraunit inlining

Tuning PL/SQL Code

You can tune your PL/SQL code by:

- Identifying the data type and constraint issues
  - Data type conversion
  - The `NOT NULL` constraint
  - `PLS_INTEGER`
  - `SIMPLE_INTEGER`
- Writing smaller executable sections of code
- Comparing SQL with PL/SQL
- Understanding how bulk binds can improve performance
- Using the `FORALL` support with bulk binding
- Handling and saving exceptions with the `SAVE EXCEPTIONS` syntax
- Rephrasing conditional statements

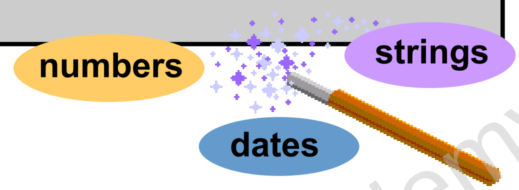
Tuning PL/SQL Code

By tuning your PL/SQL code, you can tailor its performance to best meet your needs. In the following pages, you learn about some of the main PL/SQL tuning issues that can improve the performance of your PL/SQL applications.

Avoiding Implicit Data Type Conversion

- PL/SQL performs implicit conversions between structurally different data types.
- Example: When assigning a `PLS_INTEGER` variable to a `NUMBER` variable

```
DECLARE
  n NUMBER;
BEGIN
  n := n + 15;     -- converted
  n := n + 15.0;   -- not converted
  ...
END;
```



Avoiding Implicit Data Type Conversion

At run time, PL/SQL automatically performs implicit conversions between structurally different data types. By avoiding implicit conversions, you can improve the performance of your code. The major problems with implicit data type conversion are:

- It is nonintuitive and can result in unexpected results.
- You have no control over the implicit conversion.

In the slide example, assigning a `PLS_INTEGER` variable to a `NUMBER` variable or vice versa results in a conversion, because their representations are different. Such implicit conversions can happen during parameter passing as well. 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.

To avoid implicit data type conversion, you can use the built-in functions:

- `TO_DATE`
- `TO_NUMBER`
- `TO_CHAR`
- `CAST`

Understanding the NOT NULL Constraint

```
PROCEDURE calc_m IS
 m NUMBER NOT NULL:=0;
 a NUMBER;
 b NUMBER;
BEGIN
 ...
 m := a + b;
 ...
END;
```

```
PROCEDURE calc_m IS
m NUMBER; --no
          --constraint
a NUMBER;
b NUMBER;
BEGIN
   ...
   m := a + b;
  IF m IS NULL THEN
    -- raise error
  END IF;
END;
```

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The NOT NULL Constraint

In PL/SQL, using the NOT NULL constraint incurs a small performance cost. Therefore, use it with care. Consider the example on the left in the slide that uses the NOT NULL constraint for *m*.

Because *m* is constrained by NOT NULL, the value of the expression *a + b* is assigned to a temporary variable, which is then tested for nullity. If the variable is not null, its value is assigned to *m*. Otherwise, an exception is raised. However, if *m* were not constrained, the value would be assigned to *m* directly.

A more efficient way to write the same example is shown on the right in the slide.

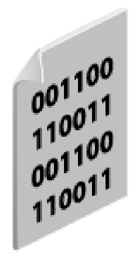
Note that the subtypes NATURALN and POSTIVEN are defined as the NOT NULL subtypes of NATURAL and POSITIVE. Using them incurs the same performance cost as seen above.

Using the NOT NULL Constraint	**Not Using the Constraint**
Slower	Faster
No extra coding is needed.	Requires extra coding that is error prone
When an error is implicitly raised, the value of *m* is preserved.	When an error is explicitly raised, the old value of *m* is lost.

Using the PLS_INTEGER Data Type for Integers

Use PLS_INTEGER when dealing with integer data:

- It is an efficient data type for integer variables.
- It requires less storage than INTEGER or NUMBER.
- Its operations use machine arithmetic, which is faster than library arithmetic.



Using the PLS_INTEGER Data Type for All Integer Operations

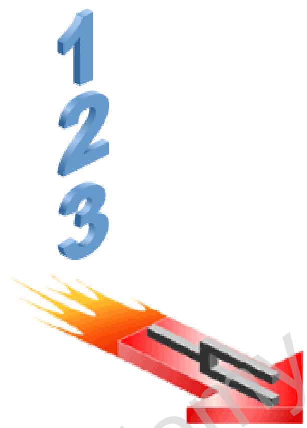
When you need to declare an integer variable, use the PLS_INTEGER data type, which is the most efficient numeric type. That is because PLS_INTEGER values require less storage than INTEGER or NUMBER values, which are represented internally as 22-byte Oracle numbers. Also, PLS_INTEGER operations use machine 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. Their variables require precision checking at run time that can affect the performance.

The BINARY_FLOAT and BINARY_DOUBLE data types are also faster than the NUMBER data type.

Using the `SIMPLE_INTEGER` Data Type

- Definition:
  – Is a predefined subtype
  – Has the range –2147483648 .. 2147483648
  – Does not include a null value
  – Is allowed anywhere in PL/SQL where the `PLS_INTEGER` data type is allowed
- Benefits:
  – Eliminates the overhead of overflow checking
  – Is estimated to be 2–10 times faster when compared with the `PLS_INTEGER` type with <u>native PL/SQL compilation</u>



Using the `SIMPLE_INTEGER` Data Type

The `SIMPLE_INTEGER` data type is a predefined subtype of the `BINARY_INTEGER` (or `PLS_INTEGER`) data type that has the same numeric range as `BINARY_INTEGER`. It differs significantly from `PLS_INTEGER` in its overflow semantics. Incrementing the largest `SIMPLE_INTEGER` value by one silently produces the smallest value, and decrementing the smallest value by one silently produces the largest value. These “wrap around” semantics conform to the Institute of Electrical and Electronics Engineers (IEEE) standard for 32-bit integer arithmetic.

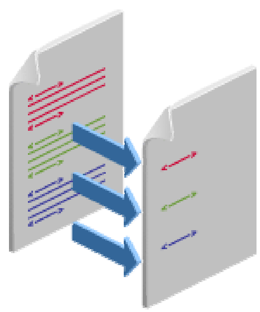
The key features of the `SIMPLE_INTEGER` predefined subtype are the following:

- Includes the range of –2147483648.. +2147483648
- Has a not null constraint
- Wraps rather than overflows
- Is faster than `PLS_INTEGER`

Without the overhead of overflow checking and nullness checking, the `SIMPLE_INTEGER` data type provides significantly better performance than `PLS_INTEGER` when the parameter `PLSQL_CODE_TYPE` is set to `native`, because arithmetic operations on the former are performed directly in the machine’s hardware. The performance difference is less noticeable when the parameter `PLSQL_CODE_TYPE` is set to `interpreted` but even with this setting, the `SIMPLE_INTEGER` type is faster than the `PLS_INTEGER` type.

Modularizing Your Code

- Limit the number of lines of code between a `BEGIN` and `END` to about a page or 60 lines of code.
- Use packaged programs to keep each executable section small.
- Use local procedures and functions to hide logic.
- Use a function interface to hide formulas and business rules.



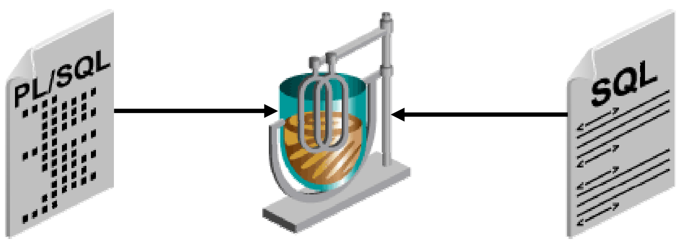
Write Smaller Executable Sections

By writing smaller sections of executable code, you can make the code easier to read, understand, and maintain. When developing an application, use a stepwise refinement. Make a general description of what you want your program to do, and then implement the details in subroutines. Using local modules and packaged programs can help keep each executable section small. This makes it easier for you to debug and refine your code.

Comparing SQL with PL/SQL

Each has its own benefits:

- SQL:
  - Accesses data in the database
  - Treats data as sets
- PL/SQL:
  - Provides procedural capabilities
  - Has more flexibility built into the language



SQL Versus PL/SQL

Both SQL and PL/SQL have their strengths. However, there are situations where one language is more appropriate to use than the other.

You use SQL to access data in the database with its powerful statements. SQL processes sets of data as groups rather than as individual units. The flow-control statements of most programming languages are absent in SQL, but present in PL/SQL. When using SQL in your PL/SQL applications, be sure not to repeat a SQL statement. Instead, encapsulate your SQL statements in a package and make calls to the package.

Using PL/SQL, you can take advantage of the PL/SQL-specific enhancements for SQL, such as autonomous transactions, fetching into cursor records, using a cursor `FOR` loop, using the `RETURNING` clause for information about modified rows, and using `BULK COLLECT` to improve the performance of multiple-row queries.

Though there are advantages of using PL/SQL over SQL in several cases, use PL/SQL with caution, especially under the following circumstances:

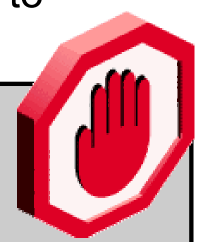
- Performing high-volume inserts
- Using user-defined PL/SQL functions
- Using external procedure calls
- Using the `utl_file` package as an alternative to SQL*Plus in high-volume reporting

Comparing SQL with PL/SQL

- Some simple set processing is markedly faster than the equivalent PL/SQL.

```
BEGIN
  INSERT INTO inventories2
    SELECT product_id, warehouse_id
    FROM main_inventories;
END;
```

- Avoid using procedural code when it may be better to use SQL.



```
...FOR I IN 1..5600 LOOP
     counter := counter + 1;
     SELECT product_id, warehouse_id
       INTO v_p_id, v_wh_id
       FROM big_inventories WHERE v_p_id = counter;
     INSERT INTO inventories2 VALUES(v_p_id, v_wh_id);
   END LOOP;...
```


SQL Versus PL/SQL (continued)

The SQL statement explained in the slide is a great deal faster than the equivalent PL/SQL loop. Take advantage of the simple set processing operations that are implicitly available in the SQL language, as it can run markedly faster than the equivalent PL/SQL loop. Avoid writing procedural code when SQL would work better.

However, there are occasions when you will get better performance from PL/SQL, even when the process could be written in SQL. Correlated updates are slow. With correlated updates, a better method is to access only correct rows by using PL/SQL. The following PL/SQL loop is faster than the equivalent correlated update SQL statement.

```
DECLARE
  CURSOR cv_raise IS
    SELECT deptno, increase
    FROM emp_raise;
BEGIN
    FOR dept IN cv_raise LOOP
      UPDATE big_emp
        SET sal = sal * dept.increase
        WHERE deptno = dept.deptno;
    END LOOP;
...
```

Comparing SQL with PL/SQL

- Instead of:

```
...
INSERT INTO order_items
  (order_id, line_item_id, product_id,
   unit_price, quantity)
VALUES (...
```

- Create a stand-alone procedure:

```
insert_order_item (
  2458, 6, 3515, 2.00, 4);
```

- Or a packaged procedure:

```
orderitems.ins (
  2458, 6, 3515, 2.00, 4);
```

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Encapsulating SQL Statements

From a design standpoint, do not embed your SQL statements directly within the application code. It is better if you write procedures to perform your SQL statements.

Pros

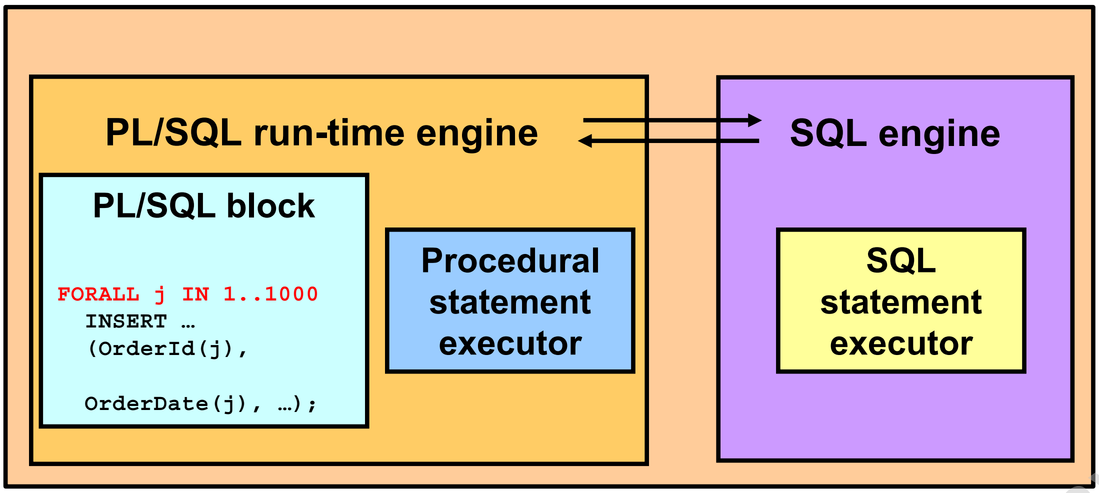
- If you design your application so that all programs that perform an insert on a specific table use the same `INSERT` statement, your application will run faster because of less parsing and reduced demands on the System Global Area (SGA) memory.
- Your program will also handle data manipulation language (DML) errors consistently.

Cons

- You may need to write more procedural code.
- You may need to write several variations of update or insert procedures to handle the combinations of columns that you are updating or inserting into.

Using Bulk Binding

Use bulk binds to reduce context switches between the PL/SQL engine and the SQL engine.



Using Bulk Binding

With bulk binds, you can improve performance by decreasing the number of context switches between the SQL and PL/SQL engines. When a PL/SQL program executes, each time a SQL statement is encountered, there is a switch between the PL/SQL engine and the SQL engine. The more the number of switches, the less the efficiency.

Improved Performance

Bulk binding enables you to implement array fetching. With bulk binding, entire collections, not just individual elements, are passed back and forth. Bulk binding can be used with nested tables, varrays, and associative arrays.

The more the rows affected by a SQL statement, the greater is the performance gain with bulk binding.

Using Bulk Binding

Bind whole arrays of values simultaneously, rather than looping to perform fetch, insert, update, and delete on multiple rows.

- Instead of:

```
...
FOR i IN 1 .. 50000 LOOP
  INSERT INTO bulk_bind_example_tbl
    VALUES(...);
END LOOP; ...
```

- Use:

```
...
FORALL i IN 1 .. 50000
  INSERT INTO bulk_bind_example_tbl
    VALUES(...);
...
```


Using Bulk Binding (continued)

In the first example shown in the slide, one row at a time is inserted into the target table. In the second example, the FOR loop is changed to a FORALL (which has an implicit loop) and all the immediately subsequent DML statements are processed in bulk. The entire code examples, along with the timing statistics for running each FOR loop example, are as follows.

First, create the demonstration table:

```
CREATE TABLE bulk_bind_example_tbl (
  num_col NUMBER,
  date_col DATE,
  char_col VARCHAR2(40));
```

Second, set the SQL*Plus TIMING variable on. Setting it on enables you to see the approximate elapsed time of the last SQL statement:

```
SET TIMING ON
```

Third, run this block of code that includes a FOR loop to insert 50,000 rows:

```
DECLARE
  TYPE typ_numlist IS TABLE OF NUMBER;
  TYPE typ_datelist IS TABLE OF DATE;
  TYPE typ_charlist IS TABLE OF VARCHAR2(40)
    INDEX BY PLS_INTEGER;
```

-- continued on the next page

Using Bulk Binding (continued)

-- continued from previous page

```
  n typ_numlist  := typ_numlist();
  d typ_datelist := typ_datelist();
  c typ_charlist;

BEGIN
  FOR i IN 1 .. 50000 LOOP
    n.extend;
    n(i) := i;
    d.extend;
    d(i) := sysdate + 1;
    c(i) := lpad(1, 40);
  END LOOP;
  FOR I in 1 .. 50000 LOOP
    INSERT INTO bulk_bind_example_tbl
      VALUES (n(i), d(i), c(i));
  END LOOP;
END;
/

2.184ms elapsed
```

Last, run this block of code that includes a `FORALL` loop to insert 50,000 rows. Note the significant decrease in the timing when using the `FORALL` processing:

```
DECLARE
  TYPE typ_numlist IS TABLE OF NUMBER;
  TYPE typ_datelist IS TABLE OF DATE;
  TYPE typ_charlist IS TABLE OF VARCHAR2(40)
    INDEX BY PLS_INTEGER;

  n typ_numlist  := typ_numlist();
  d typ_datelist := typ_datelist();
  c typ_charlist;

BEGIN
  FOR i IN 1 .. 50000 LOOP
    n.extend;
    n(i) := i;
    d.extend;
    d(i) := sysdate + 1;
    c(i) := lpad(1, 40);
  END LOOP;
  FORALL I in 1 .. 50000
    INSERT INTO bulk_bind_example_tbl
      VALUES (n(i), d(i), c(i));
END;
/

828ms elapsed
```

Using Bulk Binding

Use BULK COLLECT to improve performance:

```
CREATE OR REPLACE PROCEDURE process_customers
  (p_account_mgr customers.account_mgr_id%TYPE)
IS
  TYPE typ_numtab IS TABLE OF
    customers.customer_id%TYPE;
  TYPE typ_chartab IS TABLE OF
    customers.cust_last_name%TYPE;
  TYPE typ_emailtab IS TABLE OF
    customers.cust_email%TYPE;
  v_custnos     typ_numtab;
  v_last_names typ_chartab;
  v_emails      typ_emailtab;
BEGIN
  SELECT customer_id, cust_last_name, cust_email
    BULK COLLECT INTO v_custnos, v_last_names, v_emails
    FROM customers
    WHERE account_mgr_id = p_account_mgr;
  ...
END process_customers;
```


Using BULK COLLECT

When you require a large number of rows to be returned from the database, you can use the BULK COLLECT option for queries. This option enables you to retrieve multiple rows of data in a single request. The retrieved data is then populated into a series of collection variables. This query runs significantly faster than if it were done without the BULK COLLECT.

You can use the BULK COLLECT option with explicit cursors too:

```
BEGIN
  OPEN cv_customers INTO customers_rec;
  FETCH cv_customers BULK COLLECT INTO
    v_custnos, v_last_name, v_mails;
  ...
```

You can also use the LIMIT option with BULK COLLECT. This gives you control over the amount of processed rows in one step.

```
FETCH cv_customers BULK COLLECT
  INTO v_custnos, v_last_name, v_email
  LIMIT 200;
```

Using Bulk Binding

Use the RETURNING clause to retrieve information about the rows that are being modified:

```
DECLARE
  TYPE       typ_replist IS VARRAY(100) OF NUMBER;
  TYPE       typ_numlist IS TABLE OF
               orders.order_total%TYPE;
  repids     typ_replist :=
               typ_replist(153, 155, 156, 161);
  totlist    typ_numlist;
  c_big_total CONSTANT NUMBER := 60000;
BEGIN
  FORALL i IN repids.FIRST..repids.LAST
    UPDATE  orders
    SET     order_total = .95 * order_total
    WHERE   sales_rep_id = repids(i)
    AND     order_total > c_big_total
    RETURNING order_total BULK COLLECT INTO Totlist;
 END;
```


The RETURNING Clause

Often, applications need information about the row that is affected by a SQL operation; for example, to generate a report or take action. Using the RETURNING clause, you can retrieve information about the rows that you modified with the INSERT, UPDATE, and DELETE statements. This can improve performance, because it enables you to make changes, and at the same time, collect information about the data being changed. As a result, fewer network round trips, less server CPU time, fewer cursors, and less server memory are required. Without the RETURNING clause, you need two operations: one to make the change, and a second operation to retrieve information about the change. In the slide example, the order_total information is retrieved from the ORDERS table and collected into the totlist collection. The totlist collection is returned in bulk to the PL/SQL engine.

If you did not use the RETURNING clause, you would need to perform two operations, one for the UPDATE, and another for the SELECT:

```
UPDATE  orders SET order_total = .95 * order_total
WHERE   sales_rep_id = p_id
AND     order_total > c_big_total;

SELECT order_total FROM   orders
WHERE  sales_rep_id = p_id AND order_total > c_big_total;
```

The `RETURNING` Clause (continued)

In the following example, you update the credit limit of a customer and at the same time retrieve the customer's new credit limit into a SQL Developer environment variable:

```
CREATE OR REPLACE PROCEDURE change_credit
   (p_in_id   IN   customers.customer_id%TYPE,
    o_credit OUT NUMBER)
   IS
   BEGIN
    UPDATE customers
    SET    credit_limit = credit_limit * 1.10
    WHERE  customer_id = p_in_id
    RETURNING credit_limit INTO o_credit;
END change_credit;
/
VARIABLE g_credit NUMBER
EXECUTE change_credit(109, :g_credit)
PRINT g_credit
```

Using SAVE EXCEPTIONS

- You can use the SAVE EXCEPTIONS keyword in your FORALL statements:

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

- Exceptions raised during execution are saved in the %BULK_EXCEPTIONS cursor attribute.
- The attribute is a collection of records with two fields:

Field	Definition
ERROR_INDEX	Holds the iteration of the FORALL statement where the exception was raised
ERROR_CODE	Holds the corresponding Oracle error code

  - Note that the values always refer to the most recently executed FORALL statement.

Handling FORALL Exceptions

To handle the exceptions encountered during a BULK BIND operation, you can add the keyword SAVE EXCEPTIONS to your FORALL statement. Without it, if a row fails during the FORALL loop, the loop execution is terminated. SAVE_EXCEPTIONS allows the loop to continue processing and is required if you want the loop to continue.

All exceptions raised during the execution are saved in the %BULK_EXCEPTIONS cursor attribute, which stores a collection of records. This cursor attribute is available only from the exception handler.

Each record has two fields. The first field, %BULK_EXCEPTIONS(i).ERROR_INDEX, holds the "iteration" of the FORALL statement during which the exception was raised. The second field, BULK_EXCEPTIONS(i).ERROR_CODE, holds the corresponding Oracle error code.

The values stored by %BULK_EXCEPTIONS always refer to the most recently executed FORALL statement. The number of exceptions is saved in the count attribute of %BULK_EXCEPTIONS; that is, %BULK_EXCEPTIONS.COUNT. Its subscripts range from 1 to COUNT. If you omit the SAVE EXCEPTIONS keyword, execution of the FORALL statement stops when an exception is raised. In that case, SQL%BULK_EXCEPTIONS.COUNT returns 1, and SQL%BULK_EXCEPTIONS contains just one record. If no exception is raised during the execution, SQL%BULK_EXCEPTIONS.COUNT returns 0.

Handling `FORALL` Exceptions

```
DECLARE
  TYPE NumList IS TABLE OF NUMBER;
  num_tab   NumList :=
            NumList(100,0,110,300,0,199,200,0,400);
  bulk_errors EXCEPTION;
  PRAGMA      EXCEPTION_INIT (bulk_errors, -24381 );
BEGIN
  FORALL i IN num_tab.FIRST..num_tab.LAST
  SAVE EXCEPTIONS
  DELETE FROM orders WHERE order_total < 500000/num_tab(i);
EXCEPTION WHEN bulk_errors THEN
  DBMS_OUTPUT.PUT_LINE('Number of errors is: '
                        || SQL%BULK_EXCEPTIONS.COUNT);
  FOR j in 1..SQL%BULK_EXCEPTIONS.COUNT
  LOOP
    DBMS_OUTPUT.PUT_LINE (
      TO_CHAR(SQL%BULK_EXCEPTIONS(j).error_index) ||
      ' / ' ||
      SQLERRM(-SQL%BULK_EXCEPTIONS(j).error_code) );
  END LOOP;
END;
/
```


Example

In this example, the `EXCEPTION_INIT` pragma defines an exception named `BULK_ERRORS` and associates the name with the `ORA-24381` code, which is an "`Error in Array DML`." The PL/SQL block raises the predefined exception `ZERO_DIVIDE` when `i` equals 2, 5, 8. After the bulk bind is completed, `SQL%BULK_EXCEPTIONS.COUNT` returns 3, because the code tried to divide by zero three times. To get the Oracle error message (which includes the code), you pass `SQL%BULK_EXCEPTIONS(i).ERROR_CODE` to the error-reporting function `SQLERRM`. Here is the output:

```
Number of errors is: 5
Number of errors is: 3
2 / ORA-01476: divisor is equal to zero
5 / ORA-01476: divisor is equal to zero
8 / ORA-01476: divisor is equal to zero
```

Rephrasing Conditional Control Statements

In logical expressions, PL/SQL stops evaluating the expression as soon as the result is determined.

- Scenario 1:

```
IF TRUE|FALSE OR (v_sales_rep_id IS NULL) THEN
    ...
    ...
END IF;
```

- Scenario 2:

```
IF credit_ok(cust_id) AND (v_order_total < 5000)   THEN
  ...
END IF;
```


Rephrasing Conditional Control Statements

In logical expressions, improve performance by carefully tuning conditional constructs.

When evaluating a logical expression, PL/SQL stops evaluating the expression as soon as the result is determined. For example, in the first scenario in the slide, which involves an OR expression, when the value of the left operand yields TRUE, PL/SQL need not evaluate the right operand (because OR returns TRUE if either of its operands is true).

Now, consider the second scenario in the slide, which involves an AND expression. The Boolean function CREDIT_OK is always called. However, if you switch the operands of AND as follows, the function is called only when the expression v_order_total < 5000 is true (because AND returns TRUE only if both its operands are true):

```
IF (v_order_total < 5000 ) AND credit_ok(cust_id) THEN
        ...
END IF;
```

Rephrasing Conditional Control Statements

If your business logic results in one condition being true, use the `ELSIF` syntax for mutually exclusive clauses:

```
IF v_acct_mgr = 145 THEN
  process_acct_145;
END IF;
IF v_acct_mgr = 147 THEN
  process_acct_147;
END IF;
IF v_acct_mgr = 148 THEN
  process_acct_148;
END IF;
IF v_acct_mgr = 149 THEN
  process_acct_149;
END IF;
```

```
IF v_acct_mgr = 145
THEN
  process_acct_145;
ELSIF v_acct_mgr = 147
THEN
  process_acct_147;
ELSIF v_acct_mgr = 148
THEN
  process_acct_148;
ELSIF v_acct_mgr = 149
THEN
  process_acct_149;
END IF;
```

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Mutually Exclusive Conditions

If you have a situation where you are checking a list of choices for a mutually exclusive result, use the `ELSIF` syntax, as it offers the most efficient implementation. With `ELSIF`, after a branch evaluates to `TRUE`, the other branches are not executed.

In the example shown on the right in the slide, every `IF` statement is executed. In the example on the left, after a branch is found to be true, the rest of the branch conditions are not evaluated.

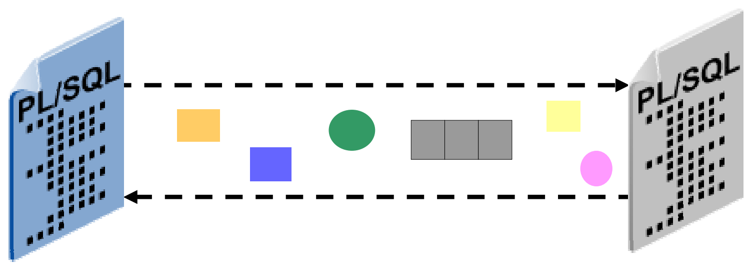
Sometimes you do not need an `IF` statement. For example, the following code can be rewritten without an `IF` statement:

```
IF date_ordered < sysdate + 7 THEN
  late_order := TRUE;
ELSE
  late_order := FALSE;
END IF;

--rewritten without an IF statement:
late_order := date_ordered < sysdate + 7;
```

Passing Data Between PL/SQL Programs

- The flexibility built into PL/SQL enables you to pass:
  - Simple scalar variables
  - Complex data structures
- You can use the `NOCOPY` hint to improve performance with the `IN OUT` parameters.



Passing Data Between PL/SQL Programs

You can pass simple scalar data or complex data structures between PL/SQL programs.

When passing collections as parameters, you may encounter a slight decrease in performance as compared with passing scalar data but the performance is still comparable. However, when passing `IN OUT` parameters that are complex (such as collections) to a procedure, you will experience significantly more overhead, because a copy of the parameter value is stored before the routine is executed. The stored value must be kept in case an exception occurs. You can use the `NOCOPY` compiler hint to improve performance in this situation. `NOCOPY` instructs the compiler not to make a backup copy of the parameter that is being passed. However, be careful when you use the `NOCOPY` compiler hint, because your results are not predictable if your program encounters an exception.

Passing Data Between PL/SQL Programs

Pass records as parameters to encapsulate data, as well as, write and maintain less code:

```
DECLARE
  TYPE CustRec IS RECORD (
    customer_id      customers.customer_id%TYPE,
    cust_last_name   VARCHAR2(20),
    cust_email       VARCHAR2(30),
    credit_limit     NUMBER(9,2));
  ...
  PROCEDURE raise_credit (cust_info CustRec);
```

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Passing Records as Arguments

You can declare user-defined records as formal parameters of procedures and functions as shown in the slide. By using records to pass values, you are encapsulating the data being passed. This requires less coding than defining, assigning, and manipulating each record field individually.

When you call a function that returns a record, use the notation:

```
function_name(parameters).field_name
```

For example, the following call to the NTH_HIGHEST_ORD_TOTAL function references the ORDER_TOTAL field in the ORD_INFO record:

```
DECLARE
  TYPE OrdRec IS RECORD (
  v_order_id      NUMBER(6),
  v_order_total   REAL);
  v_middle_total REAL;
FUNCTION nth_highest_total (n INTEGER) RETURN OrdRec IS
  order_info OrdRec;
BEGIN   ...
  RETURN order_info;  -- return record
END;
BEGIN                       -- call function
  v_middle_total := nth_highest_total(10).v_order_total;
...
```

Passing Data Between PL/SQL Programs

Use collections as arguments:

```
PACKAGE cust_actions IS
  TYPE NameTabTyp IS TABLE OF
customer.cust_last_name%TYPE
   INDEX BY PLS_INTEGER;
  TYPE CreditTabTyp IS TABLE OF
customers.credit_limit%TYPE
    INDEX BY PLS_INTEGER;
  ...
  PROCEDURE credit_batch( name_tab   IN NameTabTyp ,
                         credit_tab IN CreditTabTyp,
                        ...);
  PROCEDURE log_names ( name_tab IN NameTabTyp );
END cust_actions;
```


Passing Collections as Arguments

You can declare collections as formal parameters of procedures and functions. In the example in the slide, associative arrays are declared as the formal parameters of two packaged procedures. If you were to use scalar variables to pass the data, you would need to code and maintain many more declarations.

Lesson Agenda

- Using native and interpreted compilation methods
- Tuning PL/SQL code
- Enabling intraunit inlining

Introducing Intraunit Inlining

- Definition:
  - Inlining is the replacement of a call to a subroutine with a copy of the body of the subroutine that is called.
  - The copied procedure generally runs faster than the original.
  - The PL/SQL compiler can automatically find the calls that should be inlined.
- Benefits:
  - Inlining can provide large performance gains when applied judiciously by a factor of 2–10 times.

Introducing Inlining

Procedure inlining is an optimization process that replaces procedure calls with a copy of the body of the procedure to be called. The copied procedure almost always runs faster than the original call, because:

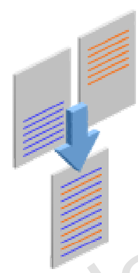
- The need to create and initialize the stack frame for the called procedure is eliminated.
- The optimization can be applied over the combined text of the call context and the copied procedure body.
- Propagation of constant actual arguments often causes the copied body to collapse under optimization.

When inlining is achieved, you can see performance gains of 2–10 times.

With Oracle Database 11*g*, the PL/SQL compiler can automatically find calls that should be inlined, and can do the inlining correctly and quickly. There are some controls to specify where and when the compiler should do this work (using the `PLSQL_OPTIMIZATION_LEVEL` database parameter), but usually, a general request is sufficient.

Using Inlining

- Influence implementing inlining via two methods:
  - Oracle parameter `PLSQL_OPTIMIZE_LEVEL`
  - `PRAGMA INLINE`
- Recommend that you:
  - Inline small programs
  - Inline programs that are frequently executed
- Use performance tools to identify the hotspots that are suitable for inline applications:
  - `plstimer`



Using Inlining

When implementing inlining, it is recommended that the process be applied to smaller programs, and/or programs that execute frequently. For example, you may want to inline small helper programs.

To help you identify which programs to inline, you can use the `plstimer` PL/SQL performance tool. This tool specifically analyzes program performance in terms of the time spent in procedures and the time spent on particular call sites. It is important that you identify the procedure calls that may benefit from inlining.

There are two ways to use inlining:

1. Set the `PLSQL_OPTIMIZE_LEVEL` parameter to 3. When this parameter is set to 3, the PL/SQL compiler searches for calls that might profit from inlining and inlines the most profitable calls. Profitability is measured by those calls that help the program speed up the most and keep the compiled object program as short as possible.
   ```
   ALTER SESSION SET plsql_optimize_level = 3;
   ```
2. Use `PRAGMA INLINE` in your PL/SQL code. This identifies whether a specific call should be inlined. Setting this pragma to “YES” has an effect only if the optimize level is set to two or higher.

Inlining Concepts

Noninlined program:

```
CREATE OR REPLACE PROCEDURE small_pgm
IS
  a NUMBER;
  b NUMBER;

  PROCEDURE touch(x IN OUT NUMBER, y NUMBER)
  IS
  BEGIN
    IF y > 0 THEN
      x := x*x;
    END IF;
  END;

BEGIN
  a := b;
  FOR I IN 1..10 LOOP
    touch(a, -17);
    a := a*b;
  END LOOP;
END small_pgm;
```


Inlining Concepts

The example shown in the slide will be expanded to show you how a procedure is inlined.

The `a:=a*b` assignment at the end of the loop looks like it could be moved before the loop. However, it cannot be, because `a` is passed as an `IN OUT` parameter to the `TOUCH` procedure. The compiler cannot be certain what the procedure does to its parameters. This results in the multiplication and in the assignment's being completed 10 times instead of only once, even though multiple executions are not necessary.

Inlining Concepts

Examine the loop after inlining:

```
...
BEGIN
  a := b;
  FOR i IN 1..10 LOOP
    IF -17 > 0 THEN
      a := a*a;
    END IF;
    a := a*b;
  END LOOP;
END small_pgm;
...
```


Inlining Concepts (continued)

The code in the slide shows what happens to the loop after inlining.

Inlining Concepts

The loop is transformed in several steps:

```
a := b;
 FOR i IN 1..10 LOOP ...
   IF false THEN
     a := a*a;
   END IF;
   a := a*b;
 END LOOP;

 a := b;
 FOR i IN 1..10 LOOP ...
   a := a*b;
 END LOOP;

 a := b;
 a := a*b;
 FOR i IN 1..10 LOOP ...
 END LOOP;

 a := b*b;
   FOR i IN 1..10 LOOP ...
 END LOOP;
```


Inlining Concepts (continued)

Because the insides of the procedure are now visible to the compiler, it can transform the loop in several steps, as shown in the slide.

Instead of 11 assignments (one outside of the loop) and 10 multiplications, only one assignment and one multiplication are performed. If the loop ran a million times (instead of 10), the savings would be a million assignments. For code that contains deep loops that are executed frequently, inlining offers tremendous savings.

Inlining: Example

- Set the `PLSQL_OPTIMIZE_LEVEL` session-level parameter to a value of 2 or 3:

```
ALTER PROCEDURE small_pgm COMPILE
  PLSQL_OPTIMIZE_LEVEL = 3 REUSE SETTINGS;
```

  – Setting it to 2 means no automatic inlining is attempted.
  – Setting it to 3 means automatic inlining is attempted but no pragmas are necessary.
- Within a PL/SQL subroutine, use `PRAGMA INLINE`:
  – NO means no inlining occurs regardless of the level and regardless of the YES pragmas.
  – YES means inline at level 2 of a particular call and increase the priority of inlining at level 3 for the call.

Inlining Concepts (continued)

To influence the optimizer to use inlining, you can set the `PLSQL_OPTIMIZE_LEVEL` parameter to a value of 2 or higher. By setting this parameter, you are making a request that inlining be used. It is up to the compiler to analyze the code and determine whether inlining is appropriate. When the optimize level is set to 3, the PL/SQL compiler searches for calls that might profit from inlining and inlines the most profitable calls.

In rare cases, if the overhead of the optimizer makes the compilation of very large applications take too long, you can lower the optimization by setting `PLSQL_OPTIMIZE_LEVEL=1` instead of its default value of 2. In even rarer cases, you might see a change in exception action, either an exception that is not raised at all, or one that is raised earlier than expected. Setting `PLSQL_OPTIMIZE_LEVEL=1` prevents the code from being rearranged.

To enable inlining within a PL/SQL subroutine, you can use `PRAGMA INLINE` to suggest that a specific call be inlined.

Inlining: Example

After setting the `PLSQL_OPTIMIZE_LEVEL` parameter, use a pragma:

```
CREATE OR REPLACE PROCEDURE small_pgm
IS
  a PLS_INTEGER;
  FUNCTION add_it(a PLS_INTEGER, b PLS_INTEGER)
  RETURN PLS_INTEGER
  IS
  BEGIN
    RETURN a + b;
  END;
BEGIN
  pragma INLINE (add_it, 'YES');
  a := add_it(3, 4) + 6;
END small_pgm;
```


Inlining Concepts (continued)

Within a PL/SQL subroutine, you can use `PRAGMA INLINE` to suggest that a specific call be inlined. When using `PRAGMA INLINE`, the first argument is the simple name of a subroutine, a function name, a procedure name, or a method name. The second argument is either the constant string ‘`NO`’ or ‘`YES`.’ The pragma can go before any statement or declaration. If you put it in the wrong place, you receive a syntax error message from the compiler.

To identify that a specific call should not be inlined, use:

```
PRAGMA INLINE (function_name, 'NO');
```

Setting the `PRAGMA INLINE` to ‘`NO`’ always works, regardless of any other pragmas that might also apply to the same statement. The pragma also applies at all optimization levels, and it applies no matter how badly the compiler would like to inline a particular call. If you are certain that you do not want some code inlined (perhaps due to the large size), you can set this to `NO`.

Setting the `PRAGMA INLINE` to ‘`YES`’ strongly encourages the compiler to inline the call. The compiler keeps track of the resources used during inlining and makes the decision to stop inlining when the cost becomes too high.

If inlining is requested and you have the compiler warnings turned on, you see the message:

```
PLW-06004: inlining of call of procedure ADD_IT requested.
```

If inlining is applied, you see the compiler warning (it is more of a message):

```
PLW-06005: inlining of call of procedure 'ADD_IT' was done.
```

Inlining: Guidelines

- Pragmas apply only to calls in the next statement following the pragma.
- Programs that make use of smaller helper subroutines are good candidates for inlining.
- Only local subroutines can be inlined.
- You cannot inline an external subroutine.
- Inlining can increase the size of a unit.
- Be careful about suggesting to inline functions that are deterministic.

Inlining: Guidelines

The compiler inlines code automatically, provided that you are using native compilation and have set the `PLSQL_OPTIMIZE_LEVEL` to 3. If you have set `PLSQL_Warnings = 'enable:all'`, using the SQL*Plus `SHOW ERRORS` command displays the name of the code that is inlined.

- The `PLW-06004` compiler message tells you that a `pragma INLINE('YES')` referring to the named procedure was found. The compiler will, if possible, inline this call.
- The `PLW-06005` compiler message tells you the name of the code that is inlined.

Alternatively, you can query the `USER/ALL/DBA_ERRORS` dictionary view.

Deterministic functions compute the same outputs for the same inputs every time it is invoked and have no side effects. In Oracle Database 11*g*, the PL/SQL compiler can figure out whether a function is deterministic; it may not find all that truly are, but it finds many of them. It never mistakes a nondeterministic function for a deterministic function.

Summary

In this lesson, you should have learned how to:

- Decide when to use native or interpreted compilation
- Tune your PL/SQL application. Tuning involves:
  - Using the `RETURNING` clause and bulk binds when appropriate
  - Rephrasing conditional statements
  - Identifying data type and constraint issues
  - Understanding when to use SQL and PL/SQL
- Identify opportunities for inlining PL/QL code
- Use native compilation for faster PL/SQL execution

Summary

There are several methods that help you tune your PL/SQL application.

When tuning PL/SQL code, consider using the `RETURNING` clause and/or bulk binds to improve processing. Be aware of conditional statements with an `OR` clause. Place the fastest processing condition first. There are several data type and constraint issues that can help in tuning an application.

By using native compilation, you can benefit from performance gains for computation-intensive procedural operations.

Practice 9: Overview

This practice covers the following topics:

- Tuning PL/SQL code to improve performance
- Coding with bulk binds to improve performance

Practice 9: Overview

In this practice, you tune some of the code that you created for the `OE` application.

- Break a previously built subroutine into smaller executable sections
- Pass collections into subroutines
- Add error handling for `BULK INSERT`

Use the `OE` schema for this practice.

For detailed instructions about performing this practice, see Appendix A, "Practice Solutions."

Practice 9

In this practice, you measure and examine performance and tuning.

Writing Better Code

1. Open the `lab_09_01.sql` file and examine the package (the package body is shown below):

```
CREATE OR REPLACE PACKAGE credit_card_pkg
IS
  PROCEDURE update_card_info
    (p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no
   VARCHAR2);

  PROCEDURE display_card_info
    (p_cust_id NUMBER);
END credit_card_pkg;  -- package spec
/

CREATE OR REPLACE PACKAGE BODY credit_card_pkg
IS

  PROCEDURE update_card_info
    (p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no
   VARCHAR2)
  IS
    v_card_info typ_cr_card_nst;
    i INTEGER;
  BEGIN
    SELECT credit_cards
      INTO v_card_info
      FROM customers
      WHERE customer_id = p_cust_id;
```

-- continued on the next page

Practice 9 (continued)

-- continued from previous page

```
    IF v_card_info.EXISTS(1) THEN  -- cards exist, add more
       i := v_card_info.LAST;
       v_card_info.EXTEND(1);
       v_card_info(i+1) := typ_cr_card(p_card_type,
                                        p_card_no);
       UPDATE customers
         SET  credit_cards = v_card_info
         WHERE customer_id = p_cust_id;
     ELSE   -- no cards for this customer yet, construct one
       UPDATE customers
         SET  credit_cards = typ_cr_card_nst
             (typ_cr_card(p_card_type, p_card_no))
         WHERE customer_id = p_cust_id;
     END IF;
   END update_card_info;

 PROCEDURE display_card_info
     (p_cust_id NUMBER)
   IS
     v_card_info typ_cr_card_nst;
     i INTEGER;
   BEGIN
     SELECT credit_cards
       INTO v_card_info
       FROM customers
       WHERE customer_id = p_cust_id;
     IF v_card_info.EXISTS(1) THEN
       FOR idx IN v_card_info.FIRST..v_card_info.LAST LOOP
           DBMS_OUTPUT.PUT('Card Type: ' ||
             v_card_info(idx).card_type || ' ');
         DBMS_OUTPUT.PUT_LINE('/ Card No: ' ||
             v_card_info(idx).card_num );
       END LOOP;
     ELSE
       DBMS_OUTPUT.PUT_LINE('Customer has no credit cards.');
     END IF;
   END display_card_info;
 END credit_card_pkg;  -- package body
 /
```

This code needs to be improved. The following issues exist in the code:

- The local variables use the `INTEGER` data type.
- The same `SELECT` statement is run in the two procedures.
- The same `IF v_card_info.EXISTS(1) THEN` statement is in the two procedures.

Practice 9 (continued)

Using Efficient Data Types

2. To improve the code, make the following modifications:

   a. Change the local `INTEGER` variables to use a more efficient data type.

   b. Move the duplicated code into a function. The package specification for the modification is:

```
CREATE OR REPLACE PACKAGE credit_card_pkg
IS
  FUNCTION cust_card_info
    (p_cust_id NUMBER, p_card_info IN OUT typ_cr_card_nst )
    RETURN BOOLEAN;
  PROCEDURE update_card_info
    (p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no
   VARCHAR2);
   PROCEDURE display_card_info
    (p_cust_id NUMBER);
END credit_card_pkg;  -- package spec
/
```

   c. Have the function return `TRUE` if the customer has credit cards. The function should return `FALSE` if the customer does not have credit cards. Pass an uninitialized nested table into the function. The function places the credit card information into this uninitialized parameter.

3. Test your modified code with the following data:

```
EXECUTE credit_card_pkg.update_card_info -
        (120, 'AM EX', 55555555555)
PL/SQL procedure successfully completed.

EXECUTE credit_card_pkg.display_card_info(120)
Card Type: Visa / Card No: 11111111
Card Type: MC / Card No: 2323232323
Card Type: DC / Card No: 4444444
Card Type: AM EX / Card No: 55555555555

PL/SQL procedure successfully completed.

-- Note: If you did not complete Practice 4, your results
-- will be:

EXECUTE credit_card_pkg.display_card_info(120)
Card Type: AM EX / Card No: 55555555555

PL/SQL procedure successfully completed.
```

Practice 9 (continued)

4. You need to modify the UPDATE_CARD_INFO procedure to return information (using the RETURNING clause) about the credit cards being updated. Assume that this information will be used by another application developer in your team, who is writing a graphical reporting utility on customer credit cards.

   a. Open the lab_09_04_a.sql file. It contains the modified code from the previous question #2.

   b. Modify the code to use the RETURNING clause to find information about the rows that are affected by the UPDATE statements.

   c. You can test your modified code with the following procedure (contained in lab_09_04_c.sql):

```
CREATE OR REPLACE PROCEDURE test_credit_update_info
(p_cust_id NUMBER, p_card_type VARCHAR2, p_card_no NUMBER)
IS
  v_card_info typ_cr_card_nst;
BEGIN
  credit_card_pkg.update_card_info
    (p_cust_id, p_card_type, p_card_no, v_card_info);
END test_credit_update_info;
/
```

   d. Test your code with the following statements set in boldface:

```
EXECUTE test_credit_update_info(125, 'AM EX', 123456789)
PL/SQL procedure successfully completed.

SELECT credit_cards FROM customers WHERE customer_id = 125;
CREDIT_CARDS(CARD_TYPE, CARD_NUM)
-------------------------------------------------------------
TYP_CR_CARD_NST(TYP_CR_CARD('AM EX', 123456789))
```

Practice 9 (continued)

Collecting Exception Information

5. In this exercise, you test exception handling with the `SAVE EXCEPTIONS` clause.
   a. Run the `lab_09_05a.sql` file to create a test table:

```
CREATE TABLE card_table
(accepted_cards VARCHAR2(50) NOT NULL);
```

   b. Open the `lab_09_05b.sql` file and run the contents:

```
DECLARE
  type typ_cards is table of VARCHAR2(50);
  v_cards typ_cards := typ_cards
  ( 'Citigroup Visa', 'Nationscard MasterCard',
    'Federal American Express', 'Citizens Visa',
    'International Discoverer', 'United Diners Club' );
BEGIN
  v_cards.Delete(3);
  v_cards.DELETE(6);
  FORALL j IN v_cards.first..v_cards.last
    SAVE EXCEPTIONS
    EXECUTE IMMEDIATE
   'insert into card_table (accepted_cards) values (
  :the_card)'
    USING v_cards(j);
END;
/
```

   c. Note the output:____

Practice 9 (continued)

d. Open the `lab_09_05_d.sql` file and run the contents:

```
 DECLARE
type typ_cards is table of VARCHAR2(50);
v_cards typ_cards := typ_cards
( 'Citigroup Visa', 'Nationscard MasterCard',
  'Federal American Express', 'Citizens Visa',
  'International Discoverer', 'United Diners Club' );
bulk_errors EXCEPTION;
PRAGMA exception_init (bulk_errors, -24381 );
BEGIN
  v_cards.Delete(3);
  v_cards.DELETE(6);
  FORALL j IN v_cards.first..v_cards.last
    SAVE EXCEPTIONS
    EXECUTE IMMEDIATE
   'insert into card_table (accepted_cards) values (
  :the_card)'
    USING v_cards(j);
 EXCEPTION
  WHEN  bulk_errors THEN
    FOR j IN 1..sql%bulk_exceptions.count
  LOOP
    Dbms_Output.Put_Line (
      TO_CHAR( sql%bulk_exceptions(j).error_index ) || ':
      ' || SQLERRM(-sql%bulk_exceptions(j).error_code) );
  END LOOP;
END;
/
```

e. Note the output:____

f. Why is the output different?

Timing Performance of SIMPLE_INTEGER and PLS_INTEGER

6. In this exercise, you compare the performance between the PLS_INTEGER and SIMPLE_INTEGER data types with native compilation:

   a. Run the lab_09_06_a.sql file to create a testing procedure that contains conditional compilation:

```
CREATE OR REPLACE PROCEDURE p
IS
  t0       NUMBER :=0;
  t1       NUMBER :=0;

 $IF $$Simple $THEN
  SUBTYPE My_Integer_t IS                     SIMPLE_INTEGER;
  My_Integer_t_Name CONSTANT VARCHAR2(30) :=
   'SIMPLE_INTEGER';
 $ELSE
  SUBTYPE My_Integer_t IS                     PLS_INTEGER;
  My_Integer_t_Name CONSTANT VARCHAR2(30) := 'PLS_INTEGER';
 $END

 v00  My_Integer_t := 0;     v01  My_Integer_t := 0;
 v02  My_Integer_t := 0;     v03  My_Integer_t := 0;
 v04  My_Integer_t := 0;     v05  My_Integer_t := 0;

 two      CONSTANT My_Integer_t := 2;
 lmt      CONSTANT My_Integer_t := 100000000;

BEGIN
  t0 := DBMS_UTILITY.GET_CPU_TIME();
  WHILE v01 < lmt LOOP
    v00 := v00 + Two;
    v01 := v01 + Two;
    v02 := v02 + Two;
    v03 := v03 + Two;
    v04 := v04 + Two;
    v05 := v05 + Two;
  END LOOP;

  IF v01 <> lmt OR v01 IS NULL THEN
    RAISE Program_Error;
  END IF;

  t1 := DBMS_UTILITY.GET_CPU_TIME();
  DBMS_OUTPUT.PUT_LINE(
    RPAD(LOWER($$PLSQL_Code_Type), 15)||
    RPAD(LOWER(My_Integer_t_Name), 15)||
    TO_CHAR((t1-t0), '9999')||' centiseconds');
END p;
```

Practice 9 (continued)

b. Open the `lab_09_06_b.sql` file and run the contents:

```
ALTER PROCEDURE p COMPILE
PLSQL_Code_Type = NATIVE PLSQL_CCFlags = 'simple:true'
REUSE SETTINGS;

EXECUTE p()

ALTER PROCEDURE p COMPILE
PLSQL_Code_Type = native PLSQL_CCFlags = 'simple:false'
REUSE SETTINGS;

EXECUTE p()
```

c. Note the output:____

d. Explain the output.