

Oracle Database 11g: Develop PL/SQL Program Units

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Preface

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Profile

Before You Begin This Course

Before you begin this course, you should have thorough knowledge of SQL and SQL*Developer or SQL*Plus, as well as working experience in developing applications.

Prerequisites

Prerequisites are any of the following Oracle University courses or combinations of courses:

- *Oracle Database 11g: PL/SQL Fundamentals*
- *Oracle Database 11g: Introduction to SQL*
- *Oracle Database 11g: SQL Fundamentals I* and *Oracle Database 11g: SQL Fundamentals II*
- *Oracle Database 11g: SQL and PL/SQL Fundamentals*

How This Course Is Organized

Oracle Database 11g: Develop PL/SQL Program Units is an instructor-led course featuring lectures and hands-on exercises. Online demonstrations and practice sessions reinforce the concepts and skills that are introduced.

Related Publications

Oracle Publications

Title	Part Number
<i>Oracle® Database Reference 11g Release 1 (11.1)</i>	B28320-01
<i>Oracle® Database SQL Language Reference 11g Release 1 (11.1)</i>	B28286-01
<i>Oracle® Database Concepts 11g Release 1 (11.1)</i>	B28318-01
<i>Oracle® Database Advanced Application Developer's Guide – 11g Release 1 (11.1)</i>	B28424-01
<i>SQL*Plus® User's Guide and Reference Release 11.1</i>	B31189-01
<i>Oracle Database SQL Developer User's Guide Release 1.2</i>	B10406-01
<i>Oracle® Database PL/SQL Language Reference 11g Release 1 (11.1)</i>	B28370-01
<i>Oracle® Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)</i>	B28419-01

Additional Publications

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

Typographic Conventions

Typographic Conventions In Text

Convention	Element	Example
Bold	Emphasized words and phrases in Web content only	To navigate within this application, do not click the Back and Forward buttons.
Bold italic	Glossary terms (if there is a glossary)	The <i>algorithm</i> inserts the new key.
Brackets	Key names	Press [Enter].
Caps and lowercase	Buttons, check boxes, triggers, windows	Click the Executable button. Select the Registration Required check box. Assign a When-Validate-Item trigger. Open the Master Schedule window.
Carets	Menu paths	Select File > Save.
Commas	Key sequences	Press and release these keys one at a time: [Alt], [F], [D]

Typographic Conventions (continued)

Typographic Conventions In Text (continued)

Convention	Object or Term	Example
Courier New, case sensitive	Code output, SQL and PL/SQL code elements, Java code elements, directory names, filenames, passwords, pathnames, URLs, user input, usernames	<p>Code output: <code>debug.seti('I',300);</code></p> <p>SQL code elements: Use the <code>SELECT</code> command to view information stored in the <code>last_name</code> column of the <code>emp</code> table.</p> <p>Java code elements: Java programming involves the <code>String</code> and <code>StringBuffer</code> classes.</p> <p>Directory names: <code>bin</code> (DOS), <code>\$FMHOME</code> (UNIX)</p> <p>Filenames: Locate the <code>init.ora</code> file.</p> <p>Passwords: Use <code>tiger</code> as your password.</p> <p>Pathnames: Open <code>c:\my_docs\projects</code>.</p> <p>URLs: Go to <code>http://www.oracle.com</code>.</p> <p>User input: Enter <code>300</code>.</p> <p>Usernames: Log on as <code>scott</code>.</p>
Initial cap	Graphics labels (unless the term is a proper noun)	Customer address (<i>but</i> Oracle Payables)
Italic	Emphasized words and phrases in print publications, titles of books and courses, variables	<p>Do <i>not</i> save changes to the database.</p> <p>For further information, see <i>Oracle7 Server SQL Language Reference Manual</i>.</p> <p>Enter <u><i>user_id@us.oracle.com</i></u>, where <i>user_id</i> is the name of the user.</p>
Plus signs	Key combinations	<p>Press and hold these keys simultaneously:</p> <p>[Control] + [Alt] + [Delete]</p>
Quotation marks	Lesson and chapter titles in cross references, interface elements with long names that have only initial caps	<p>This subject is covered in Unit II, Lesson 3, “Working with Objects.”</p> <p>Select the “Include a reusable module component” and click Finish.</p> <p>Use the “WHERE clause of query” property.</p>

Typographic Conventions (continued)

Typographic Conventions in Navigation Paths

This course uses simplified navigation paths, such as the following example, to direct you through Oracle Applications.

Example:

Invoice Batch Summary

(N) Invoice > Entry > Invoice Batches Summary (M) Query > Find (B) Approve

This simplified path translates to the following:

1. (N) From the Navigator window, select Invoice > Entry > Invoice Batches Summary.
2. (M) From the menu, select Query > Find.
3. (B) Click the Approve button.

Notation:

(N) = Navigator	(I) = Icon
(M) = Menu	(H) = Hyperlink
(T) = Tab	(B) = Button

1

Introduction

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Lesson Objectives

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

- Discuss the goals of the course
- Identify the available 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

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Lesson Aim

PL/SQL supports many program constructs. In this lesson, you review program units in the form of anonymous blocks, and you are introduced to named PL/SQL blocks. The named PL/SQL blocks are also referred to as subprograms. The named PL/SQL blocks include procedures and functions.

The tables from the Human Resources (HR) schema (which is used for the practices in this course) are briefly discussed. The development tools for writing, testing, and debugging PL/SQL are listed.

Lesson Agenda

- Course objectives and course agenda
- The schema and appendixes used in this course and the available PL/SQL development in this course
- Overview of Oracle SQL Developer
- Oracle 11g documentation and additional resources

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Course Objectives

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

- Create, execute, and maintain:
 - Procedures and functions with OUT parameters
 - Package constructs
 - Database triggers
- Manage PL/SQL subprograms and triggers
- Use a subset of Oracle-supplied packages to:
 - Generate screen and file output

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Course Objectives

You can develop modularized applications with database procedures by using database objects such as the following:

- Procedures and functions
- Packages
- Database triggers

Modular applications improve:

- Functionality
- Security
- Overall performance

Course Agenda

Day 1:

- Introduction
- Creating Procedures
- Creating Functions
- Creating Packages
- Working with Packages

Day 2:

- Using Oracle-Supplied Packages in Application Development
- Using Dynamic SQL
- Design Considerations for PL/SQL Code
- Creating Triggers

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Course Agenda

Day 3:

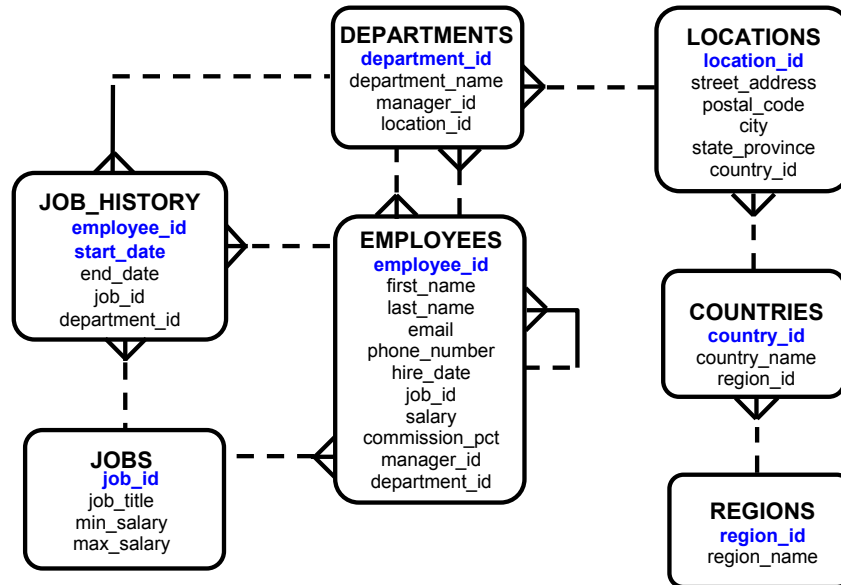
- Creating Compound, DDL, and Event Database Triggers
- Using the PL/SQL Compiler
- Managing PL/SQL Code
- Managing Dependencies

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The Human Resources (HR) Schema That Is Used in This Course



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The Human Resources (HR) Schema Description

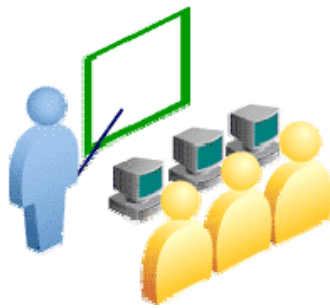
The Human Resources (HR) schema is part of the Oracle Sample Schemas that can be installed in an Oracle database. The practice sessions in this course use data from the HR schema.

Table Descriptions

- REGIONS contains rows that represent a region such as Americas, Asia, and so on.
- COUNTRIES contains rows for countries, each of which is associated with a region.
- LOCATIONS contains the specific address of a specific office, warehouse, or production site of a company in a particular country.
- DEPARTMENTS shows details about the departments in which employees work. Each department may have a relationship representing the department manager in the EMPLOYEES table.
- EMPLOYEES contains details about each employee working for a department. Some employees may not be assigned to any department.
- JOBS contains the job types that can be held by each employee.
- JOB_HISTORY contains the job history of the employees. If an employee changes departments within a job or changes jobs within a department, a new row is inserted into this table with the old job information of the employee.

Class Account Information

- Cloned HR account IDs are set up for you.
- Your account IDs are ora61 - ora80.
- The password matches your account ID.
- Each machine is assigned one account.
- The instructor has a separate ID.



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Appendixes Used in This Course

- Appendix A: Practices and Solutions
- Appendix APS: Additional Practice: Solutions
- Appendix B: Table Descriptions
- Appendix C: Using SQL Developer
- Appendix D: Review of PL/SQL
- Appendix E: Using SQL*Plus
- Appendix F: Studies for Implementing Triggers
- Appendix G: Using the DBMS_SCHEDULER and HTP Packages
- Appendix H: Review of JDeveloper

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PL/SQL Development Environments

This course setup provides the following tools for developing PL/SQL code:

- Oracle SQL Developer (used in this course)
- Oracle SQL*Plus
- Oracle JDeveloper IDE

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PL/SQL Development Environments

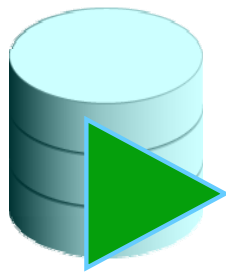
There are many tools that provide an environment for developing PL/SQL code. Oracle provides several tools that can be used to write PL/SQL code. Some of the development tools that are available for use in this course are:

- **Oracle SQL Developer:** A graphical tool
- **Oracle SQL*Plus:** A window or command-line application
- **Oracle JDeveloper:** A window-based integrated development environment (IDE)

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

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 using standard Oracle database authentication.
- You use SQL Developer in this course.



SQL Developer

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What Is Oracle SQL Developer?

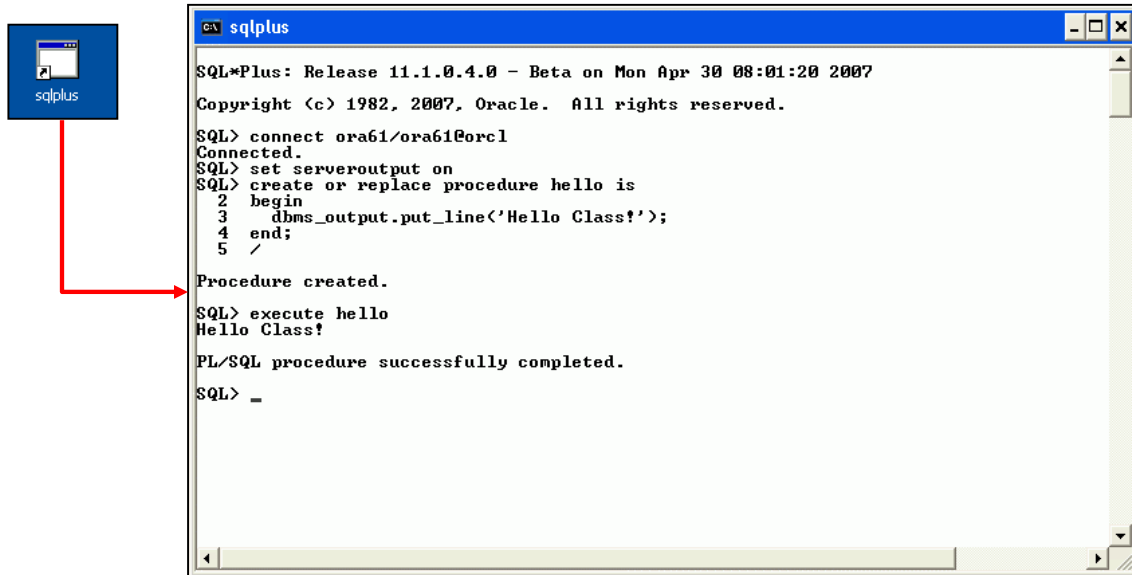
Oracle SQL Developer is a free graphical tool designed to improve your productivity and simplify the development of everyday database tasks. With just a few clicks, you can easily create and maintain stored procedures, test SQL statements, and view optimizer plans.

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 using standard Oracle database authentication. When connected, you can perform operations on objects in the database.

Coding PL/SQL in SQL*Plus



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Coding PL/SQL in SQL*Plus

Oracle SQL*Plus is a graphical user interface (GUI) or 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.

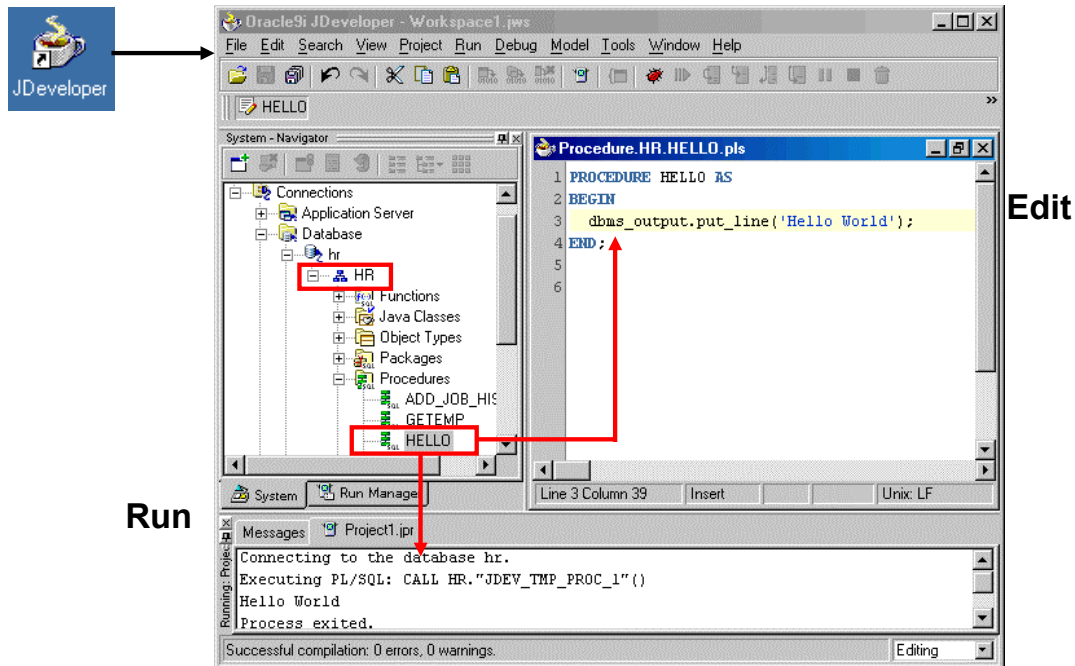
SQL*Plus is:

- 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 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.

Coding PL/SQL in Oracle JDeveloper



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Coding PL/SQL in Oracle JDeveloper

Oracle JDeveloper allows developers to create, edit, test, and debug PL/SQL code by using a sophisticated GUI. Oracle JDeveloper is a part of Oracle Developer Suite and is also available as a separate product.

When coding PL/SQL in JDeveloper, consider the following:

- You first create a database connection to enable JDeveloper to access a database schema owner for the subprograms.
- You can then use the JDeveloper context menus on the Database connection to create a new subprogram construct using the built-in JDeveloper Code Editor. The JDeveloper Code Editor provides an excellent environment for PL/SQL development, with features such as the following:
 - Different colors for syntactical components of the PL/SQL language
 - Code insight to rapidly locate procedures and functions in supplied packages
- You invoke a subprogram by using a Run command on the context menu for the named subprogram. The output appears in the JDeveloper Log Message window, as shown in the lower portion of the screenshot.

Note: JDeveloper provides color-coding syntax in the JDeveloper Code Editor and is sensitive to PL/SQL language constructs and statements.

Lesson Agenda

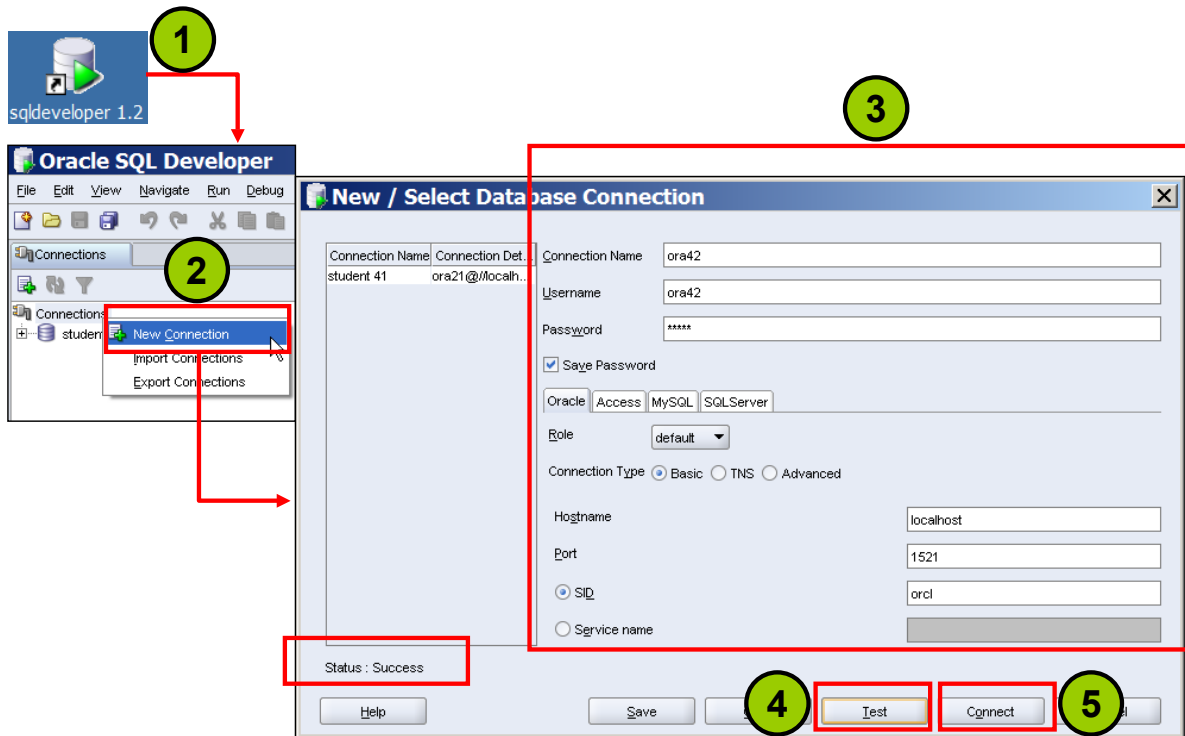
- Course objectives and course agenda
- The schema and appendixes used in this course and the available PL/SQL development in this course
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- Oracle 11g documentation and additional resources

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Starting SQL Developer and Creating a Database Connection



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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 you want to connect to.
4. Click Test to make sure that the connection has been 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. So, after you close the SQL Developer connection and open it again, you will not be prompted for the password.

Creating Schema Objects

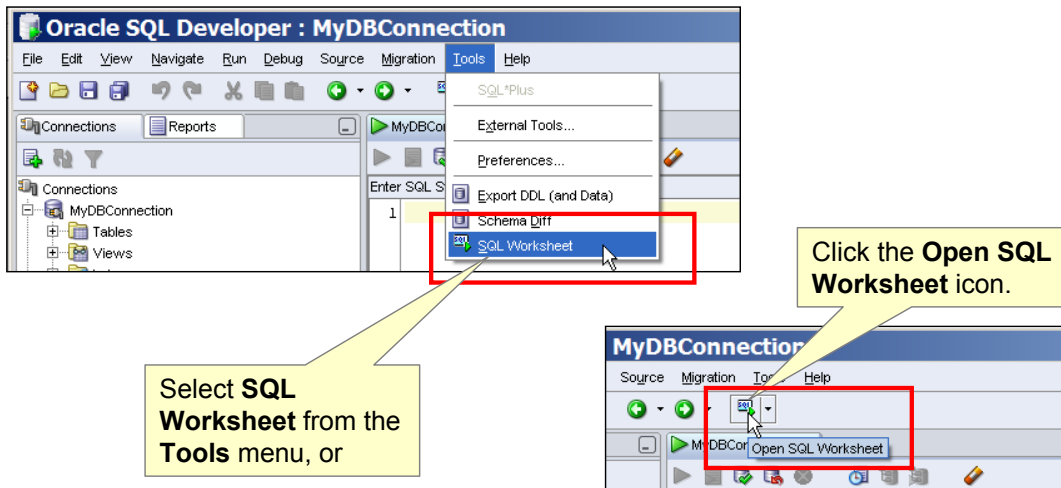
- You can create any schema object in SQL Developer using one of the following methods:
 - Executing a SQL statement in the SQL Worksheet
 - Using the context menu
- Edit the objects using an edit dialog box or one of the many context-sensitive menus.
- View the DDL for adjustments such as creating a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

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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.



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Using the SQL Worksheet

When you connect to a database, a SQL Worksheet window for that connection is automatically opened. You can use the SQL Worksheet to enter and execute SQL, PL/SQL, and SQL*Plus statements. The SQL Worksheet supports SQL*Plus statements to a certain extent. SQL*Plus statements that are not supported by the SQL Worksheet are ignored and not passed to the database.

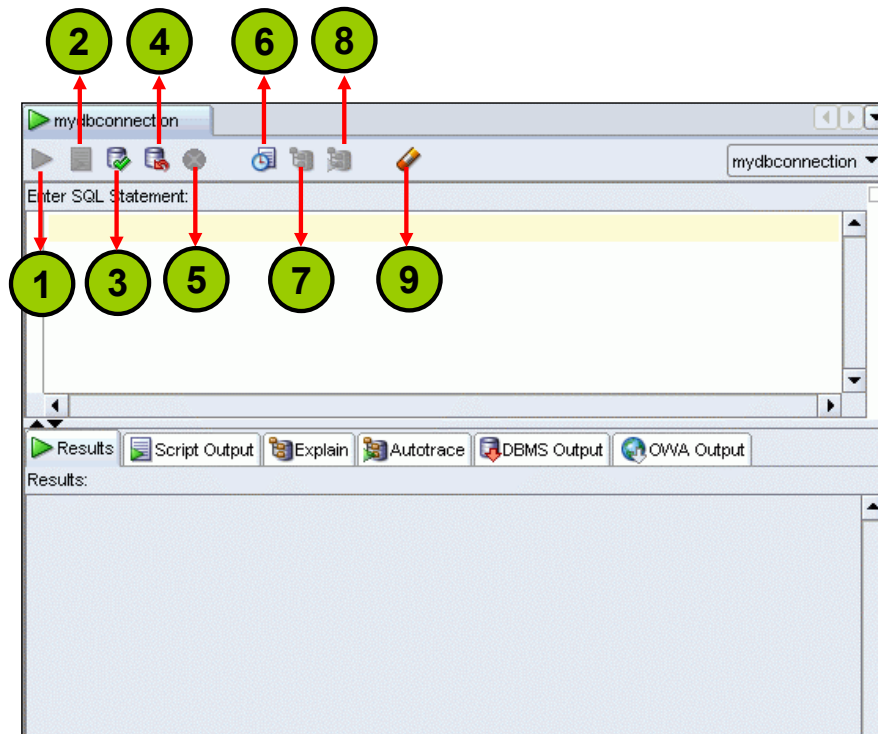
You can specify any actions that can be processed by the database connection associated with the worksheet, such as:

- 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 any of the following two options:

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

Using the SQL Worksheet



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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, and viewing the history of SQL statements that you have 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 but not substitution variables.
2. **Run Script:** Executes all statements in the Enter SQL Statement box using the Script Runner. You can use substitution variables in the SQL statements but not bind variables.
3. **Commit:** Writes any changes to the database and ends the transaction
4. **Rollback:** Discards any changes to the database, without writing them to the database, and ends the transaction
5. **Cancel:** Stops the execution of any statements currently being executed
6. **SQL History:** Displays a dialog box with information about SQL statements that you have 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.

The screenshot shows the SQL Worksheet interface. The 'Enter SQL Statement' box is highlighted with a red rectangle. It contains the following SQL statements:

```
1 SELECT last_name, salary
2 FROM employees
3 WHERE salary > 10000;
4
5 SELECT last_name "Name", salary*12 "Annual Salary"
6 FROM employees;
```

The 'Script Output' tabbed page is also highlighted with a red rectangle. It displays the results of the first statement:

Name	Annual Salary
Ozer	11500
Abel	11000

Below the table, it indicates '15 rows selected'.

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

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

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Executing SQL Statements

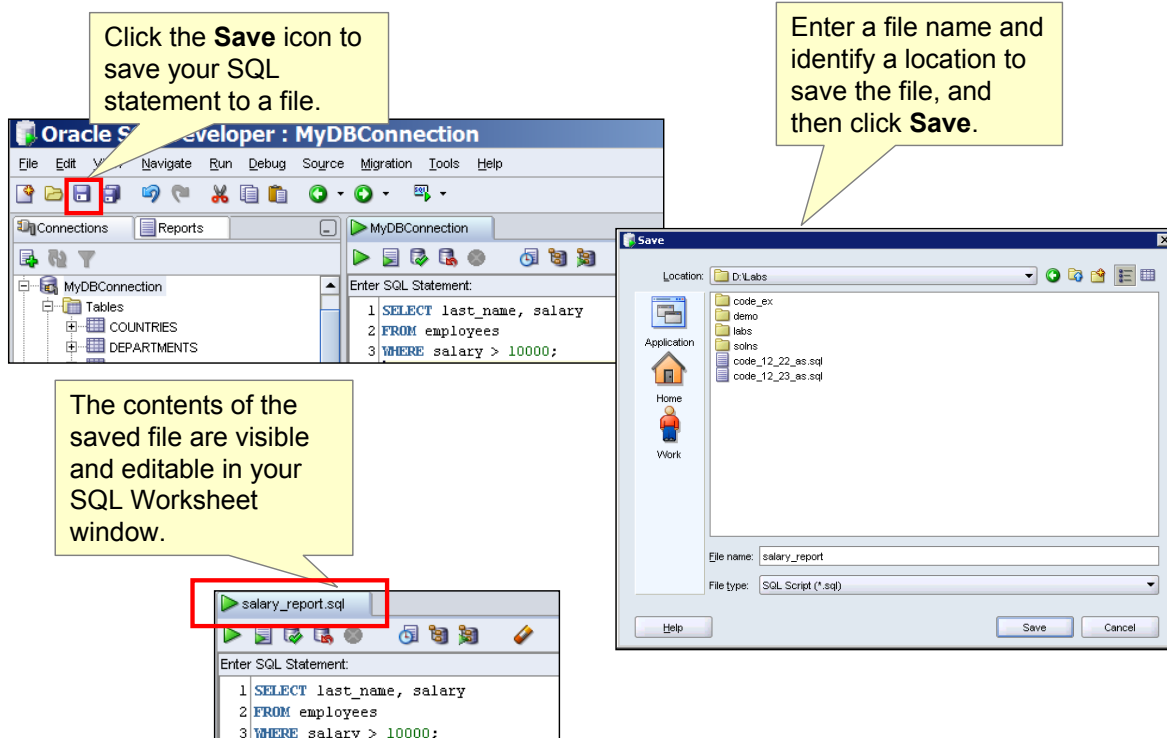
In the SQL Worksheet, you can use the Enter SQL Statement box to enter a single or multiple SQL statements. For a single statement, the semicolon at the end is optional.

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 the **F9** key.

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

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.

Saving SQL Scripts



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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, follow these steps:

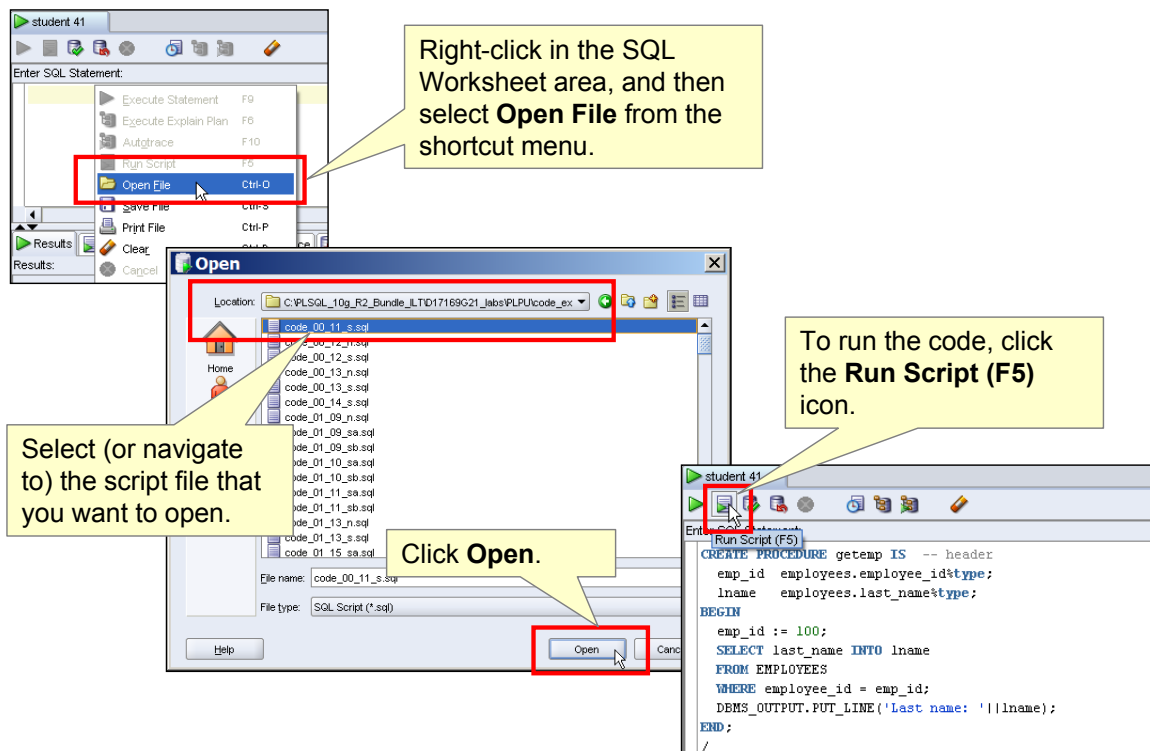
1. Click the Save icon or use the **File > Save** menu item.
2. In the Windows Save dialog box, enter a file name and the location where you want the file saved.
3. Click Save.

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

Executing Saved Script Files: Method 1



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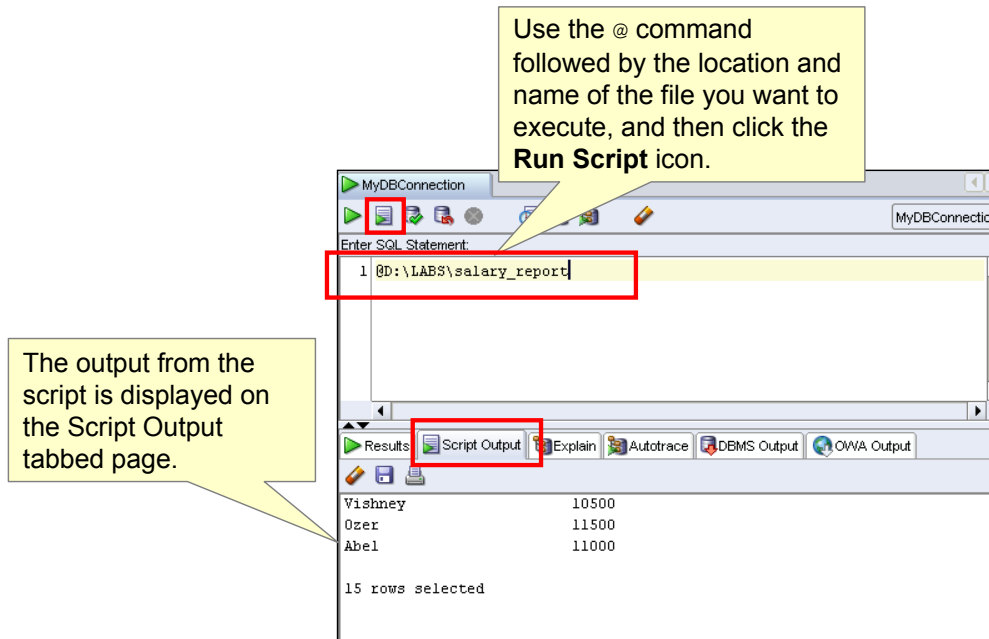
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Executing Saved Script Files: Method 1

You can open and execute a script file in the SQL Worksheet area as follows:

1. Right-click in the SQL Worksheet area, and then select **Open File** from the pop-up menu. The **Open** dialog box is displayed.
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 **Run Script (F5)** from the SQL Worksheet toolbar.

Executing Saved SQL Scripts: Method 2



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Executing Saved Script Files: Method 2

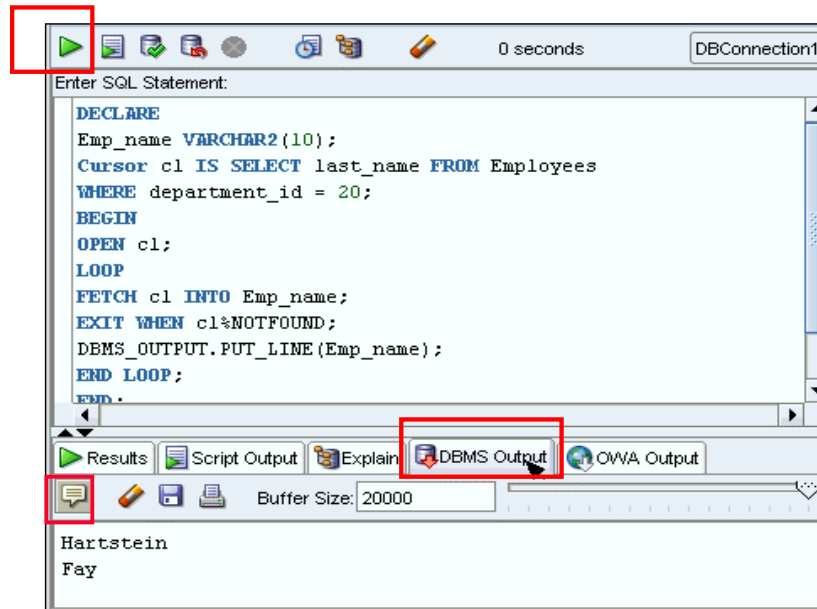
To run a saved SQL script, follow these steps:

1. In the Enter SQL Statement window, use the @ command, followed by the location and name of the file 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.



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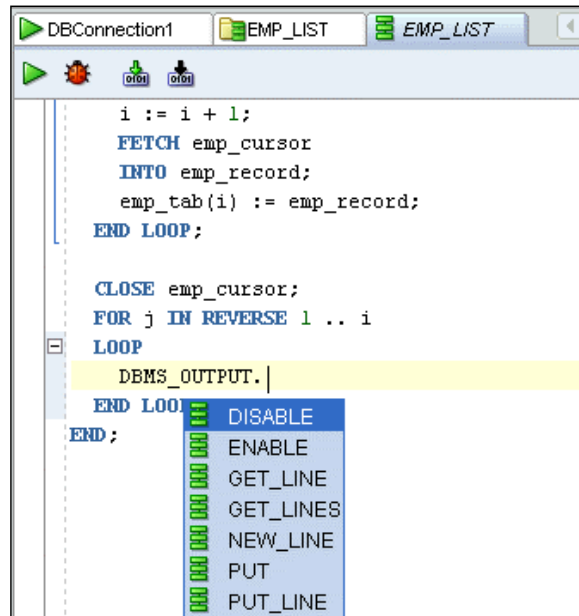
Creating an Anonymous Block

You can create an anonymous block 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** pane. Then click the **Enable DBMS Output** icon to set the server output ON.
3. Click the **Execute Statement** icon above the Enter SQL Statement box. Then click the **DBMS Output** pane to see the results.

Editing the PL/SQL Code

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



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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 perform an update only if you are on the Edit tabbed page.

The Code Insight feature is shown in the slide. 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. Debugging is covered in the appendix titled “Using SQL Developer.”

Lesson Agenda

- Course objectives and course agenda
- The schema and appendices used in this course and the available PL/SQL development in this course
- Overview of Oracle SQL Developer
- Oracle 11g documentation and additional resources

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Oracle 11g SQL and PL/SQL Documentation

- *Oracle Database New Features Guide 11g Release 1 (11.1)*
- *Oracle Database Advanced Application Developer's Guide 11g Release 1 (11.1)*
- *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)*
- *Oracle Database Reference 11g Release 1 (11.1)*
- *Oracle Database SQL Language Reference 11g Release 1 (11.1)*
- *Oracle Database Concepts 11g Release 1 (11.1)*
- *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)*
- *Oracle Database SQL Developer User's Guide Release 1.1.2*

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Oracle 11g SQL and PL/SQL Documentation

Navigate to <http://www.oracle.com/pls/db111/homepage> and click the Master Book List link in the left frame.

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Additional Resources

For additional information about the new Oracle 11g SQL and PL/SQL new features, refer to the following:

- Oracle Database 11g: New Features eStudies
- Oracle by Example (OBE) series: Oracle Database 11g:
 - http://www.oracle.com/technology/obe/11gr1_db/admin/11gr1db.html
- What's New in PL/SQL in Oracle Database 11g on the Oracle Technology Network (OTN):
 - http://www.oracle.com/technology/tech/pl_sql/

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Summary

In this lesson, you should have learned how to:

- Discuss the goals of the course
- Identify the available 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

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Summary

The PL/SQL language provides different program constructs for blocks of reusable code. Unnamed or anonymous PL/SQL blocks can be used to invoke SQL and PL/SQL actions, procedures, functions, and package components. Named PL/SQL blocks, otherwise known as subprograms, include:

- Procedures
- Functions
- Package procedures and functions
- Triggers

Oracle supplies several tools to develop your PL/SQL functionality. Oracle provides a client-side or middle-tier PL/SQL run-time environment for Oracle Forms and Oracle Reports, and provides a PL/SQL run-time engine inside the Oracle database. Procedures and functions inside the database can be invoked from any application code that can connect to an Oracle database and execute PL/SQL code.

Practice 1 Overview: Getting Started

This practice covers the following topics:

- Reviewing the available SQL Developer resources
- Starting SQL Developer and creating a new database connection and browsing the HR tables
- Setting some SQL Developer preferences
- Executing SQL statements and an anonymous PL/SQL block using SQL Worksheet
- Accessing and bookmarking the Oracle Database 11g documentation and other useful Web sites

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Practice 1: Overview

In this practice, you use SQL Developer to execute SQL statements to examine data in the HR schema. 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 or JDeveloper environments that are 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 that are presented in the corresponding lesson.

Identifying the Available SQL Developer Resources

1. Familiarize yourself with Oracle SQL Developer as needed using Appendix C: Using SQL Developer.
2. Access the online SQL Developer home page 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 available online at:
<http://st-curriculum.oracle.com/tutorial/SQLDeveloper/index.htm>
5. Preview and experiment with the available links and demos in the tutorial as needed, especially the Creating a Database Connection and Accessing Data links.

Creating and Using a New SQL Developer Database Connection

1. Start up SQL Developer using the user ID and password that are provided to you by the instructor such as `oraxx` where `xx` is the number assigned to your PC.
2. Create a database connection using the following information:
 - a. Connection Name: `MyDBConnection`
 - b. Username: `oraxx` where `xx` is the number assigned to your PC by the instructor
 - c. Password: `oraxx` where `xx` is the number assigned to your PC by the instructor
 - d. Hostname: Enter the host name for your PC.
 - e. Port: `1521`
 - f. SID: `ORCL`
3. Test the new connection. If the Status is Success, connect to the database using this new connection.
 - a. Double-click the `MyDBConnection` 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.

Practice 1 (continued)

Browsing Your HR Schema Tables

1. Browse the structure of the EMPLOYEES table and display its data.
 - a. Expand the MyDBConnection connection by clicking the plus sign next to it.
 - b. Expand the Tables icon by clicking the plus sign next to it.
 - c. Display the structure of the EMPLOYEES table.
2. Browse the EMPLOYEES table and display its data.
3. Use the SQL Worksheet to select the last names and salaries of all employees whose annual salary is greater than \$10,000. Use both the Execute Statement (F9) and the Run Script icon (F5) icons to execute the SELECT statement. Review the results of both methods of executing the SELECT statements on the appropriate tabbed pages.

Note: Take a few minutes to familiarize yourself with the data, or consult Appendix B, which provides the description and data for all tables in the HR schema that you use in this course.

4. 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.

Setting Some SQL Developer Preferences

1. In the SQL Developer menu, navigate to Tools > Preferences. The Preferences window is displayed.
2. Expand the Code Editor option, and then click the Display option. The “Code Editor: Display” section contains general options for the appearance and behavior of the code editor.
 - a. Enter 100 in the Right Margin Column text box in the Show Visible Right Margin section. This renders a right margin that you can set to control the length of lines of code.
 - b. Click the Line Gutter option. The Line Gutter option specifies options for the line gutter (left margin of the code editor). Select the Show Line Numbers check box to display the code line numbers.
3. Click the Worksheet Parameters option under the Database option. In the “Select default path to look for scripts” text box, specify the D:\labs\PLPU folder. This folder contains the solutions scripts, code examples scripts, and any labs or demos used in this course.

Practice 1 (continued)

Setting Some SQL Developer Preferences (continued)

4. Configure SQL Developer so that you can access SQL*Plus from within SQL Developer.
 - a. In the Preferences window, click the SQL*Plus option.
 - b. In the SQL*Plus Executable text box, enter the path for the SQL*Plus executable.
Note: To find the path for SQL*Plus: Right-click the SQL*Plus icon on your desktop, select Properties from the pop-up menu, and then copy the SQL*Plus path from the Target text box but do not include the /nolog at the end of the Target path.
 - c. Paste the SQL*Plus path in the SQL*Plus Executable text box.
 - d. Click OK to accept your changes and exit the Preferences window.
5. Test accessing SQL*Plus from within SQL Developer, and change the default background and text colors.
 - a. Click your Database Connection name on the Connections tabbed page.
 - b. Select SQL*Plus from the Tools menu. The SQL*Plus command window is displayed.
 - c. Enter your password.
 - d. Change the default screen background and text colors. Click the C:\ icon on the SQL*Plus command window title bar, and then select Properties from the pop-up menu.
 - e. On the Colors tabbed page, select the Screen Background option, and then click the white color sample from the available color palettes.
 - f. Select the Screen Text option, and then click the black color sample from the available color palettes.
 - g. Click OK. The Apply Properties window is displayed. Select the “Save properties for future windows with same title” option, and then click OK.
 - h. Issue the following simple SQL command to test SQL*Plus:


```
SELECT *
FROM employees;
```
6. Familiarize yourself with the labs folder on the D:\ drive:
 - a. Right-click the SQL Worksheet area, and then select Open File from the shortcut menu. The Open window is displayed.
 - b. Ensure that the path that you set in a previous step is the default path that is displayed in the Open window.
 - c. How many subfolders do you see in the labs folder?
 - d. Navigate through the folders, and open a script file without executing the code.
 - e. Clear the displayed code in the SQL Worksheet area.

Practice 1 (continued)

Accessing the Oracle Database 11g Release 1 Online Documentation Library

1. Access the Oracle Database 11g Release 1 documentation Web page at:
<http://www.oracle.com/pls/db111/homepage>
2. Bookmark the page for easier future access.
3. Display the complete list of books available for Oracle Database 11g Release 1.
4. Make a note of the following documentation references that you 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

Creating Procedures

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Objectives

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

- Identify the benefits of modularized and layered subprogram design
- Create and call procedures
- Use formal and actual parameters
- Use positional, named, or mixed notation for passing parameters
- Identify the available parameter-passing modes
- Handle exceptions in procedures
- Remove a procedure
- Display the procedures' information

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Lesson Aim

In this lesson, you learn to create, execute, and remove procedures with or without parameters. Procedures are the foundation of modular programming in PL/SQL. To make procedures more flexible, it is important that varying data is either calculated or passed into a procedure by using input parameters. Calculated results can be returned to the caller of a procedure by using OUT parameters.

To make your programs robust, you should always manage exception conditions by using the exception-handling features of PL/SQL.

Lesson Agenda

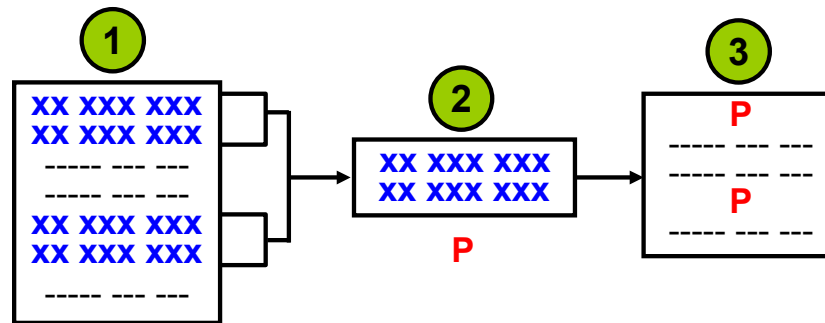
- Using a modularized and layered subprogram design and identifying the benefits of subprograms
- Working with procedures:
 - Creating and calling procedures
 - Identifying the available parameter-passing modes
 - Using formal and actual parameters
 - Using positional, named, or mixed notation
- Handling exceptions in procedures, removing a procedure, and displaying the procedures' information

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Creating a Modularized Subprogram Design



Modularize code into subprograms.

1. Locate code sequences repeated more than once.
2. Create subprogram P containing the repeated code
3. Modify original code to invoke the new subprogram.

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Creating a Modularized and Layered Subprogram Design

The diagram illustrates the principle of modularization with subprograms: the creation of smaller manageable pieces of flexible and reusable code. Flexibility is achieved by using subprograms with parameters, which in turn makes the same code reusable for different input values. To modularize existing code, perform the following steps:

1. Locate and identify repetitive sequences of code.
2. Move the repetitive code into a PL/SQL subprogram.
3. Replace the original repetitive code with calls to the new PL/SQL subprogram.

Following this modular and layered approach can help you create code that is easier to maintain, particularly when the business rules change. In addition, keeping the SQL logic simple and free of complex business logic can benefit from the work of Oracle Database Optimizer, which can reuse parsed SQL statements for better use of server-side resources.

Creating a Layered Subprogram Design

Create subprogram layers for your application.

- Data access subprogram layer with SQL logic
- Business logic subprogram layer, which may or may not use the data access layer

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Creating a Layered Subprogram Design

Because PL/SQL allows SQL statements to be seamlessly embedded into the logic, it is too easy to have SQL statement spread all over the code. However, it is recommended that you keep the SQL logic separate from the business logic—that is, create a layered application design with a minimum of two layers:

- **Data access layer:** For subroutines to access the data by using SQL statements
- **Business logic layer:** For subprograms to implement the business processing rules, which may or may not call on the data access layer routines

Following this modular and layered approach can help you create code that is easier to maintain, particularly when the business rules change. In addition, keeping the SQL logic simple and free of complex business logic can benefit from using the Oracle Database Optimizer. The Optimizer can reuse parsed SQL statements for better use of server-side resources.

Modularizing Development with PL/SQL Blocks

- PL/SQL is a block-structured language. The PL/SQL code block helps modularize code by using:
 - Anonymous blocks
 - Procedures and functions
 - Packages
 - Database triggers
- The benefits of using modular program constructs are:
 - Easy maintenance
 - Improved data security and integrity
 - Improved performance
 - Improved code clarity

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Modularizing Development with PL/SQL Blocks

A subprogram is based on standard PL/SQL structures. It contains a declarative section, an executable section, and an optional exception-handling section (for example, anonymous blocks, procedures, functions, packages, and triggers). Subprograms can be compiled and stored in the database, providing modularity, extensibility, reusability, and maintainability.

Modularization converts large blocks of code into smaller groups of code called modules. After modularization, the modules can be reused by the same program or shared with other programs. It is easier to maintain and debug code that comprises smaller modules than it is to maintain code in a single large program. Modules can be easily extended for customization by incorporating more functionality, if required, without affecting the remaining modules of the program.

Subprograms provide easy maintenance because the code is located in one place and any modifications required to the subprogram can, therefore, be performed in this single location. Subprograms provide improved data integrity and security. The data objects are accessed through the subprogram, and a user can invoke the subprogram only if the appropriate access privilege is granted to the user.

Note: Knowing how to develop anonymous blocks is a prerequisite for this course. For detailed information about anonymous blocks, see the course titled *Oracle 11g: PL/SQL Fundamentals*.

Anonymous Blocks: Overview

Anonymous blocks:

- Form the basic PL/SQL block structure
- Initiate PL/SQL processing tasks from applications
- Can be nested within the executable section of any PL/SQL block

```
[DECLARE      -- Declaration Section (Optional)
  variable declarations; ... ]
BEGIN         -- Executable Section (Mandatory)
  SQL or PL/SQL statements;
[EXCEPTION   -- Exception Section (Optional)
  WHEN exception THEN statements; ]
END;         -- End of Block (Mandatory)
```

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Anonymous Blocks: Overview

Anonymous blocks are typically used for:

- Writing trigger code for Oracle Forms components
- Initiating calls to procedures, functions, and package constructs
- Isolating exception handling within a block of code
- Nesting inside other PL/SQL blocks for managing code flow control

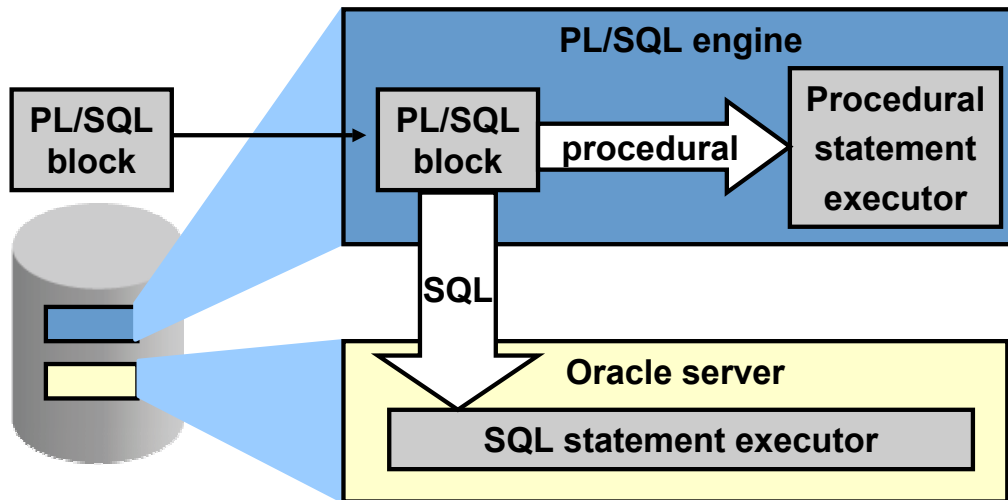
The DECLARE keyword is optional, but it is required if you declare variables, constants, and exceptions to be used within the PL/SQL block.

BEGIN and END are mandatory and require at least one statement between them, either SQL, PL/SQL, or both.

The exception section is optional and is used to handle errors that occur within the scope of the PL/SQL block. Exceptions can be propagated to the caller of the anonymous block by excluding an exception handler for the specific exception, thus creating what is known as an *unhandled* exception.

PL/SQL Execution Environment

The PL/SQL run-time architecture:



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PL/SQL Execution Environment

The diagram shows a PL/SQL block being executed by the PL/SQL engine. The PL/SQL engine resides in:

- The Oracle database for executing stored subprograms
- The Oracle Forms client when running client/server applications, or in the Oracle Application Server when using Oracle Forms Services to run Forms on the Web

Irrespective of the PL/SQL run-time environment, the basic architecture remains the same.

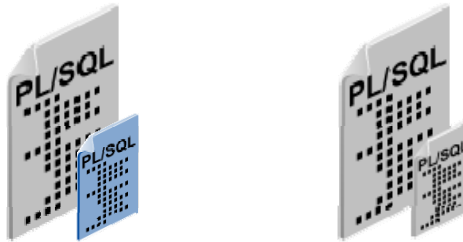
Therefore, all PL/SQL statements are processed in the Procedural Statement Executor, and all SQL statements must be sent to the SQL Statement Executor for processing by the Oracle server processes.

The PL/SQL engine is a virtual machine that resides in memory and processes the PL/SQL m-code instructions. When the PL/SQL engine encounters a SQL statement, a context switch is made to pass the SQL statement to the Oracle server processes. The PL/SQL engine waits for the SQL statement to complete and for the results to be returned before it continues to process subsequent statements in the PL/SQL block.

The Oracle Forms PL/SQL engine runs in the client for the client/server implementation, and in the application server for the Forms Services implementation. In either case, SQL statements are typically sent over a network to an Oracle server for processing.

What Are PL/SQL Subprograms?

- A PL/SQL subprogram is a named PL/SQL block that can be called with a set of parameters.
- You can declare and define a subprogram within either a PL/SQL block or another subprogram.
- A subprogram consists of a specification and a body.
- A subprogram can be a procedure or a function.
- Typically, you use a procedure to perform an action and a function to compute and return a value.



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What Are PL/SQL Subprograms?

A PL/SQL subprogram is a named PL/SQL block that can be called with a set of parameters. You can declare and define a subprogram within either a PL/SQL block or another subprogram.

Subprogram Parts

A subprogram consists of a specification (spec) and a body. To declare a subprogram, you must provide the spec, which includes descriptions of any parameters. To define a subprogram, you must provide both the spec and the body. You can either declare a subprogram first and define it later in the same block or subprogram, or declare and define it at the same time.

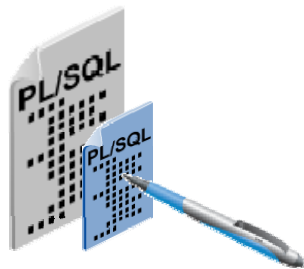
Subprogram Types

PL/SQL has two types of subprograms: procedures and functions. Typically, you use a procedure to perform an action and a function to compute and return a value.

A procedure and a function have the same structure, except that only a function has some additional items such as the RETURN clause or the RETURN statement.

The RETURN clause specifies the data type of the return value (required). A RETURN statement specifies the return value (required). Functions are covered in more detail in the next lesson titled “Creating Functions.”

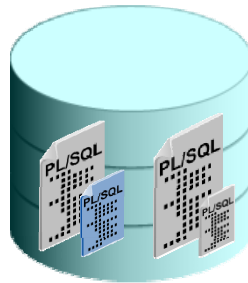
The Benefits of Using PL/SQL Subprograms



Easy maintenance



Improved data security and integrity



**Subprograms:
Stored procedures
and functions**



Improved code clarity



Improved performance

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Benefits of Subprograms

Procedures and functions have many benefits due to the modularizing of the code:

- **Easy maintenance** is realized because subprograms are located in one place. Modifications need to be done in only one place to affect multiple applications and minimize excessive testing.
- **Improved data security** can be achieved by controlling indirect access to database objects from nonprivileged users with security privileges. The subprograms are by default executed with definer's right. The execute privilege does not allow a calling user direct access to objects that are accessible to the subprogram.
- **Data integrity** is managed by having related actions performed together or not at all.
- **Improved performance** can be realized from reuse of parsed PL/SQL code that becomes available in the shared SQL area of the server. Subsequent calls to the subprogram avoid parsing the code again. Because PL/SQL code is parsed at compile time, the parsing overhead of SQL statements is avoided at run time. Code can be written to reduce the number of network calls to the database, and therefore, decrease network traffic.
- **Improved code clarity** can be attained by using appropriate names and conventions to describe the action of the routines, thereby reducing the need for comments and enhancing the clarity of the code.

Differences Between Anonymous Blocks and Subprograms

Anonymous Blocks	Subprograms
Unnamed PL/SQL blocks	Named PL/SQL blocks
Compiled every time	Compiled only once
Not stored in the database	Stored in the database
Cannot be invoked by other applications	Named and, therefore, can be invoked by other applications
Do not return values	Subprograms called functions must return values.
Cannot take parameters	Can take parameters

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Differences Between Anonymous Blocks and Subprograms

The table in the slide not only shows the differences between anonymous blocks and subprograms, but also highlights the general benefits of subprograms.

Anonymous blocks are not persistent database objects. They are compiled and executed only once. They are not stored in the database for reuse. If you want to reuse, you must rerun the script that creates the anonymous block, which causes recompilation and execution.

Procedures and functions are compiled and stored in the database in a compiled form.

They are recompiled only when they are modified. Because they are stored in the database, any application can make use of these subprograms based on appropriate permissions. The calling application can pass parameters to the procedures if the procedure is designed to accept parameters. Similarly, a calling application can retrieve a value if it invokes a function or a procedure.

Lesson Agenda

- Using a modularized and layered subprogram design and identifying the benefits of subprograms
- Working with procedures:
 - Creating and calling procedures
 - Identifying the available parameter-passing modes
 - Using formal and actual parameters
 - Using positional, named, or mixed notation
- Handling exceptions in procedures, removing a procedure, and displaying the procedures' information

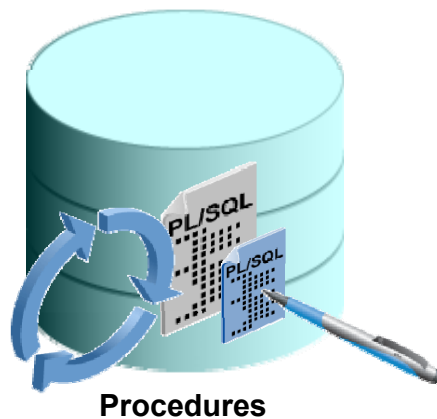
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What Are Procedures?

- Are a type of subprogram that perform an action
- Can be stored in the database as a schema object
- Promote reusability and maintainability



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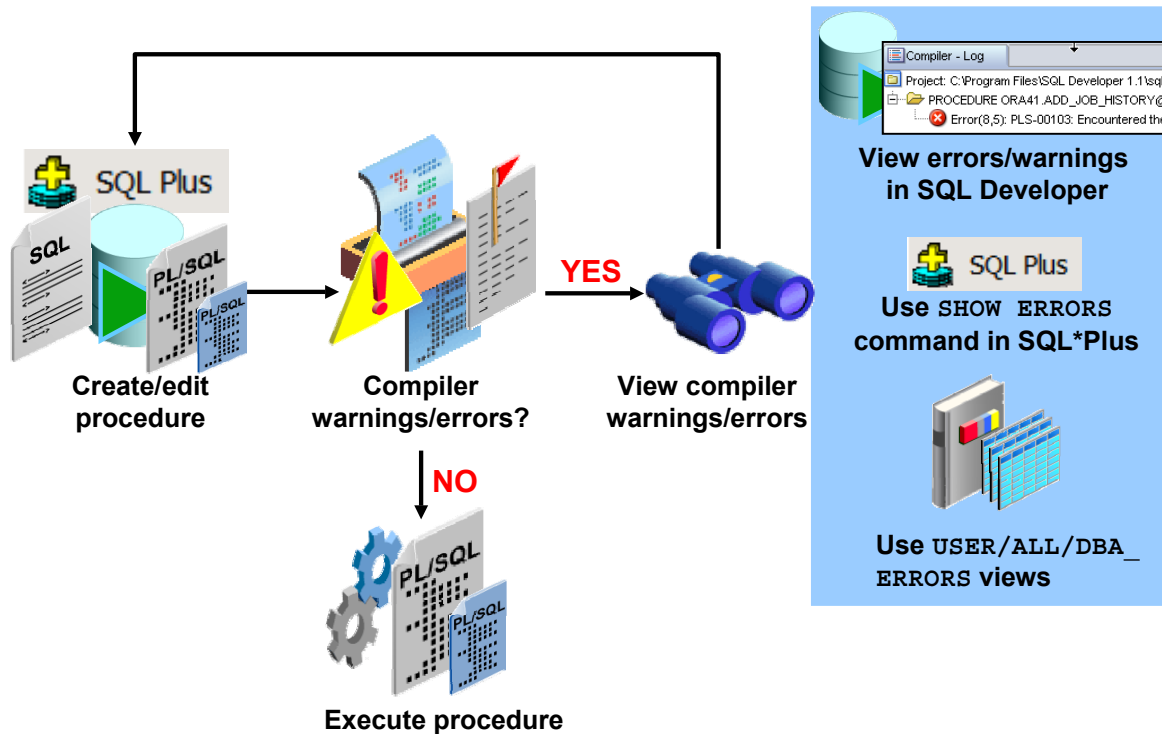
Definition of a Procedure

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. It has a header, a declaration section, an executable section, and an optional exception-handling section. A procedure is invoked by using the procedure name in the execution section of another PL/SQL block.

A procedure is compiled and stored in the database as a schema object. If you are using the procedures with Oracle Forms and Reports, then they can be compiled within the Oracle Forms or Oracle Reports executables.

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

Creating Procedures: Overview



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Creating Procedures: Overview

To develop a procedure using a tool such as SQL Developer, perform the following steps:

1. Create the procedure using SQL Developer's Object Navigator tree or the SQL Worksheet area.
2. Compile the procedure. The procedure is created in the database. The CREATE PROCEDURE statement creates and stores source code and the compiled *m-code* in the database. To compile the procedure, right-click the procedure's name in the Object Navigator tree, and then click Compile.
3. If compilation errors exist, then the *m-code* is not stored and you must edit the source code to make corrections. You cannot invoke a procedure that contains compilation errors. You can view the compilation errors in SQL Developer, SQL*Plus, or the appropriate data dictionary views as shown in the slide.
4. After successful compilation, execute the procedure to perform the desired action. You can run the procedure using SQL Developer or use the EXECUTE command in SQL*Plus.

Note: If compilation errors occur, use a CREATE OR REPLACE PROCEDURE statement to overwrite the existing code if you previously used a CREATE PROCEDURE statement. Otherwise, drop the procedure first (using DROP) and then execute the CREATE PROCEDURE statement.

Creating Procedures with the SQL CREATE OR REPLACE Statement

- Use the `CREATE` clause to create a stand-alone procedure that is stored in the Oracle database.
- Use the `OR REPLACE` option to overwrite an existing procedure.

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

PL/SQL block

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Creating Procedures with the SQL `CREATE OR REPLACE` Statement

You can use the `CREATE PROCEDURE` SQL statement to create stand-alone procedures that are stored in an Oracle database. A procedure is similar to a miniature program: it performs a specific action. You specify the name of the procedure, its parameters, its local variables, and the `BEGIN-END` block that contains its code and handles any exceptions.

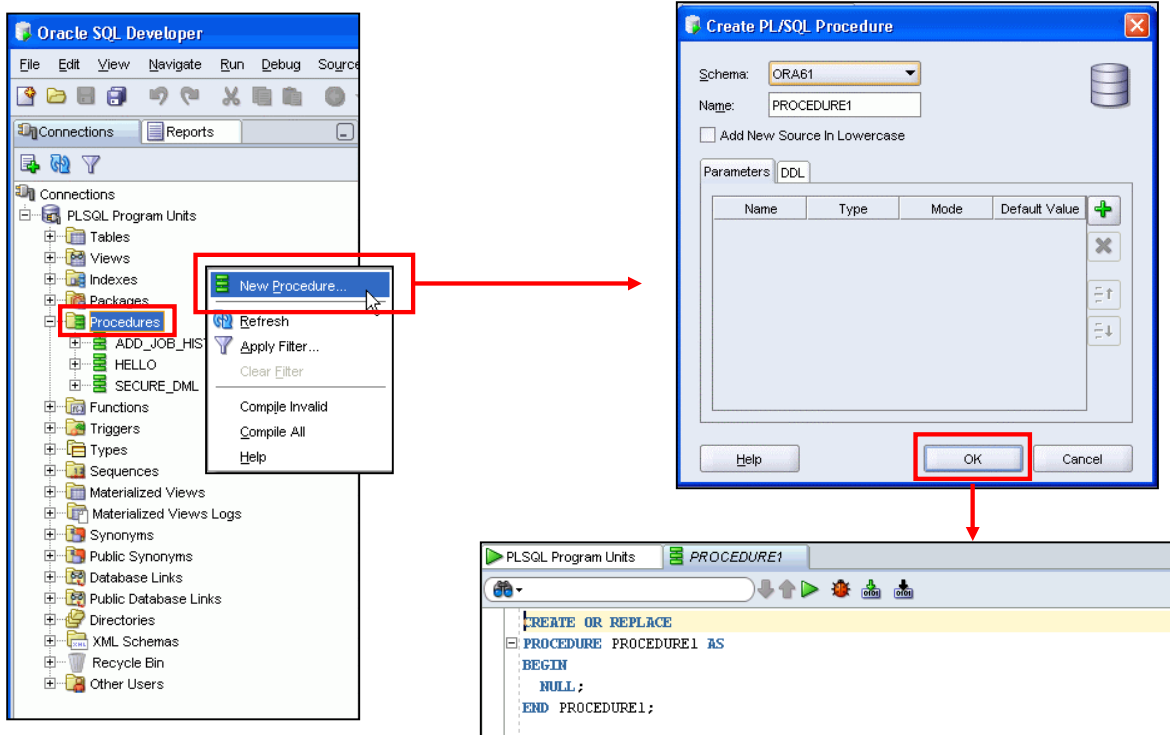
- PL/SQL blocks start with `BEGIN`, optionally preceded by the declaration of local variables. PL/SQL blocks end with either `END` or `END procedure_name`.
- The `REPLACE` option indicates that if the procedure exists, it is dropped and replaced with the new version created by the statement. The `REPLACE` option does not drop any of the privileges associated with the procedure.

Other Syntactic Elements

- *parameter1* represents the name of a parameter.
- The *mode* option defines how a parameter is used: `IN` (default), `OUT`, or `IN OUT`.
- *datatype1* specifies the parameter data type, without any precision.

Note: Parameters can be considered as local variables. Substitution and host (bind) variables cannot be referenced anywhere in the definition of a PL/SQL stored procedure. The `OR REPLACE` option does not require any change in object security, as long as you own the object and have the `CREATE [ANY] PROCEDURE` privilege.

Creating Procedures Using SQL Developer



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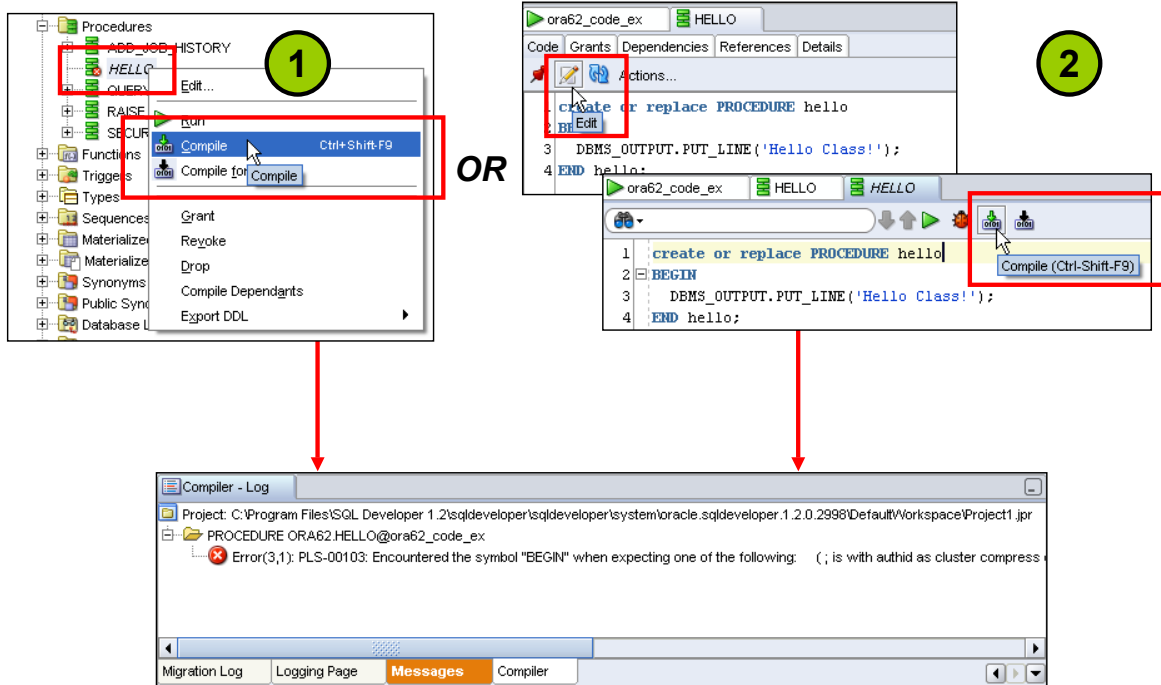
Creating Procedures Using SQL Developer

1. Right-click the **Procedures** node on the **Connections** tabbed page.
2. Select **New Procedure** from the shortcut menu. The **Create PL/SQL Procedure** dialog box is displayed. Specify the information for the new procedure, and then click OK to create the subprogram and have it displayed in the Editor window, where you can enter the details.

The components of the **Create PL/SQL Procedure** dialog box are as follows:

- **Schema:** The database schema in which to create the PL/SQL subprogram
- **Name:** The name of the subprogram that must be unique within a schema
- **Add New Source in Lowercase:** If this option is selected, new text is entered in lowercase regardless of the case in which you type it. This option affects only the appearance of the code, because PL/SQL is not case-sensitive in its execution.
- **Parameters tab:** To add a parameter, click the Add (+) icon. For each parameter in the procedure to be created, specify the parameter name, data type, mode, and optionally the default Value. Use the Remove (X) icon and the arrow icons to delete and to move a parameter up or down in the list respectively.
- **DDL tab:** This tab contains a read-only display of a SQL statement that reflects the current definition of the subprogram.

Compiling Procedures and Displaying Compilation Errors in SQL Developer



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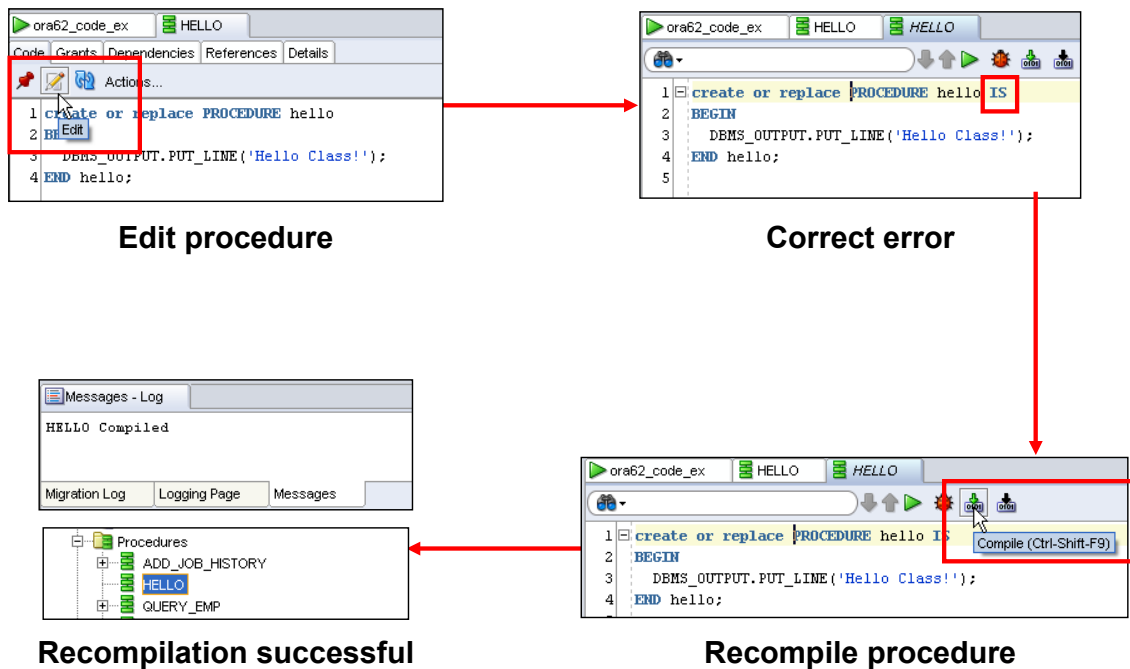
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Compiling Procedures and Displaying Compilation Errors in SQL Developer

You can compile procedures using one of the following two methods:

- Navigate to the Procedures node in the Object Navigator tree. Right-click the procedure's name, and then select Compile from the shortcut menu. To view any compilation messages, view the Messages subtab in the **Compiler – Log** tab.
- Edit the procedure using the Edit icon on the procedure's code toolbar. Make the necessary edits, and then click the Compile icon on the code toolbar. To view any compilation messages, view the Messages subtab in the **Compiler – Log** tab.

Correcting Compilation Errors in SQL Developer



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Correcting Compilation Errors in SQL Developer

1. Edit the procedure using the Edit icon on the procedure's code toolbar. A new procedure code tab is opened in Read/Write mode.
2. Make the necessary corrections.
3. Click the Compile icon on the code toolbar.
4. To view any compilation messages, view the Messages subtab in the **Compiler – Log** tab. In addition, if the procedure compiled successfully, the red X on the procedure's name in the Object Navigator tree is removed.

Naming Conventions of PL/SQL Structures Used in This Course

PL/SQL Structure	Convention	Example
Variable	<i>v_variable_name</i>	v_rate
Constant	<i>c_constant_name</i>	c_rate
Subprogram parameter	<i>p_parameter_name</i>	p_id
Bind (host) variable	<i>b_bind_name</i>	b_salary
Cursor	<i>cur_cursor_name</i>	cur_emp
Record	<i>rec_record_name</i>	rec_emp
Type	<i>type_name_type</i>	ename_table_type
Exception	<i>e_exception_name</i>	e_products_invalid
File handle	<i>f_file_handle_name</i>	f_file

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Naming Conventions of PL/SQL Structures Used in This Course

The slide table displays some examples of the naming conventions for PL/SQL structures that are used in this course.

What Are Parameters and Parameter Modes?

- Are declared after the subprogram name in the PL/SQL header
- Pass or communicate data between the caller and the subprogram
- Are used like local variables but are dependent on their parameter-passing mode:
 - An **IN** parameter mode (the default) provides values for a subprogram to process
 - An **OUT** parameter mode returns a value to the caller
 - An **IN OUT** parameter mode supplies an input value, which may be returned (output) as a modified value

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What Are Parameters?

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.

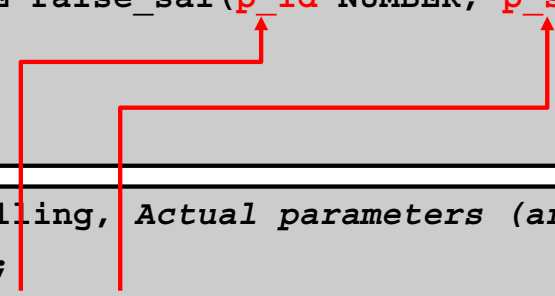
Parameters are subject to one of the three parameter-passing modes: **IN**, **OUT**, or **IN OUT**.

- 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.

Parameters can be thought of as a special form of local variable, whose input values are initialized by the calling environment when the subprogram is called, and whose output values are returned to the calling environment when the subprogram returns control to the caller.

Formal and Actual Parameters

- Formal parameters: Local variables declared in the parameter list of a subprogram specification
- Actual parameters (or arguments): Literal values, variables, and expressions used in the parameter list of the calling subprogram



```

-- Procedure definition, Formal parameters
CREATE PROCEDURE raise_sal(p_id NUMBER, p_sal NUMBER) IS
BEGIN
. . .
END raise_sal;

-- Procedure calling, Actual parameters (arguments)
v_emp_id := 100;
raise_sal(v_emp_id, 2000)
  
```

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Formal and Actual Parameters

Formal parameters are local variables that are declared in the parameter list of a subprogram specification. In the first example, in the `raise_sal` procedure, the variable `p_id` and `p_sal` identifiers represent the formal parameters.

The actual parameters can be literal values, variables, and expressions that are provided in the parameter list of a calling subprogram. In the second example, a call is made to `raise_sal`, where the `v_emp_id` variable provides the actual parameter value for the `p_id` formal parameter and `2000` is supplied as the actual parameter value for `p_sal`. Actual parameters:

- Are associated with formal parameters during the subprogram call
- Can also be expressions, as in the following example:
`raise_sal(v_emp_id, raise+100);`

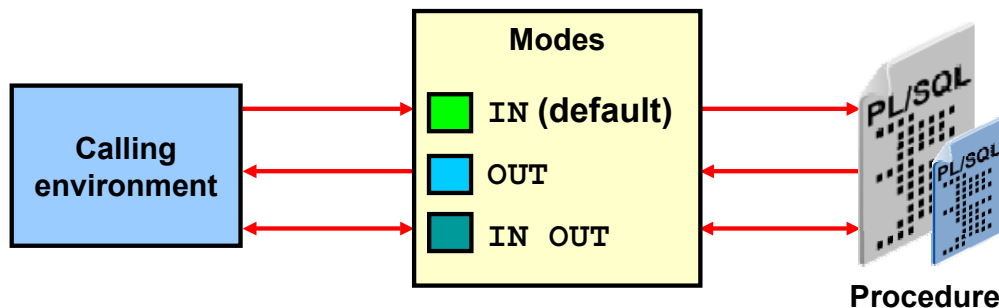
The formal and actual parameters should be of compatible data types. If necessary, before assigning the value, PL/SQL converts the data type of the actual parameter value to that of the formal parameter.

Note: Actual parameters are also referred to as *actual arguments*.

Procedural Parameter Modes

- Parameter modes are specified in the formal parameter declaration, after the parameter name and before its data type.
- The `IN` mode is the default if no mode is specified.

```
CREATE PROCEDURE proc_name(param_name [mode] datatype)  
...
```



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Procedural Parameter Modes

When you create a procedure, the formal parameter defines a variable name whose value is used in the executable section of the PL/SQL block. The actual parameter is used when invoking the procedure to provide input values or receive output results.

The parameter mode `IN` is the default passing mode—that is, if no mode is specified with a parameter declaration, the parameter is considered to be an `IN` parameter. The parameter modes `OUT` and `IN OUT` must be explicitly specified in their parameter declarations.

The *datatype* parameter is specified without a size specification. It can be specified:

- As an explicit data type
- Using the `%TYPE` definition
- Using the `%ROWTYPE` definition

Note: One or more formal parameters can be declared, each separated by a comma.

Comparing the Parameter Modes

IN	OUT	IN OUT
Default mode	Must be specified	Must be specified
Value is passed into subprogram	Returned to calling environment	Passed into subprogram; returned to calling environment
Formal parameter acts as a constant	Uninitialized variable	Initialized variable
Actual parameter can be a literal, expression, constant, or initialized variable	Must be a variable	Must be a variable
Can be assigned a default value	Cannot be assigned a default value	Cannot be assigned a default value

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Comparing the Parameter Modes

The IN parameter mode is the default mode if no mode is specified in the declaration. The OUT and IN OUT parameter modes must be explicitly specified with the parameter declaration.

A formal parameter of IN mode cannot be assigned a value and cannot be modified in the body of the procedure. By default, the IN parameter is passed by reference. An IN parameter can be assigned a default value in the formal parameter declaration, in which case the caller need not provide a value for the parameter if the default applies.

An OUT or IN OUT parameter must be assigned a value before returning to the calling environment. The OUT and IN OUT parameters cannot be assigned default values. To improve performance with OUT and IN OUT parameters, the NOCOPY compiler hint can be used to request to pass by reference.

Note: Using NOCOPY is discussed later in this course.

Using the IN Parameter Mode: Example

```
CREATE OR REPLACE PROCEDURE raise_salary
(p_id      IN employees.employee_id%TYPE,
p_percent IN NUMBER)
IS
BEGIN
  UPDATE employees
  SET    salary = salary * (1 + p_percent/100)
  WHERE  employee_id = p_id;
END raise_salary;
/
```



```
EXECUTE raise_salary(176, 10)
```

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Using IN Parameters: Example

The example shows a procedure with two IN parameters. Running the first slide example creates the `raise_salary` procedure in the database. The second slide example invokes `raise_salary` and provides the first parameter value of 176 for the employee ID, and a percentage salary increase of 10 percent for the second parameter value.

To invoke a procedure by using the SQL Worksheet of SQL Developer or by using SQL*Plus, use the following EXECUTE command:

```
EXECUTE raise_salary (176, 10)
```

To invoke a procedure from another procedure, use a direct call inside an executable section of the calling block. At the location of calling the new procedure, enter the procedure name and actual parameters. For example:

```
...
BEGIN
  raise_salary (176, 10);
END;
```

Note: IN parameters are passed as read-only values from the calling environment into the procedure. Attempts to change the value of an IN parameter result in a compile-time error.

Using the OUT Parameter Mode: Example

```
CREATE OR REPLACE PROCEDURE query_emp
(p_id      IN  employees.employee_id%TYPE,
p_name     OUT employees.last_name%TYPE,
p_salary  OUT employees.salary%TYPE) IS
BEGIN
  SELECT  last_name, salary INTO p_name, p_salary
  FROM    employees
  WHERE   employee_id = p_id;
END query_emp;
/
```

```
DECLARE
  v_emp_name employees.last_name%TYPE;
  v_emp_sal  employees.salary%TYPE;
BEGIN
  query_emp(171, v_emp_name, v_emp_sal);
  DBMS_OUTPUT.PUT_LINE(v_emp_name || ' earns ' ||
    to_char(v_emp_sal, '$999,999.00'));
END;/
```

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Using the OUT Parameters: Example

In the slide example, you create a procedure with OUT parameters to retrieve information about an employee. The procedure accepts the value 171 for employee ID and retrieves the name and salary of the employee with ID 171 into the two OUT parameters. The `query_emp` procedure has three formal parameters. Two of them are OUT parameters that return values to the calling environment, shown in the second code box in the slide. The procedure accepts an employee ID value through the `p_id` parameter. The `v_emp_name` and `v_emp_salary` variables are populated with the information retrieved from the query into their two corresponding OUT parameters. The following is the result of running the code in the second code example in the slide. `v_emp_name` holds the value Smith and `v_emp_salary` holds the value 7400:



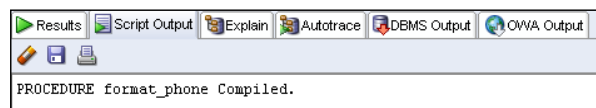
Note: Make sure that the data type for the actual parameter variables used to retrieve values from the OUT parameters has a size sufficient to hold the data values being returned.

Using the IN OUT Parameter Mode: Example

Calling environment

p_phone_no (before the call)	p_phone_no (after the call)
'8006330575'	'(800) 633-0575'

```
CREATE OR REPLACE PROCEDURE format_phone
(p_phone_no IN OUT VARCHAR2) IS
BEGIN
    p_phone_no := '(' || SUBSTR(p_phone_no,1,3) ||
                  ')' || SUBSTR(p_phone_no,4,3) ||
                  '-' || SUBSTR(p_phone_no,7);
END format_phone;
/
```



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Using IN OUT Parameters: Example

Using an IN OUT parameter, you can pass a value into a procedure that can be updated. The actual parameter value supplied from the calling environment can return either the original unchanged value or a new value that is set within the procedure.

Note: An IN OUT parameter acts as an initialized variable.

The slide example creates a procedure with an IN OUT parameter to accept a 10-character string containing digits for a phone number. The procedure returns the phone number formatted with parentheses around the first three characters and a hyphen after the sixth digit—for example, the phone string 8006330575 is returned as (800) 633-0575.

The following code uses the b_phone_no host variable of SQL*Plus to provide the input value passed to the FORMAT_PHONE procedure. The procedure is executed and returns an updated string in the b_phone_no host variable.

```
VARIABLE b_phone_no VARCHAR2(15)
EXECUTE :b_phone_no := '8006330575'
PRINT b_phone_no
EXECUTE format_phone (:b_phone_no)
PRINT b_phone_no
```

Viewing the OUT Parameters: Using the DBMS_OUTPUT.PUT_LINE Subroutine

Use PL/SQL variables that are printed with calls to the DBMS_OUTPUT.PUT_LINE procedure.

```
SET SERVEROUTPUT ON

DECLARE
  v_emp_name employees.last_name%TYPE;
  v_emp_sal   employees.salary%TYPE;
BEGIN
  query_emp(171, v_emp_name, v_emp_sal);
  DBMS_OUTPUT.PUT_LINE('Name: ' || v_emp_name);
  DBMS_OUTPUT.PUT_LINE('Salary: ' || v_emp_sal);
END;
```

```
anonymous block completed
Name: Smith
Salary: 7400
```

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Viewing the OUT Parameters: Using the DBMS_OUTPUT Subroutine

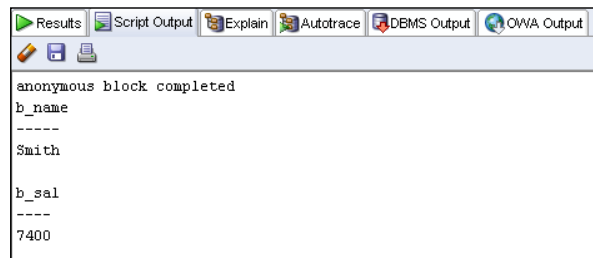
The slide example illustrates how to view the values returned from the OUT parameters in SQL*Plus or the SQL Developer Worksheet.

You can use PL/SQL variables in an anonymous block to retrieve the OUT parameter values. The DBMS_OUTPUT.PUT_LINE procedure is called to print the values held in the PL/SQL variables. The SET SERVEROUTPUT must be ON.

Viewing OUT Parameters: Using SQL*Plus Host Variables

1. Use SQL*Plus host variables.
2. Execute QUERY_EMP using host variables.
3. Print the host variables.

```
VARIABLE b_name  VARCHAR2(25)
VARIABLE b_sal    NUMBER
EXECUTE query_emp(171, :b_name, :b_sal)
PRINT b_name b_sal
```



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Viewing OUT Parameters: Using SQL*Plus Host Variables

The slide example demonstrates how to use SQL*Plus host variables that are created using the VARIABLE command. The SQL*Plus variables are external to the PL/SQL block and are known as host or bind variables. To reference host variables from a PL/SQL block, you must prefix their names with a colon (:). To display the values stored in the host variables, you must use the SQL*Plus PRINT command followed by the name of the SQL*Plus variable (without the colon because this is not a PL/SQL command or context).

Note: For details about the VARIABLE command, see the SQL*Plus Command Reference.

Available Notations for Passing Actual Parameters

When calling a subprogram, you can write the actual parameters using the following notations:

- **Positional:**
 - Lists the actual parameters in the same order as the formal parameters
- **Named:**
 - Lists the actual parameters in arbitrary order and uses the association operator (`=>`) to associate a named formal parameter with its actual parameter
- **Mixed:**
 - Lists some of the actual parameters as positional and some as named

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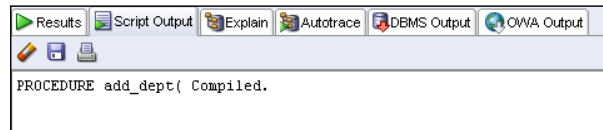
Syntax for Passing Parameters

When calling a subprogram, you can write the actual parameters using the following notations:

- **Positional:** You list the actual parameter values in the same order in which the formal parameters are declared. This notation is compact, but if you specify the parameters (especially literals) in the wrong order, the error can be hard to detect. You must change your code if the procedure's parameter list changes.
- **Named:** You list the actual values in arbitrary order and use the association operator to associate each actual parameter with its formal parameter by name. The PL/SQL **association operator** is an “equal” sign followed by an “is greater than” sign, without spaces: `=>`. The order of the parameters is not significant. This notation is more verbose, but makes your code easier to read and maintain. You can sometimes avoid changing your code if the procedure's parameter list changes, for example, if the parameters are reordered or a new optional parameter is added.
- **Mixed:** You list the first parameter values by their position and the remainder by using the special syntax of the named method. You can use this notation to call procedures that have some required parameters, followed by some optional parameters.

Passing Actual Parameters: Creating the add_dept Procedure

```
CREATE OR REPLACE PROCEDURE add_dept(  
  p_name IN departments.department_name%TYPE,  
  p_loc  IN departments.location_id%TYPE) IS  
BEGIN  
  INSERT INTO departments(department_id,  
                           department_name, location_id)  
  VALUES (departments_seq.NEXTVAL, p_name , p_loc );  
END add_dept;  
/
```



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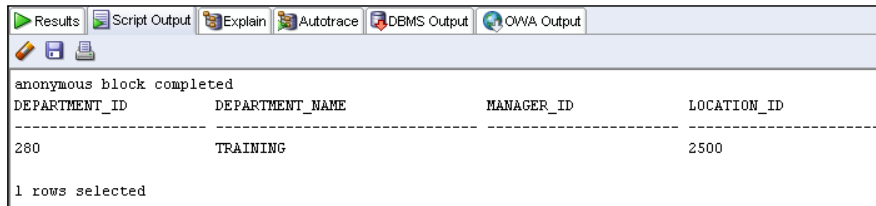
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Passing Parameters: Examples

In the slide example, the add_dept procedure declares two IN formal parameters: p_name and p_loc. The values of these parameters are used in the INSERT statement to set the department_name and location_id columns, respectively.

Passing Actual Parameters: Examples

```
-- Passing parameters using the positional notation.  
EXECUTE add_dept ('TRAINING', 2500)
```

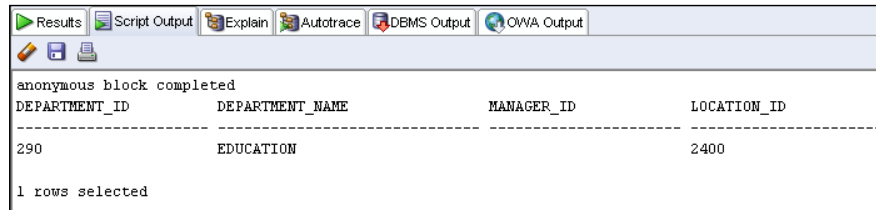


The screenshot shows the SQL Developer interface with the 'Results' tab selected. It displays the output of the first SQL statement, indicating that an anonymous block completed successfully. Below this, a table shows the results of the query, with columns for DEPARTMENT_ID, DEPARTMENT_NAME, MANAGER_ID, and LOCATION_ID. The table contains one row with the values 280, TRAINING, and 2500. The status '1 rows selected' is shown at the bottom.

DEPARTMENT_ID	DEPARTMENT_NAME	MANAGER_ID	LOCATION_ID
280	TRAINING		2500

1 rows selected

```
-- Passing parameters using the named notation.  
EXECUTE add_dept (p_loc=>2400, p_name=>'EDUCATION')
```



The screenshot shows the SQL Developer interface with the 'Results' tab selected. It displays the output of the second SQL statement, indicating that an anonymous block completed successfully. Below this, a table shows the results of the query, with columns for DEPARTMENT_ID, DEPARTMENT_NAME, MANAGER_ID, and LOCATION_ID. The table contains one row with the values 290, EDUCATION, and 2400. The status '1 rows selected' is shown at the bottom.

DEPARTMENT_ID	DEPARTMENT_NAME	MANAGER_ID	LOCATION_ID
290	EDUCATION		2400

1 rows selected

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Passing Actual Parameters: Examples

Passing actual parameters by position is shown in the first call to execute add_dept in the first code example in the slide. The first actual parameter supplies the value TRAINING for the name formal parameter. The second actual parameter value of 2500 is assigned by position to the loc formal parameter.

Passing parameters using the named notation is shown in the second code example in the slide. The loc actual parameter, which is declared as the second formal parameter, is referenced by name in the call, where it is associated with the actual value of 2400. The name parameter is associated with the value EDUCATION. The order of the actual parameters is irrelevant if all parameter values are specified.

Note: You must provide a value for each parameter unless the formal parameter is assigned a default value. Specifying default values for formal parameters is discussed next.

Using the DEFAULT Option for the Parameters

- Defines default values for parameters.
- Provides flexibility by combining the positional and named parameter-passing syntax.

```
CREATE OR REPLACE PROCEDURE add_dept(  
  p_name departments.department_name%TYPE := 'Unknown',  
  p_loc  departments.location_id%TYPE DEFAULT 1700)  
IS  
BEGIN  
  INSERT INTO departments (department_id,  
    department_name, location_id)  
  VALUES (departments_seq.NEXTVAL, p_name, p_loc);  
END add_dept;
```

```
EXECUTE add_dept  
EXECUTE add_dept ('ADVERTISING', p_loc => 1200)  
EXECUTE add_dept (p_loc => 1200)
```

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Using the DEFAULT Option for Parameters

You can assign a default value to an IN parameter as follows:

- The assignment operator (: =), as shown for the name parameter in the slide
- The DEFAULT option, as shown for the loc parameter in the slide

When default values are assigned to formal parameters, you can call the procedure without supplying an actual parameter value for the parameter. Thus, you can pass different numbers of actual parameters to a subprogram, either by accepting or by overriding the default values as required. It is recommended that you declare parameters without default values first. Then, you can add formal parameters with default values without having to change every call to the procedure.

Note: You cannot assign default values to the OUT and IN OUT parameters.

The second code box in the slide shows three ways of invoking the add_dept procedure:

- The first example assigns the default values for each parameter.
- The second example illustrates a combination of position and named notation to assign values. In this case, using named notation is presented as an example.
- The last example uses the default value for the name parameter, Unknown, and the supplied value for the loc parameter.

Using the DEFAULT Option for Parameters (continued)

The following is the result of the second slide code example in the previous slide:

```
anonymous block completed
anonymous block completed
anonymous block completed
```

DEPARTMENT_ID	DEPARTMENT_NAME	MANAGER_ID	LOCATION_ID
280	TRAINING		2500
290	EDUCATION		2400
300	Unknown		1700
310	ADVERTISING		1200
320	Unknown		1200
10	Administration	200	1700
20	Marketing	201	1800
30	Purchasing	114	1700
40	Human Resources	203	2400
50	Shipping	121	1500
60	IT	103	1400
70	Public Relations	204	2700
80	Sales	145	2500
90	Executive	100	1700
100	Finance	108	1700
110	Accounting	205	1700
120	Treasury		1700
130	Corporate Tax		1700
140	Control And Credit		1700
150	Shareholder Services		1700
160	Benefits		1700
170	Manufacturing		1700
180	Construction		1700
190	Contracting		1700
200	Operations		1700
210	IT Support		1700
220	NOC		1700
230	IT Helpdesk		1700
240	Government Sales		1700
250	Retail Sales		1700
260	Recruiting		1700
270	Payroll		1700

32 rows selected

Usually, you can use named notation to override the default values of formal parameters.

However, you cannot skip providing an actual parameter if there is no default value provided for a formal parameter.

Note: All the positional parameters should precede the named parameters in a subprogram call. Otherwise, you receive an error message, as shown in the following example:

```
EXECUTE add_dept(p_name=>'new dept', 'new location')
```

```
Error starting at line 1 in command:
EXECUTE add_dept(p_name=>'new dept', 'new location')
Error report:
ORA-06550: line 1, column 36:
PLS-00312: a positional parameter association may not follow a named association
ORA-06550: line 1, column 7:
PL/SQL: Statement ignored
06550. 00000 - "line %s, column %s:\n%s"
*Cause:      Usually a PL/SQL compilation error.
*Action:
```

Calling Procedures

You can call procedures using anonymous blocks, another procedure, or packages.

```
CREATE OR REPLACE PROCEDURE process_employees
IS
    CURSOR cur_emp_cursor IS
        SELECT employee_id
        FROM   employees;
BEGIN
    FOR emp_rec IN cur_emp_cursor
    LOOP
        raise_salary(emp_rec.employee_id, 10);
    END LOOP;
    COMMIT;
END process_employees;
/
```

```
PROCEDURE process_employees Compiled.
```

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Calling Procedures

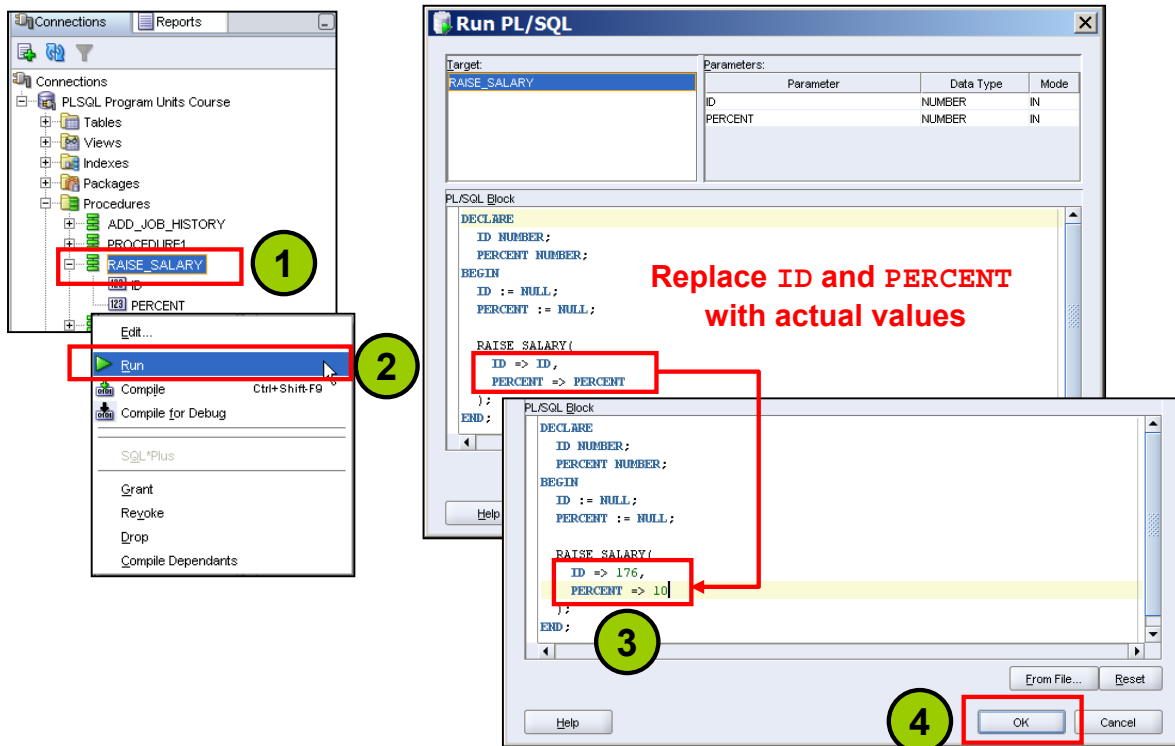
You can invoke procedures by using:

- Anonymous blocks
- Another procedure or PL/SQL subprogram

Examples on the preceding pages have illustrated how to use anonymous blocks (or the EXECUTE command in SQL Developer or SQL*Plus).

The slide example shows you how to invoke a procedure from another stored procedure. The PROCESS_EMPLOYEES stored procedure uses a cursor to process all the records in the EMPLOYEES table and passes each employee's ID to the RAISE_SALARY procedure, which results in a 10% salary increase across the company.

Calling Procedures Using SQL Developer



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Calling Procedures Using SQL Developer

In the slide example, the `raise_salary` procedure is called to raise the current salary of employee 176 (\$ 8,600) by 10 percent as follows:

1. Right-click the procedure name in the **Procedures** node, and then click **Run**. The **Run PL/SQL** dialog box is displayed.
2. In the **PL/SQL Block** section, change the displayed formal IN and IN/OUT parameter specifications displayed after the association operator, “=>” to the *actual* values that you want to use for running or debugging the function or procedure. For example, to raise the current salary of employee 176 from 8,600 by 10 percent, you can call the `raise_salary` procedure as shown in the slide. Provide the values for the ID and PERCENT input parameters that are specified as 176 and 10 respectively. This is done by changing the displayed `ID => ID` with `ID => 176` and `PERCENT => PERCENT` with `PERCENT => 10`.
3. Click OK. SQL Developer runs the procedure. The updated salary of 9,460 is shown

Results:		
EMPLOYEE_ID	SALARY	
1	176	9460

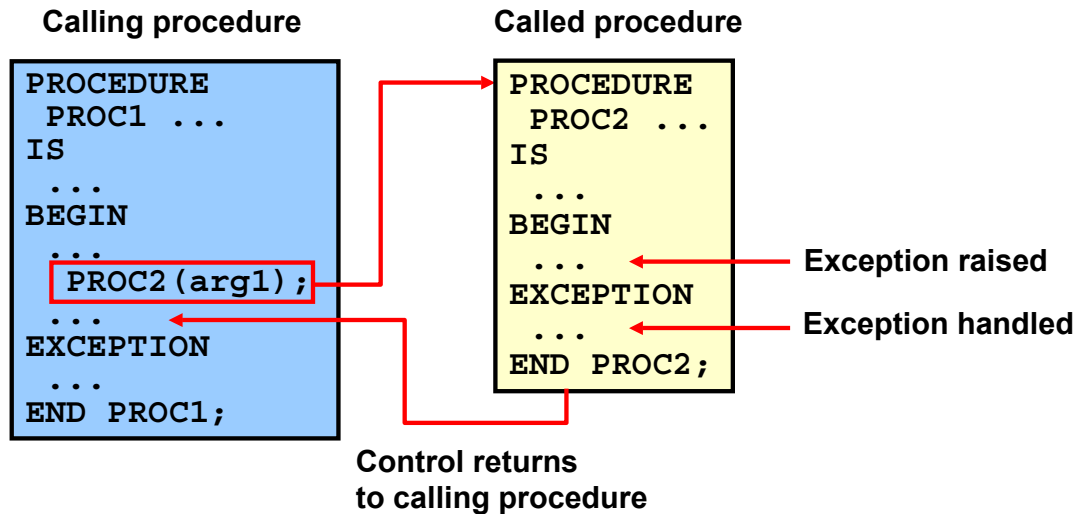
Lesson Agenda

- Using a modularized and layered subprogram design and identifying the benefits of subprograms
- Working with procedures:
 - Creating and calling procedures
 - Identifying the available parameter-passing modes
 - Using formal and actual parameters
 - Using positional, named, or mixed notation
- Handling exceptions in procedures, removing a procedure, and displaying the procedures' information

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Handled Exceptions



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Handled Exceptions

When you develop procedures that are called from other procedures, you should be aware of the effects that handled and unhandled exceptions have on the transaction and the calling procedure. When an exception is raised in a called procedure, the control immediately goes to the exception section of that block. An exception is considered handled if the exception section provides a handler for the exception raised.

When an exception occurs and is handled, the following code flow takes place:

1. The exception is raised.
2. Control is transferred to the exception handler.
3. The block is terminated.
4. The calling program/block continues to execute as if nothing has happened.

If a transaction was started (that is, if any data manipulation language [DML] statements executed before executing the procedure in which the exception was raised), then the transaction is unaffected. A DML operation is rolled back if it was performed within the procedure before the exception.

Note: You can explicitly end a transaction by executing a COMMIT or ROLLBACK operation in the exception section.

Handled Exceptions: Example

```
CREATE PROCEDURE add_department(  
    p_name VARCHAR2, p_mgr NUMBER, p_loc NUMBER) IS  
BEGIN  
    INSERT INTO DEPARTMENTS (department_id,  
        department_name, manager_id, location_id)  
    VALUES (DEPARTMENTS_SEQ.NEXTVAL, p_name, p_mgr, p_loc);  
    DBMS_OUTPUT.PUT_LINE('Added Dept: ' || p_name);  
EXCEPTION  
    WHEN OTHERS THEN  
        DBMS_OUTPUT.PUT_LINE('Err: adding dept: ' || p_name);  
END;
```

```
CREATE PROCEDURE create_departments IS  
BEGIN  
    add_department('Media', 100, 1800);  
    add_department('Editing', 99, 1800);  
    add_department('Advertising', 101, 1800);  
END;
```

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Handled Exceptions: Example

The two procedures in the slide are the following:

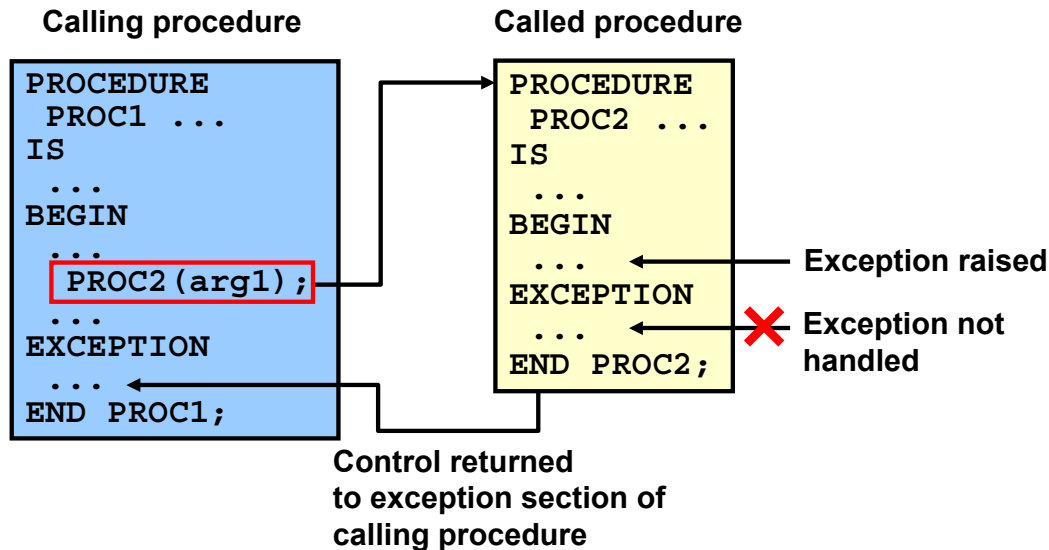
- The `add_department` procedure creates a new department record by allocating a new department number from an Oracle sequence, and sets the `department_name`, `manager_id`, and `location_id` column values using the `p_name`, `p_mgr`, and `p_loc` parameters, respectively.
- The `create_departments` procedure creates more than one department by using calls to the `add_department` procedure.

The `add_department` procedure catches all raised exceptions in its own handler. When `create_departments` is executed, the following output is generated:

```
Added Dept: Media  
Err: adding dept: Editing  
Added Dept: Advertising
```

The Editing department with a `manager_id` of 99 is not inserted because a foreign key integrity constraint violation on `manager_id` ensures that no manager has an ID of 99. Because the exception was handled in the `add_department` procedure, the `create_department` procedure continues to execute. A query on the `DEPARTMENTS` table where the `location_id` is 1800 shows that Media and Advertising are added but the Editing record is not.

Exceptions Not Handled



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Exceptions Not Handled

As discussed earlier, when an exception is raised in a called procedure, control immediately goes to the exception section of that block. If the exception section does not provide a handler for the raised exception, then it is not handled. The following code flow occurs:

1. The exception is raised.
2. The block terminates because no exception handler exists; any DML operations performed within the procedure are rolled back.
3. The exception propagates to the exception section of the calling procedure—that is, control is returned to the exception section of the calling block, if one exists.

If an exception is not handled, then all the DML statements in the calling procedure and the called procedure are rolled back along with any changes to any host variables. The DML statements that are not affected are statements that were executed before calling the PL/SQL code whose exceptions are not handled.

Exceptions Not Handled: Example

```
SET SERVEROUTPUT ON
CREATE PROCEDURE add_department_noex(
    p_name VARCHAR2, p_mgr NUMBER, p_loc NUMBER) IS
BEGIN
    INSERT INTO DEPARTMENTS (department_id,
        department_name, manager_id, location_id)
    VALUES (DEPARTMENTS_SEQ.NEXTVAL, p_name, p_mgr, p_loc);
    DBMS_OUTPUT.PUT_LINE('Added Dept: ' || p_name);
END;
```

```
CREATE PROCEDURE create_departments_noex IS
BEGIN
    add_department_noex('Media', 100, 1800);
    add_department_noex('Editing', 99, 1800);
    add_department_noex('Advertising', 101, 1800);
END;
```

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Exceptions Not Handled: Example

The code example in the slide shows `add_department_noex`, which does not have an exception section. In this case, the exception occurs when the `Editing` department is added. Because of the lack of exception handling in either of the subprograms, no new department records are added into the `DEPARTMENTS` table. Executing the `create_departments_noex` procedure produces a result that is similar to the following:

```
Error starting at line 8 in command:
EXECUTE create_departments_noex
Error report:
ORA-02291: integrity constraint (ORA62.DEPT_MGR_FK) violated - parent key not found
ORA-06512: at "ORA62.ADD_DEPARTMENT_NOEX", line 4
ORA-06512: at "ORA62.CREATE_DEPARTMENTS_NOEX", line 4
ORA-06512: at line 1
02291. 00000 - "integrity constraint (%s.%s) violated - parent key not found"
*Cause:      A foreign key value has no matching primary key value.
*Action:     Delete the foreign key or add a matching primary key.
```

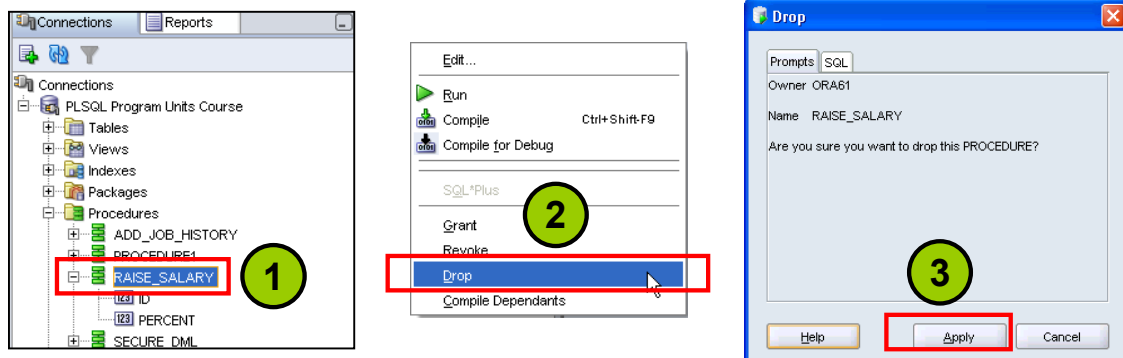
Although the results show that the `Media` department was added, its operation is rolled back because the exception was not handled in either of the subprograms invoked.

Removing Procedures: Using the DROP SQL Statement or SQL Developer

- Using the DROP statement:

```
DROP PROCEDURE raise_salary;
```

- Using SQL Developer:



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Removing Procedures: Using the DROP SQL Statement or SQL Developer

When a stored procedure is no longer required, you can use the `DROP PROCEDURE SQL` statement followed by the procedure's name to remove it as follows:

```
DROP PROCEDURE procedure_name
```

You can also use SQL Developer to drop a stored procedure as follows:

- Right-click the procedure name in the **Procedures** node, and then click **Drop**. The **Drop** dialog box is displayed.
- Click **Apply** to drop the procedure.

Note

- Whether successful or not, executing a data definition language (DDL) command such as `DROP PROCEDURE` commits any pending transactions that cannot be rolled back.
- You might have to refresh the **Procedures** node before you can see the results of the drop operation. To refresh the **Procedures** node, right-click the procedure name in the **Procedures** node, and then click **Refresh**.

Viewing Procedure Information Using the Data Dictionary Views

```
DESCRIBE user_source
```

Name	Null	Type
NAME		VARCHAR2(30)
TYPE		VARCHAR2(12)
LINE		NUMBER
TEXT		VARCHAR2(4000)

4 rows selected

```
SELECT text
FROM   user_source
WHERE  name = 'ADD_DEPT' AND type = 'PROCEDURE'
ORDER BY line;
```

TEXT
1 PROCEDURE add_dept(
2 p_name IN departments.department_name%TYPE,
3 p_loc IN departments.location_id%TYPE) IS
4
5 BEGIN
6 INSERT INTO departments(department_id, department_name, location_id)
7 VALUES (departments_seq.NEXTVAL, p_name, p_loc);
8 END add_dept;

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Viewing Procedure in the Data Dictionary

The source code for PL/SQL subprograms is stored in the data dictionary tables. The source code is accessible to PL/SQL procedures that are successfully or unsuccessfully compiled. To view the PL/SQL source code stored in the data dictionary, execute a `SELECT` statement on the following tables:

- The `USER_SOURCE` table to display PL/SQL code that you own
- The `ALL_SOURCE` table to display PL/SQL code to which you have been granted the `EXECUTE` right by the owner of that subprogram code

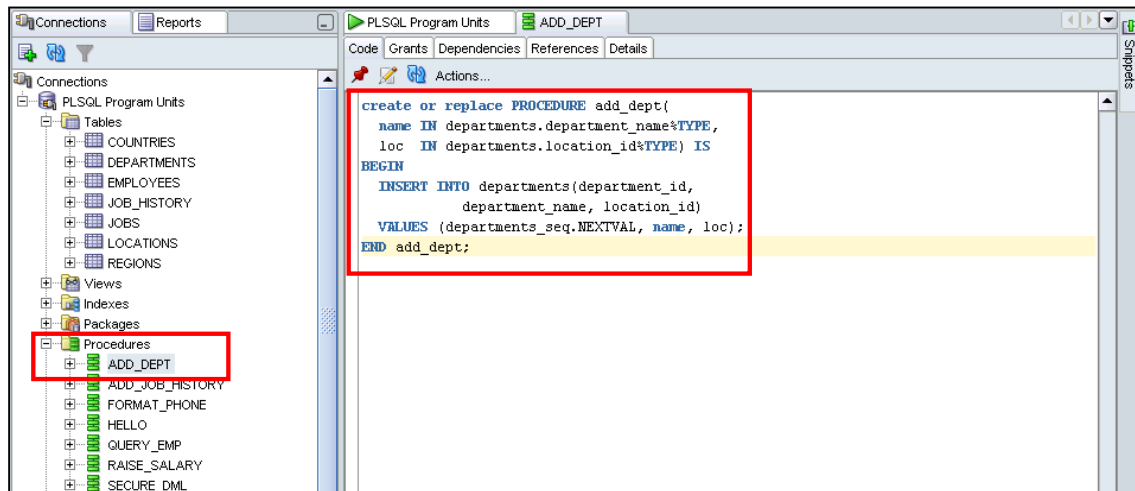
The query example shows all the columns provided by the `USER_SOURCE` table:

- The `TEXT` column holds a line of PL/SQL source code.
- The `NAME` column holds the name of the subprogram in uppercase text.
- The `TYPE` column holds the subprogram type, such as `PROCEDURE` or `FUNCTION`.
- The `LINE` column stores the line number for each source code line.

The `ALL_SOURCE` table provides an `OWNER` column in addition to the preceding columns.

Note: You cannot display the source code for Oracle PL/SQL built-in packages, or PL/SQL whose source code has been wrapped by using a `WRAP` utility. The `WRAP` utility converts the PL/SQL source code into a form that cannot be deciphered by humans.

Viewing Procedure Information Using SQL Developer



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Viewing Procedure Information Using SQL Developer

To view a procedure's code in SQL Developer, use the following steps:

1. Right-click the procedure's name in the **Procedures** node.
2. The procedure code is displayed in the **Code** tab as shown in the slide.

Quiz

Formal parameters are literal values, variables, and expressions used in the parameter list of the calling subprogram

1. True
2. False

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Answer: 2

Formal and Actual (or arguments) Parameters

Formal parameters: Local variables declared in the parameter list of a subprogram specification.

Actual parameters: Literal values, variables, and expressions used in the parameter list of the calling subprogram.

Summary

In this lesson, you should have learned how to:

- Identify the benefits of modularized and layered subprogram design
- Create and call procedures
- Use formal and actual parameters
- Use positional, named, or mixed notation for passing parameters
- Identify the available parameter-passing modes
- Handle exceptions in procedures
- Remove a procedure
- Display the procedures' information

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Practice 2 Overview: Creating, Compiling, and Calling Procedures

This practice covers the following topics:

- Creating stored procedures to:
 - Insert new rows into a table using the supplied parameter values
 - Update data in a table for rows that match the supplied parameter values
 - Delete rows from a table that match the supplied parameter values
 - Query a table and retrieve data based on supplied parameter values
- Handling exceptions in procedures
- Compiling and invoking procedures

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Practice 2: Overview

In this practice, you create, compile, and invoke procedures that issue DML and query commands. You also learn how to handle exceptions in procedures.

If you encounter compilation errors when you execute procedures, you can use the Compiler-Log tab in SQL Developer.

Note: It is recommended to use SQL Developer for this practice.

Important

All practices in this course and the practice solutions assume that you create objects such as procedures, functions, and so on using the SQL Worksheet area in SQL Developer. When you create an object in the SQL Worksheet area, you need to refresh the object node in order for the new object to be displayed in the Navigator tree. To compile the newly created object, you can right-click the object name in the Navigator tree, and then select Compile from the shortcut menu. For example, after you enter the code to create a procedure in the SQL Worksheet area, you click the Run Script icon (or press [F5]) to run the code. This creates and compiles the procedure.

Alternatively, you can create objects such as procedures using the PROCEDURES node in the Navigator tree, and then compile the procedure. Creating objects using the Navigator tree, automatically display the newly created object.

Practice 2

1. Create, compile, and invoke the ADD_JOB procedure and review the results.
 - a. Create a procedure called ADD_JOB to insert a new job into the JOBS table. Provide the ID and job title using two parameters.
Note: You can create the procedure (and other objects) by entering the code in the SQL Worksheet area, and then click the Run Script (F5) icon. This creates and compiles the procedure. To find out whether or not the procedure has any errors, right-click the procedure name in the Procedures node, and then select Compile from the pop-up menu.
 - b. Compile the code, and then invoke the procedure with IT_DBA as the job ID and Database Administrator as the job title. Query the JOBS table and view the results.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_DBA	Database Administrator		

1 rows selected

- c. Invoke your procedure again, passing a job ID of ST_MAN and a job title of Stock Manager. What happens and why?
-

2. Create a procedure called UPD_JOB to modify a job in the JOBS table.
 - a. Create a procedure called UPD_JOB to update the job title. Provide the job ID and a new title using two parameters. Include the necessary exception handling if no update occurs.
 - b. Compile the procedure. Invoke the procedure to change the job title of the job ID IT_DBA to Data Administrator. Query the JOBS table and view the results.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_DBA	Data Administrator		

1 rows selected

- c. Test the exception handling section of the procedure by trying to update a job that does not exist. You can use the job ID IT_WEB and the job title Web Master.

```
Error starting at line 1 in command:
EXECUTE upd_job ('IT_WEB', 'Web Master')
Error report:
ORA-20202: No job updated.
ORA-06512: at "ORA80.UPD_JOB", line 9
ORA-06512: at line 1
```

Practice 2 (continued)

3. Create a procedure called DEL_JOB to delete a job from the JOBS table.
 - a. Create a procedure called DEL_JOB to delete a job. Include the necessary exception handling code if no job is deleted.
 - b. Compile the code; invoke the procedure using the job ID IT_DBA. Query the JOBS table and view the results.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY

0 rows selected			

- c. Test the exception handling section of the procedure by trying to delete a job that does not exist. Use the IT_WEB as the job ID. You should get the message that you included in the exception handling section of the procedure as the output.

```
Error starting at line 1 in command:
EXECUTE del_job ('IT_WEB')
Error report:
ORA-20203: No jobs deleted.
ORA-06512: at "ORA80.DEL_JOB", line 6
ORA-06512: at line 1
```

4. Create a procedure called GET_EMPLOYEE to query the EMPLOYEES table, retrieving the salary and job ID for an employee when provided with the employee ID.
 - a. Create a procedure that returns a value from the SALARY and JOB_ID columns for a specified employee ID. Compile the code and remove syntax errors, if any.
 - b. Execute the procedure using host variables for the two OUT parameters—one for the salary and the other for the job ID. Display the salary and job ID for employee ID 120.

```
v_salary
-----
8000

v_job
-----
ST_MAN
```

- c. Invoke the procedure again, passing an EMPLOYEE_ID of 300. What happens and why?

3

Creating Functions

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Objectives

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

- Differentiate between a procedure and a function
- Describe the uses of functions
- Create stored functions
- Invoke a function
- Remove a function

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Lesson Aim

In this lesson, you learn how to create, invoke, and maintain functions.

Overview of Stored Functions

A function:

- Is a named PL/SQL block that returns a value
- Can be stored in the database as a schema object for repeated execution
- Is called as part of an expression or is used to provide a parameter value

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Overview of Stored 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.

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.

Creating Functions

The PL/SQL block must have at least one RETURN statement.

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

PL/SQL Block

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Syntax for Creating Functions

A function is a PL/SQL block that returns a value. A RETURN statement must be provided to return a value with a data type that is consistent with the function declaration.

You create new functions with the CREATE FUNCTION statement, which may declare a list of parameters, must return one value, and must define the actions to be performed by the standard PL/SQL block.

You should consider the following points about the CREATE FUNCTION statement:

- The REPLACE option indicates that if the function exists, it is dropped and replaced with the new version that is created by the statement.
- The RETURN data type must not include a size specification.
- The PL/SQL block starts with a BEGIN after the declaration of any local variables and ends with an END, optionally followed by the *function_name*.
- There must be at least one RETURN *expression* statement.
- You cannot reference host or bind variables in the PL/SQL block of a stored function.

Note: Although the OUT and IN OUT parameter modes can be used with functions, it is not good programming practice to use them with functions. However, if you need to return more than one value from a function, consider returning the values in a composite data structure such as a PL/SQL record or a PL/SQL table.

The Difference Between Procedures and Functions

Procedures	Functions
Execute as a PL/SQL statement	Invoke as part of an expression
Do not contain RETURN clause in the header	Must contain a RETURN clause in the header
Can pass values (if any) using output parameters	Must return a single value
Can contain a RETURN statement without a value	Must contain at least one RETURN statement

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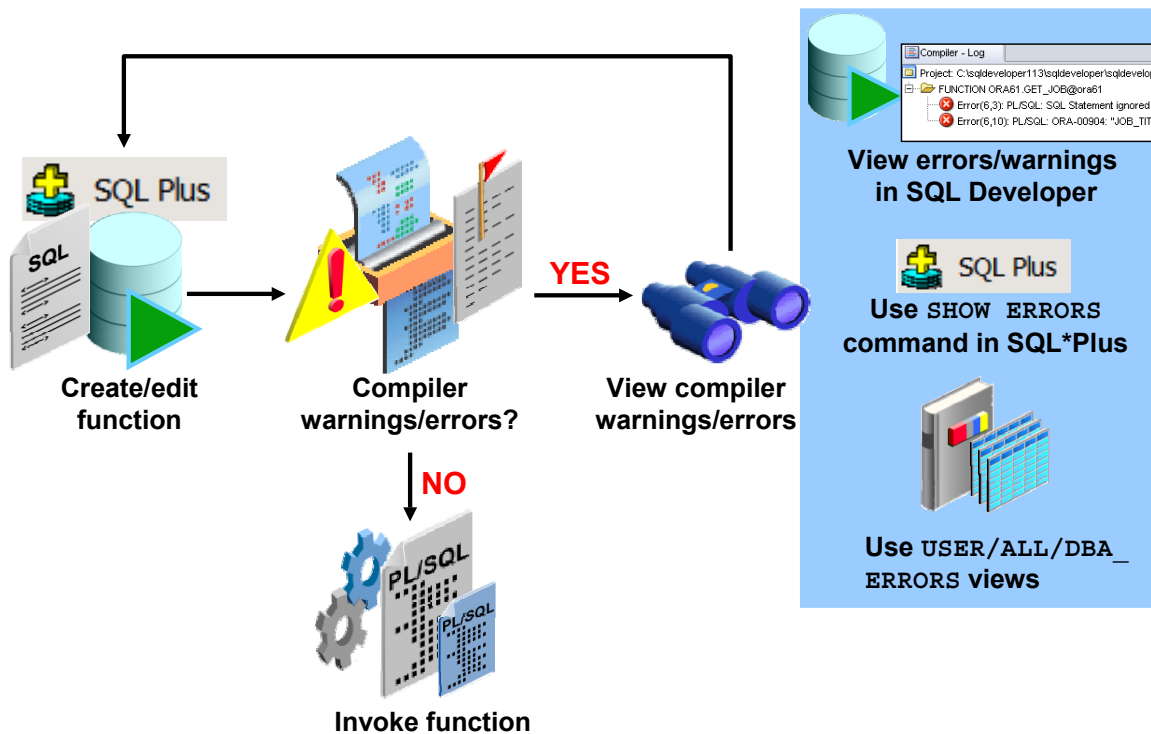
The Difference Between Procedures and Functions

You create a procedure to store a series of actions for later execution. A procedure can contain zero or more parameters that can be transferred to and from the calling environment, but a procedure does not have to return a value. A procedure can call a function to assist with its actions.

Note: A procedure containing a single OUT parameter would be better rewritten as a function returning the value.

You create a function when you want to compute a value that must be returned to the calling environment. A function can contain zero or more parameters that are transferred from the calling environment. Functions typically return only a single value, and the value is returned through a RETURN statement. The functions used in SQL statements should not use OUT or IN OUT mode parameters. Although a function using output parameters can be used in a PL/SQL procedure or block, it cannot be used in SQL statements.

Creating and Running Functions: Overview



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Creating and Running Functions: Overview

The diagram in the slide illustrates the basic steps involved in creating and running a function:

1. Create the function using SQL Developer's Object Navigator tree or the SQL Worksheet area.
2. Compile the function. The function is created in the database. The CREATE FUNCTION statement creates and stores source code and the compiled *m-code* in the database. To compile the function, right-click the function's name in the Object Navigator tree, and then click Compile.
3. If there are compilation warning or errors, you can view (and then correct) the warnings or errors using one of the following methods:
 - Using the SQL Developer interface (the Compiler – Log tab)
 - Using the SHOW ERRORS SQL*Plus command
 - Using the USER/ALL/DBA_ERRORS views
4. After successful compilation, invoke the function to return the desired value.

Creating and Invoking a Stored Function Using the CREATE FUNCTION Statement: Example

```
CREATE OR REPLACE FUNCTION get_sal
(p_id employees.employee_id%TYPE) RETURN NUMBER IS
v_sal employees.salary%TYPE := 0;
BEGIN
  SELECT salary
  INTO    v_sal
  FROM    employees
  WHERE   employee_id = p_id;
  RETURN v_sal;
END get_sal; /
```

```
FUNCTION get_sal Compiled.
```

```
-- Invoke the function as an expression or as
-- a parameter value.

EXECUTE dbms_output.put_line(get_sal(100))
```

```
anonymous block completed
24000
```

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Stored Function: Example

The `get_sal` function is created with a single input parameter and returns the salary as a number. Execute the command as shown, or save it in a script file and run the script to create the `get_sal` function.

The `get_sal` function follows a common programming practice of using a single `RETURN` statement that returns a value assigned to a local variable. If your function has an exception section, then it may also contain a `RETURN` statement.

Invoke a function as part of a PL/SQL expression because the function will return 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 function `get_sal`. In this case, `get_sal` is invoked first to calculate the salary of the employee with ID 100. The salary value returned is supplied as the value of the `DBMS_OUTPUT.PUT_LINE` parameter, which displays the result (if you have executed a `SET SERVEROUTPUT ON`).

Note: 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.

Using Different Methods for Executing Functions

```
-- As a PL/SQL expression, get the results using host variables  
  
VARIABLE b_salary NUMBER  
EXECUTE :b_salary := get_sal(100)
```

```
anonymous block completed  
b_salary  
-----  
24000
```

```
-- As a PL/SQL expression, get the results using a local  
-- variable  
  
DECLARE  
    sal employees.salary%type;  
BEGIN  
    sal := get_sal(100);  
    DBMS_OUTPUT.PUT_LINE('The salary is: ' || sal);  
END;/
```

```
anonymous block completed  
The salary is: 24000
```

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Using Different Methods for Executing Functions

If functions are well designed, 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.

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

Using Different Methods for Executing Functions

```
-- Use as a parameter to another subprogram
```

```
EXECUTE dbms_output.put_line(get_sal(100))
```

```
anonymous block completed  
24000
```

```
-- Use in a SQL statement (subject to restrictions)
```

```
SELECT job_id, get_sal(employee_id) FROM employees;
```

```
JOB_ID    GET_SAL(EMPLOYEE_ID)  
-----  
SH_CLERK  2600  
SH_CLERK  2600  
AD_ASST   4400  
MK_MAN    13000
```

...

```
SH_CLERK  3100  
SH_CLERK  3000  
  
107 rows selected
```

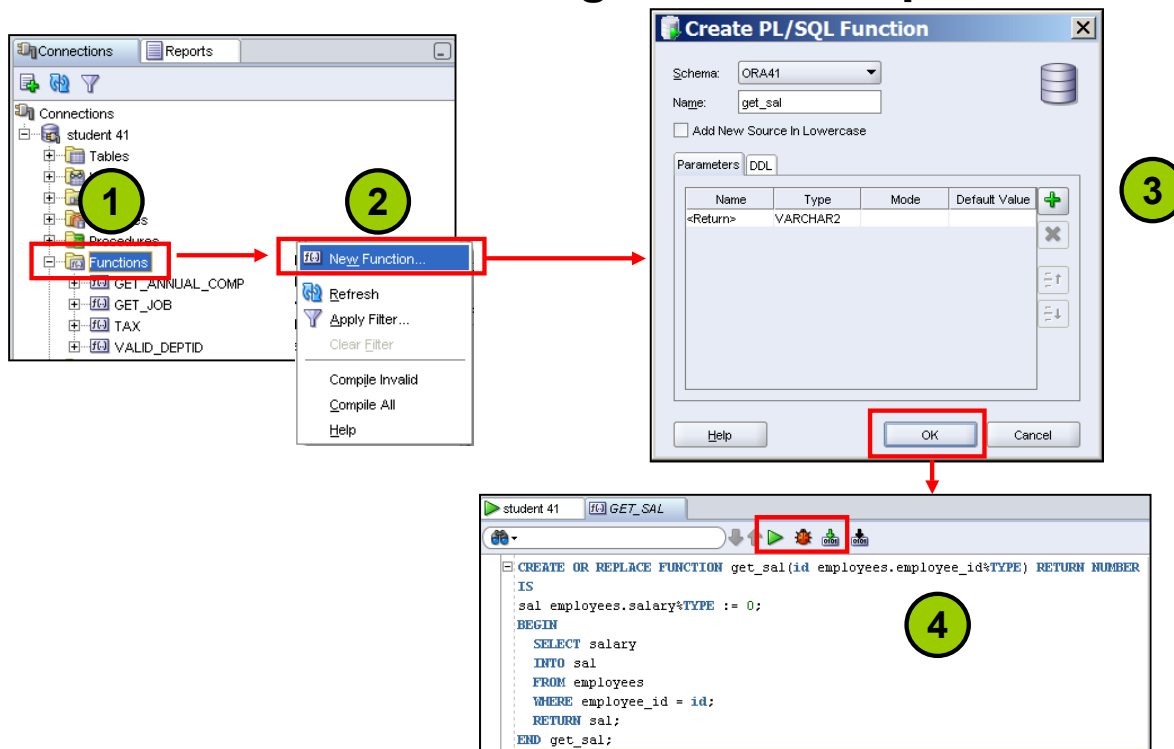
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Using Different Methods for Executing Functions (continued)

- **As a parameter to another subprogram:** The third example in the slide demonstrates this usage. The `get_sal` 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 course titled *Oracle Database 11g: SQL Fundamentals I*.
- **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.

Creating and Compiling Functions Using SQL Developer



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Creating and Compiling Functions Using SQL Developer

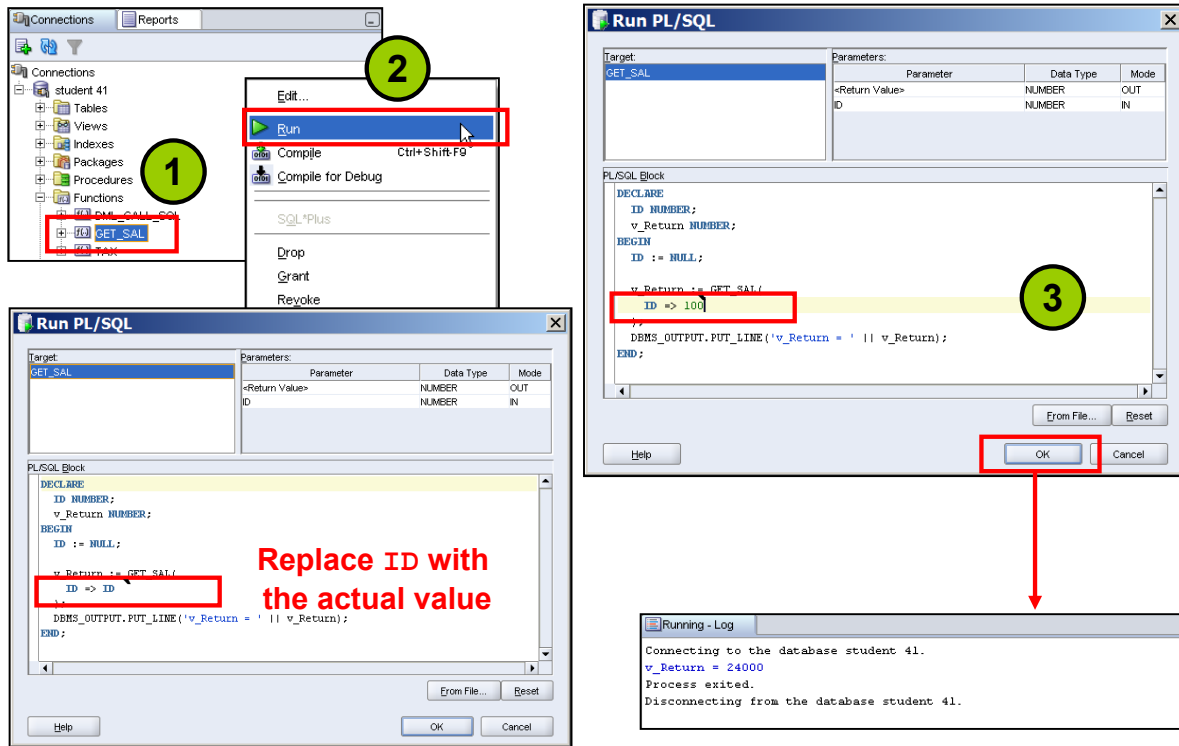
You can create a new function in SQL Developer using the following steps:

1. Right-click the **Functions** node, and then select **New Function**. The **Create PL/SQL Function** dialog box is displayed.
2. Select the schema, function name, and the parameters list (using the + icon), and then click **OK**. The code editor for the function is displayed.
3. Enter the function's code.
4. To compile the function, click the **Compile** icon.

Note

- To create a new function in SQL Developer, you can also enter the code in the SQL Worksheet, and then click the Run Script icon.
- For additional information about creating functions in SQL Developer, access the appropriate online help topic titled “Create PL/SQL Subprogram Function or Procedure.”

Executing Functions Using SQL Developer



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Executing Functions Using SQL Developer

You can execute a function in SQL Developer using the following steps:

1. Right-click the **Functions** node.
2. Right-click the function's name, and then select **Run**. The **Run PL/SQL** dialog box is displayed.
3. Replace the second parameter name with the actual parameter value as shown in the slide example, and then click OK.

Note: For additional information about running functions in SQL Developer, access the online help topic titled "Running and Debugging Functions and Procedures."

Advantages of User-Defined Functions in SQL Statements

- Can extend SQL where activities are too complex, too awkward, or unavailable with SQL
- Can increase efficiency when used in the `WHERE` clause to filter data, as opposed to filtering the data in the application
- Can manipulate data values

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Advantages of User-Defined Functions in SQL Statements

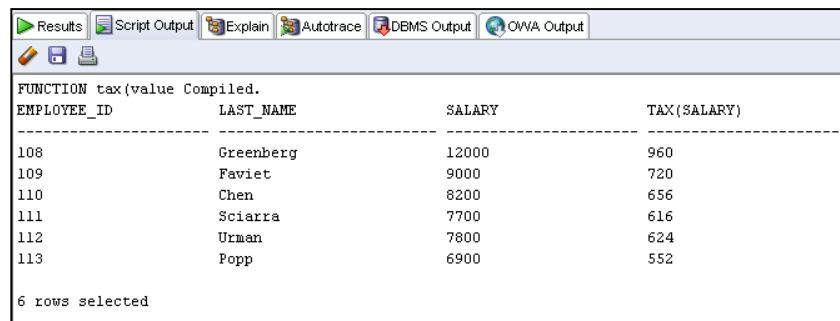
SQL statements can reference PL/SQL user-defined functions anywhere a SQL expression is allowed. For example, a user-defined function can be used anywhere that a built-in SQL function, such as `UPPER ()`, can be placed.

Advantages

- Permits calculations that are too complex, awkward, or unavailable with SQL
- Increases data independence by processing complex data analysis within the Oracle server, rather than by retrieving the data into an application
- Increases efficiency of queries by performing functions in the query rather than in the application
- Manipulates new types of data (for example, latitude and longitude) by encoding character strings and using functions to operate on the strings

Using a Function in a SQL Expression: Example

```
CREATE OR REPLACE FUNCTION tax(p_value IN NUMBER)
  RETURN NUMBER IS
BEGIN
  RETURN (p_value * 0.08);
END tax;
/
SELECT employee_id, last_name, salary, tax(salary)
FROM   employees
WHERE  department_id = 100;
```



The screenshot shows the 'Results' tab in SQL Developer. It displays the output of the SQL query, including the function definition and the query results. The function 'tax' is shown as 'FUNCTION tax(value Compiled.' and the query results are shown as a table with columns 'EMPLOYEE_ID', 'LAST_NAME', 'SALARY', and 'TAX(SALARY)'. The results show 6 rows selected.

EMPLOYEE_ID	LAST_NAME	SALARY	TAX(SALARY)
108	Greenberg	12000	960
109	Faviet	9000	720
110	Chen	8200	656
111	Sciarra	7700	616
112	Urman	7800	624
113	Popp	6900	552

6 rows selected

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Function in SQL Expressions: Example

The example in the slide shows how to create a `tax` function to calculate income tax. The function accepts a `NUMBER` parameter and returns the calculated income tax based on a simple flat tax rate of 8%.

To execute the code shown in the slide example in SQL Developer, enter the code in the SQL Worksheet, and then click the **Run Script** icon. The `tax` function is invoked as an expression in the `SELECT` clause along with the employee ID, last name, and salary for employees in a department with ID 100. The return result from the `tax` function is displayed with the regular output from the query.

Calling User-Defined Functions in SQL Statements

User-defined functions act like built-in single-row functions and can be used in:

- The `SELECT` list or clause of a query
- Conditional expressions of the `WHERE` and `HAVING` clauses
- The `CONNECT BY`, `START WITH`, `ORDER BY`, and `GROUP BY` clauses of a query
- The `VALUES` clause of the `INSERT` statement
- The `SET` clause of the `UPDATE` statement

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Calling User-Defined Functions in SQL Statements

A PL/SQL user-defined function can be called from any SQL expression where a built-in single-row function can be called as shown in the following example:

```
SELECT employee_id, tax(salary)
FROM   employees
WHERE  tax(salary) > (SELECT MAX(tax(salary))
                     FROM employees
                     WHERE department_id = 30)
ORDER BY tax(salary) DESC;
```

EMPLOYEE_ID	TAX(SALARY)
100	1920
101	1360
102	1360
145	1120
146	1080
201	1040
205	960
147	960
108	960
168	920
10 rows selected	

Restrictions When 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:
 - You must own the function or have the `EXECUTE` privilege

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Restrictions When 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 `IN` and of 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.

Controlling Side Effects When 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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Controlling Side Effects When Calling Functions from SQL Expressions

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

Additional restrictions apply when a function is called in expressions of SQL statements:

- When a function is called from a `SELECT` statement or a parallel `UPDATE` or `DELETE` statement, the function cannot modify database tables.
- When a function is called from an `UPDATE` or `DELETE` statement, the function cannot query or modify database tables modified by that statement.
- When a function is called from a `SELECT`, `INSERT`, `UPDATE`, or `DELETE` statement, the function cannot execute directly or indirectly through another subprogram or SQL transaction control statements such as:
 - A `COMMIT` or `ROLLBACK` statement
 - A session control statement (such as `SET ROLE`)
 - A system control statement (such as `ALTER SYSTEM`)
 - Any DDL statements (such as `CREATE`) because they are followed by an automatic commit

Restrictions on Calling Functions from SQL: Example

```
CREATE OR REPLACE FUNCTION dml_call_sql(p_sal NUMBER)
RETURN NUMBER IS
BEGIN
    INSERT INTO employees(employee_id, last_name,
                           email, hire_date, job_id, salary)
    VALUES(1, 'Frost', 'jfrost@company.com',
            SYSDATE, 'SA_MAN', p_sal);
    RETURN (p_sal + 100);
END;
```

```
UPDATE employees
SET salary = dml_call_sql(2000)
WHERE employee_id = 170;
```

```
FUNCTION dml_call_sql(p_sal Compiled.

Error starting at line 1 in command:
UPDATE employees
  SET salary = dml_call_sql(2000)
 WHERE employee_id = 170
Error report:
SQL Error: ORA-04091: table ORA62.EMPLOYEES is mutating, trigger/function may not see it
ORA-06512: at "ORA62.DML_CALL_SQL", line 4
04091. 00000 - "table %s.%s is mutating, trigger/function may not see it"
*Cause:      A trigger (or a user defined plsql function that is referenced in
             this statement) attempted to look at (or modify) a table that was
             in the middle of being modified by the statement which fired it.
*Action:     Rewrite the trigger (or function) so it does not read that table.
```

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Restrictions on Calling Functions from SQL: Example

The `dml_call_sql` function in the slide contains an `INSERT` statement that inserts a new record into the `EMPLOYEES` table and returns the input salary value incremented by 100. This function is invoked in the `UPDATE` statement that modifies the salary of employee 170 to the amount returned from the function. The `UPDATE` statement fails with an error indicating that the table is mutating (that is, changes are already in progress in the same table). In the following example, the `query_call_sql` function queries the `SALARY` column of the `EMPLOYEES` table:

```
CREATE OR REPLACE FUNCTION query_call_sql(p_a NUMBER)
RETURN NUMBER IS
    v_s NUMBER;
BEGIN
    SELECT salary INTO v_s FROM employees
    WHERE employee_id = 170;
    RETURN (v_s + p_a);
END;
```

When invoked from the following `UPDATE` statement, it returns the error message similar to the error message shown in the slide:

```
UPDATE employees SET salary = query_call_sql(100)
WHERE employee_id = 170;
```

Named and Mixed Notation from SQL

- PL/SQL allows arguments in a subroutine call to be specified using positional, named, or mixed notation
- Prior to Oracle Database 11g, only the positional notation is supported in calls from SQL
- Starting in Oracle Database 11g, named and mixed notation can be used for specifying arguments in calls to PL/SQL subroutines from SQL statements
- For long parameter lists, with most having default values, you can omit values from the optional parameters
- You can avoid duplicating the default value of the optional parameter at each call site

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Named and Mixed Notation from SQL: Example

```
CREATE OR REPLACE FUNCTION f(
  p_parameter_1 IN NUMBER DEFAULT 1,
  p_parameter_5 IN NUMBER DEFAULT 5)
RETURN NUMBER
IS
  v_var number;
BEGIN
  v_var := p_parameter_1 + (p_parameter_5 * 2);
  RETURN v_var;
END f;
/
```

```
FUNCTION f( Compiled.
```

```
SELECT f(p_parameter_5 => 10) FROM DUAL;
```

```
F(P_PARAMETER_5=>10)
-----
21
1 rows selected
```

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Example of Using Named and Mixed Notation from a SQL Statement

In the slide example, the call to the function `f` within the SQL `SELECT` statement uses the named notation. Before Oracle Database 11g, you could not use the named or mixed notation when passing parameters to a function from within a SQL statement. Before Oracle Database 11g, you received the following error:

```
SELECT f(p_parameter_5 => 10) FROM DUAL;
```

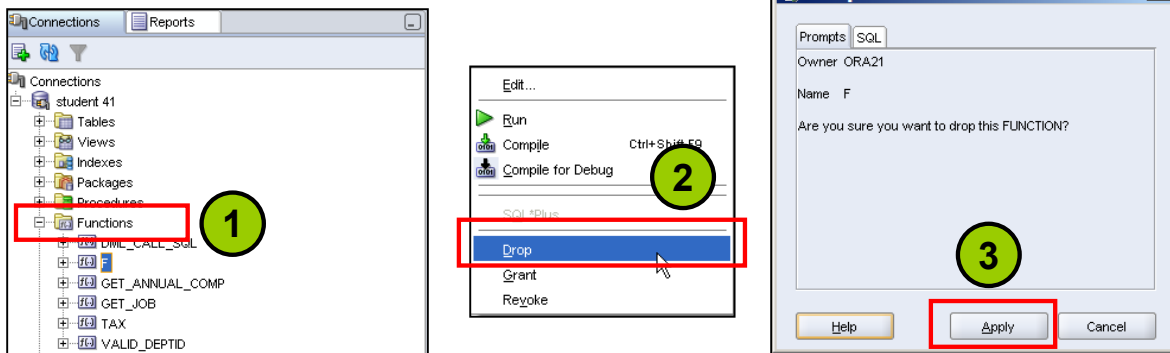
```
ORA-00907: missing right parenthesis
```

Removing Functions: Using the DROP SQL Statement or SQL Developer

- Using the DROP statement:

```
DROP FUNCTION f;
```

- Using SQL Developer:



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Removing Functions

Using the DROP statement

When a stored function is no longer required, you can use a SQL statement in SQL*Plus to drop it. To remove a stored function by using SQL*Plus, execute the `DROP FUNCTION SQL` command.

Using CREATE OR REPLACE Versus DROP and CREATE

The `REPLACE` clause in the `CREATE OR REPLACE` syntax is equivalent to dropping a function and re-creating it. When you use the `CREATE OR REPLACE` syntax, the privileges granted on this object to other users remain the same. When you `DROP` a function and then re-create it, all the privileges granted on this function are automatically revoked.

Using SQL Developer

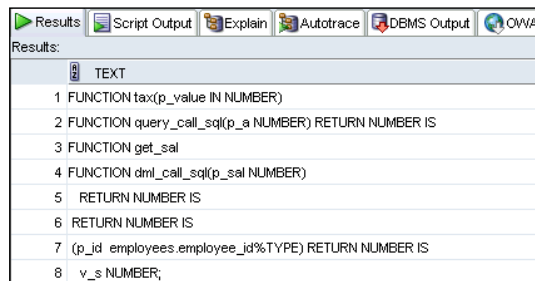
To drop a function in SQL Developer, right-click the function name in the **Functions** node, and then select **Drop**. The **Drop** dialog box is displayed. To drop the function, click **Apply**.

Viewing Functions Using Data Dictionary Views

```
DESCRIBE USER_SOURCE
```

```
DESCRIBE user_source
Name                Null    Type
-----
NAME                VARCHAR2(30)
TYPE                VARCHAR2(12)
LINE                NUMBER
TEXT                VARCHAR2(4000)
4 rows selected
```

```
SELECT text
FROM   user_source
WHERE  type = 'FUNCTION'
ORDER BY line;
```



	TEXT
1	FUNCTION tax(p_value IN NUMBER)
2	FUNCTION query_call_sql(p_a NUMBER) RETURN NUMBER IS
3	FUNCTION get_sal
4	FUNCTION dml_call_sql(p_sal NUMBER)
5	RETURN NUMBER IS
6	RETURN NUMBER IS
7	(p_id employees.employee_id%TYPE) RETURN NUMBER IS
8	v_s NUMBER;

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Viewing Functions Using Data Dictionary Views

The source code for PL/SQL functions is stored in the data dictionary tables. The source code is accessible for PL/SQL functions that are successfully or unsuccessfully compiled. To view the PL/SQL function code stored in the data dictionary, execute a SELECT statement on the following tables where the TYPE column value is FUNCTION:

- The USER_SOURCE table to display the PL/SQL code that you own
- The ALL_SOURCE table to display the PL/SQL code to which you have been granted the EXECUTE right by the owner of that subprogram code

The second slide example uses the USER_SOURCE table to display the source code for all the functions in your schema.

You can also use the USER_OBJECTS data dictionary view to display a list of your function names.

Quiz

A PL/SQL function:

1. Can be invoked as part of an expression
2. Must contain a RETURN clause in the header
3. Must return a single value
4. Must contain at least one RETURN statement
5. Does not contain a RETURN clause in the header

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Answers: 1, 2, 3, 4

Summary

In this lesson, you should have learned how to:

- Differentiate between a procedure and a function
- Describe the uses of functions
- Create stored functions
- Invoke a function
- Remove a function

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Summary

A function is a named PL/SQL block that must return a value. Generally, you create a function to compute and return a value, and you create a procedure to perform an action.

A function can be created or dropped.

A function is invoked as a part of an expression.

Practice 3: Overview

This practice covers the following topics:

- Creating stored functions:
 - To query a database table and return specific values
 - To be used in a SQL statement
 - To insert a new row, with specified parameter values, into a database table
 - Using default parameter values
- Invoking a stored function from a SQL statement
- Invoking a stored function from a stored procedure

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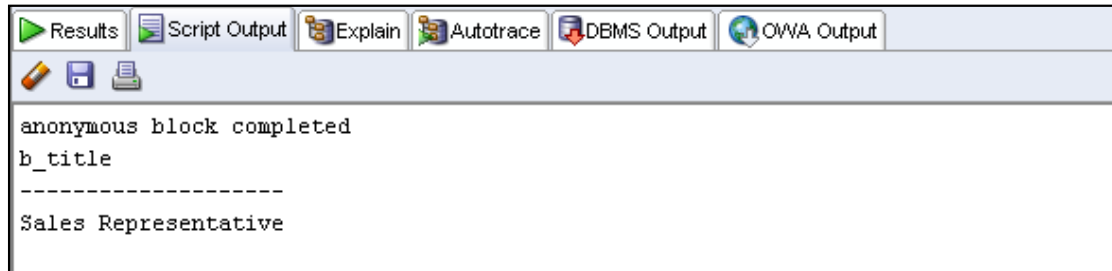
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Practice 3: Overview

It is recommended to use SQL Developer for this practice.

Practice 3

1. Create and invoke the GET_JOB function to return a job title.
 - a. Create and compile a function called GET_JOB to return a job title.
 - b. Create a VARCHAR2 host variable called b_title, allowing a length of 35 characters. Invoke the function with the SA_REP job ID to return the value in the host variable, and then print the host variable to view the result.



```
anonymous block completed
b_title
-----
Sales Representative
```

2. Create a function called GET_ANNUAL_COMP to return the annual salary computed from an employee's monthly salary and commission passed as parameters.
 - a. Create the GET_ANNUAL_COMP function, which accepts parameter values for the monthly salary and commission. Either or both values passed can be NULL, but the function should still return a non-NULL annual salary. Use the following basic formula to calculate the annual salary:
$$(\text{salary} * 12) + (\text{commission_pct} * \text{salary} * 12)$$
 - b. Use the function in a SELECT statement against the EMPLOYEES table for employees in department 30.

EMPLOYEE_ID	LAST_NAME	Annual Compensation
114	Raphaely	132000
115	Khoo	37200
116	Baida	34800
117	Tobias	33600
118	Himuro	31200
119	Colmenares	30000
6 rows selected		

3. Create a procedure, ADD_EMPLOYEE, to insert a new employee into the EMPLOYEES table. The procedure should call a VALID_DEPTID function to check whether the department ID specified for the new employee exists in the DEPARTMENTS table.
 - a. Create a function called VALID_DEPTID to validate a specified department ID and return a BOOLEAN value of TRUE if the department exists.

Practice 3 (continued)

- b. Create the `ADD_EMPLOYEE` procedure to add an employee to the `EMPLOYEES` table. The row should be added to the `EMPLOYEES` table if the `VALID_DEPTID` function returns `TRUE`; otherwise, alert the user with an appropriate message. Provide the following parameters:
 - `first_name`
 - `last_name`
 - `email`
 - `job`: Use `'SA_REP'` as the default
 - `mgr`: Use `145` as the default
 - `sal`: Use `1000` as the default
 - `comm`: Use `0` as the default
 - `deptid`: Use `30` as the default
 - Use the `EMPLOYEES_SEQ` sequence to set the `employee_id` column
 - Set the `hire_date` column to `TRUNC(SYSDATE)`
- c. Call `ADD_EMPLOYEE` for the name `Jane Harris` in department `15`, leaving other parameters with their default values. What is the result?
- d. Add another employee named `Joe Harris` in department `80`, leaving remaining parameters with their default values. What is the result?

4

Creating Packages

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Objectives

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

- Describe packages and list their components
- Create a package to group together related variables, cursors, constants, exceptions, procedures, and functions
- Designate a package construct as either public or private
- Invoke a package construct
- Describe the use of a bodiless package

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Lesson Aim

In this lesson, you learn what a package is and what its components are. You also learn how to create and use packages.

Lesson Agenda

- Identifying the benefits and the components of packages
- Working with packages:
 - Creating the package specification and body
 - Invoking the package subprograms
 - Removing a package
 - Displaying the package information

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What Are PL/SQL Packages?

- A package is a schema object that groups logically related PL/SQL types, variables, and subprograms.
- Packages usually have two parts:
 - A specification (spec)
 - A body
- The specification is the interface to the package. It declares the types, variables, constants, exceptions, cursors, and subprograms that can be referenced from outside the package.
- The body defines the queries for the cursors and the code for the subprograms.
- Enable the Oracle server to read multiple objects into memory at once.

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PL/SQL Packages: Overview

PL/SQL packages enable you to bundle related PL/SQL types, variables, data structures, exceptions, and subprograms into one container. For example, a Human Resources package can contain hiring and firing procedures, commission and bonus functions, and tax exemption variables.

A package usually consists of two parts 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. Subsequent access to constructs in the same package does not require disk input/output (I/O).

Advantages of Using Packages

- Modularity: Encapsulating related constructs
- Easier maintenance: Keeping logically related functionality together
- Easier application design: Coding and compiling the specification and body separately
- Hiding information:
 - Only the declarations in the package specification are visible and accessible to applications
 - Private constructs in the package body are hidden and inaccessible
 - All coding is hidden in the package body

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Advantages of Using Packages

Packages provide an alternative to creating procedures and functions as stand-alone schema objects, and they offer several benefits.

Modularity and easier maintenance: You encapsulate logically related programming structures in a named module. Each package is easy to understand, and the interface between packages is simple, clear, and well defined.

Easier application design: All you need initially is the interface information in the package specification. You can code and compile a specification without its body. Thereafter, stored subprograms that reference the package can compile as well. You need not define the package body fully until you are ready to complete the application.

Hiding information: You decide which constructs are public (visible and accessible) and which are private (hidden and inaccessible). Declarations in the package specification are visible and accessible to applications. The package body hides the definition of the private constructs, so that only the package is affected (not your application or any calling programs) if the definition changes. This enables you to change the implementation without having to recompile the calling programs. Also, by hiding implementation details from users, you protect the integrity of the package.

Advantages of Using Packages

- Added functionality: Persistency of public variables and cursors
- Better performance:
 - The entire package is loaded into memory when the package is first referenced.
 - There is only one copy in memory for all users.
 - The dependency hierarchy is simplified.
- Overloading: Multiple subprograms of the same name

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Advantages of Using Packages (continued)

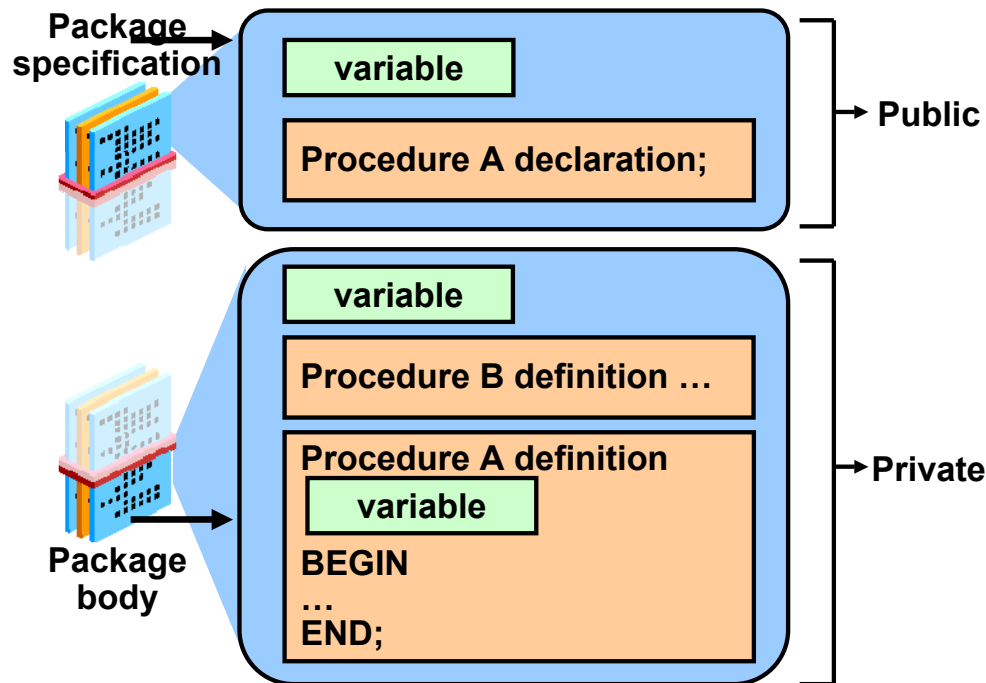
Added functionality: Packaged public variables and cursors persist for the duration of a session. Thus, they can be shared by all subprograms that execute in the environment. They also enable you to maintain data across transactions without having to store it in the database. Private constructs also persist for the duration of the session but can be accessed only within the package.

Better performance: When you call a packaged subprogram the first time, the entire package is loaded into memory. Later calls to related subprograms in the package, therefore, require no further disk I/O. Packaged subprograms also stop cascading dependencies and thus avoid unnecessary compilation.

Overloading: With packages, you can overload procedures and functions, which means you can create multiple subprograms with the same name in the same package, each taking parameters of different number or data type.

Note: Dependencies are covered in detail in the lesson titled “Managing Dependencies.”

Components of a PL/SQL Package



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Components of a PL/SQL Package

You create a package in two parts:

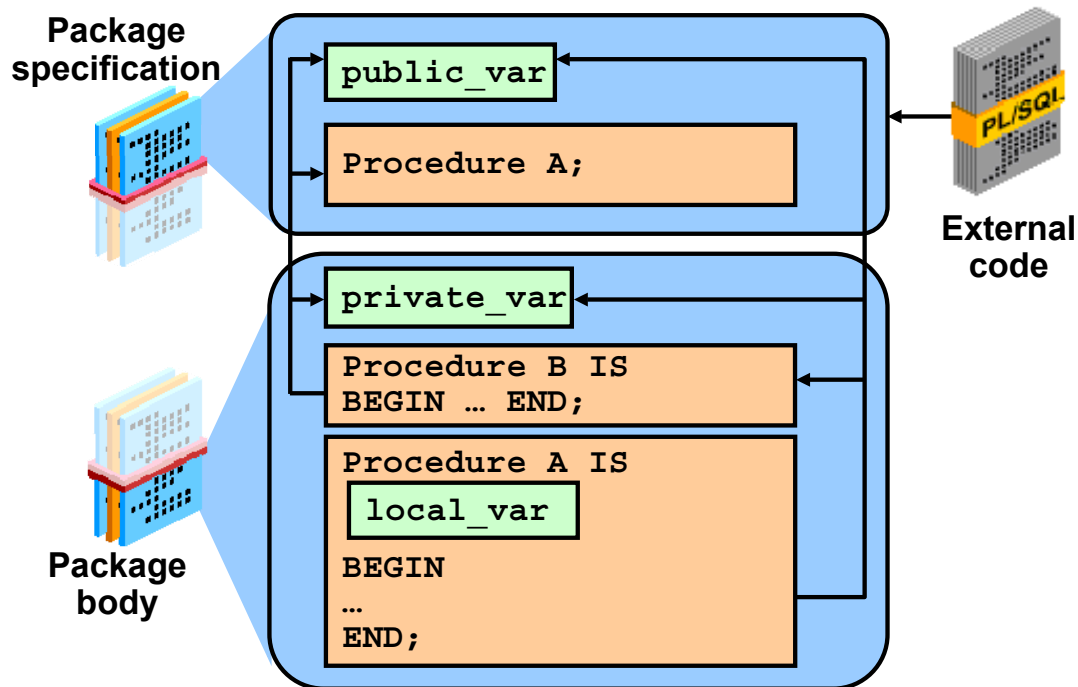
- The **package specification** is the interface to your applications. It declares the public types, variables, constants, exceptions, cursors, and subprograms available for use. The package specification may also include PRAGMAs, which are directives to the compiler.
- The **package body** defines its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

Public components are declared in the package specification. The specification defines a public application programming interface (API) for users of 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 and can be referenced only by other constructs within the same package body. Private components can reference the package public components.

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

The Visibility of a Package's Components



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Visibility of Package Components

The visibility of a component describes whether that component can be seen, that is, referenced and used by other components or objects. The visibility of components depends on whether they are *locally* or *globally* declared.

Local components are visible within the structure in which they are declared, such as:

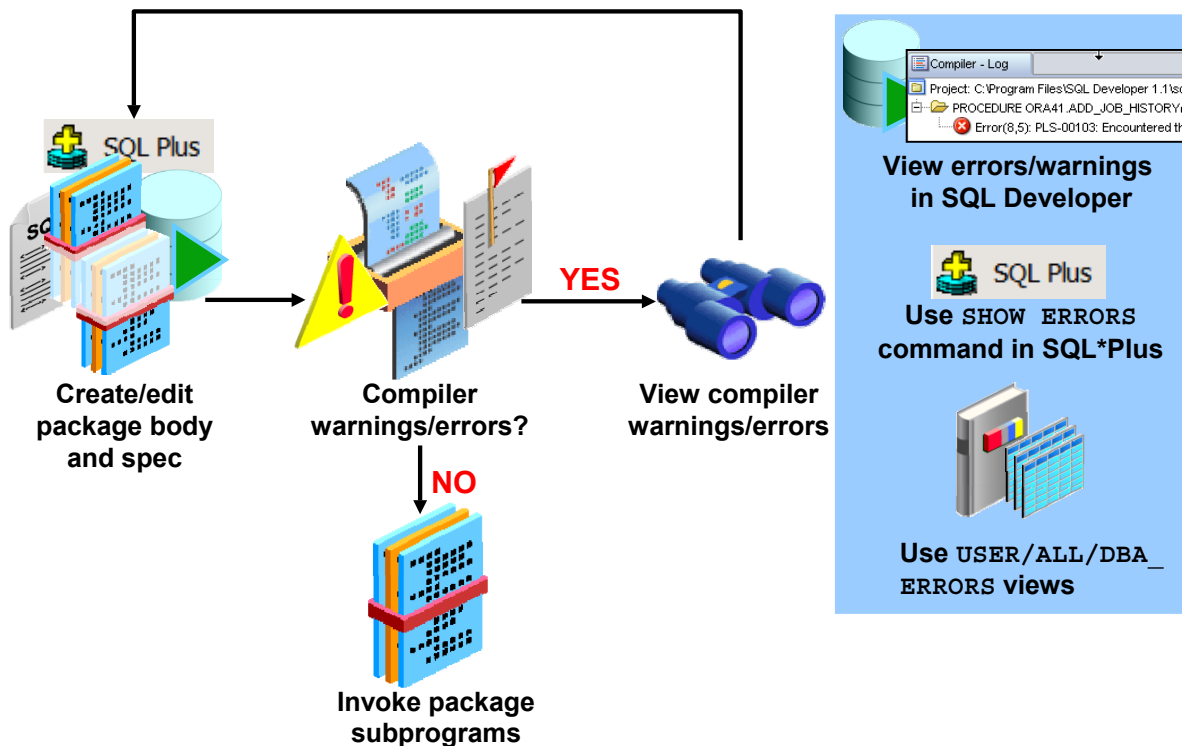
- Variables defined in a subprogram can be referenced within that subprogram, and are not visible to external components—for example, `local_var` can be used in procedure A.
- Private package variables, which are declared in a package body, can be referenced by other components in the same package body. They are not visible to any subprograms or objects that are outside the package. For example, `private_var` can be used by procedures A and B within the package body, but not outside the package.

Globally declared components are visible internally and externally to the package, such as:

- A public variable, which is declared in a package specification, can be referenced and changed outside the package (for example, `public_var` can be referenced externally).
- A package subprogram in the specification can be called from external code sources (for example, procedure A can be called from an environment external to the package).

Note: Private subprograms, such as procedure B, can be invoked only with public subprograms, such as procedure A, or other private package constructs.

Developing PL/SQL Packages: Overview



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Developing PL/SQL Packages

The diagram in the slide illustrates the basic steps involved in developing and using a package:

1. Create the procedure using SQL Developer's Object Navigator tree or the SQL Worksheet area.
2. Compile the package. The package is created in the database. The `CREATE PACKAGE` statement creates and stores source code and the compiled *m-code* in the database. To compile the package, right-click the package's name in the Object Navigator tree, and then click Compile.
3. If there are no compilation warnings or errors, you execute any public construct within the package specification from an Oracle Server environment.
4. If there are compilation warning or errors, you can view (and then correct) the warnings or errors using one of the following methods:
 - a. Using the SQL Developer interface (the Compiler – Log tab)
 - b. Using the `SHOW ERRORS SQL*Plus` command
 - c. Using the `USER/ALL/DBA_ERRORS` views

Lesson Agenda

- Identifying the benefits and the components of packages
- Working with packages:
 - Creating the package specification and body
 - Invoking the package subprograms
 - Removing a package
 - Displaying the package information

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Creating the Package Specification: Using the CREATE PACKAGE Statement

```
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 the constructs declared in a package specification are visible to users who are granted privileges on the package.

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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.

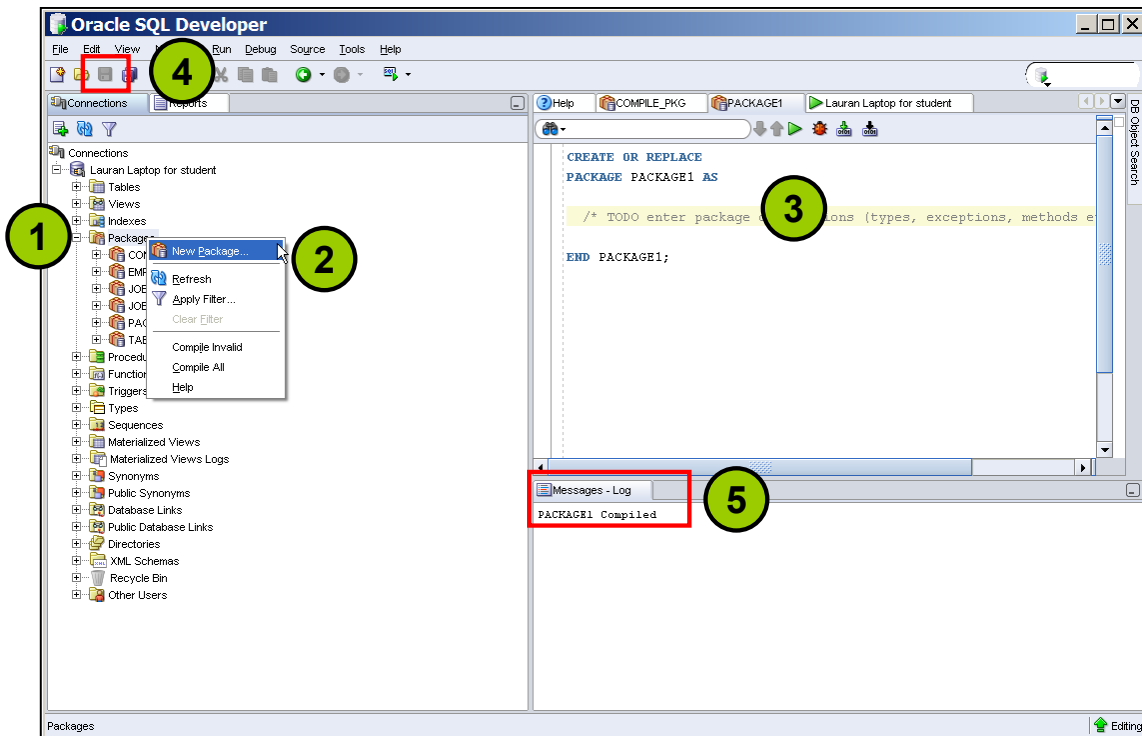
The following are definitions of items in the package syntax:

- **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 specification** specifies the public procedure or function declarations.

The package specification should contain procedure and function headings terminated by a semicolon, without the IS (or AS) keyword and its PL/SQL block. The implementation of a procedure or function that is declared in a package specification is done in the package body.

The Oracle database stores the specification and body of a package separately. This enables you to change the implementation of a program construct in the package body without invalidating other schema objects that call or reference the program construct.

Creating the Package Specification: Using SQL Developer



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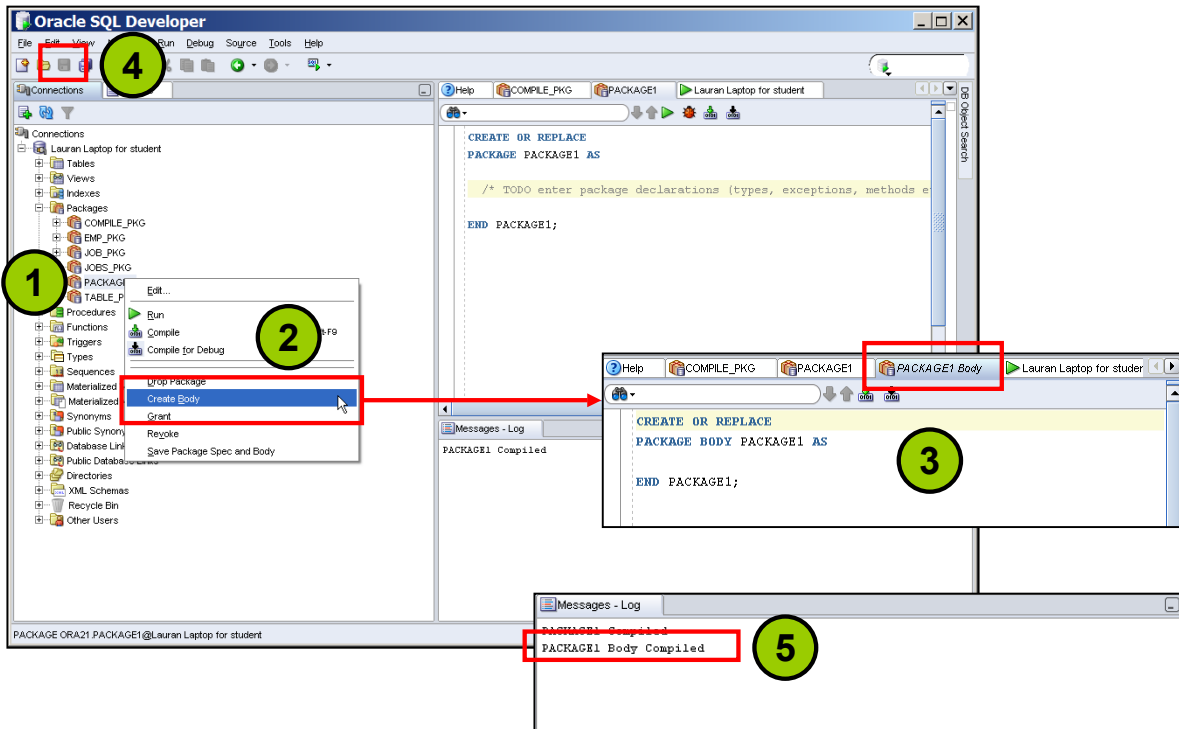
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Creating the Package Specification: Using SQL Developer

You can use SQL Developer to create the package specification as follows:

1. Right-click the **Packages** node in the Connections navigation tree.
2. Select **New Package** from the shortcut menu. In the **Create PL/SQL Package** window (not shown in the slide), select the schema name, enter the name for the new package, and then click OK. A tab for the new package is displayed along with the shell for the new package.
3. Enter the code for the new package.
4. Compile or save the new package.
5. The **Messages – Log** tab displays whether or not the compilation was successful.

Creating the Package Body: Using SQL Developer



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Creating the Package Body: Using SQL Developer

You can use SQL Developer to create the package body as follows:

1. Right-click the package name for which you are creating a body in the **Packages** node in the Connections navigation tree.
2. Select **Create Body** from the shortcut menu. A tab for the new package body is displayed along with the shell for the new package body.
3. Enter the code for the new package body.
4. Compile or save the package body.
5. The **Messages – Log** tab displays whether or not the compilation was successful.

Example of a Package Specification: comm_pkg

```
-- The package spec with a public variable and a
-- public procedure that are accessible from
-- outside the package.

CREATE OR REPLACE PACKAGE comm_pkg IS
  v_std_comm NUMBER := 0.10;  --initialized to 0.10
  PROCEDURE reset_comm(p_new_comm NUMBER);
END comm_pkg;
/
```

- V_STD_COMM is a *public* global variable initialized to 0.10.
- RESET_COMM is a *public* procedure used to reset the standard commission based on some business rules. It is implemented in the package body.

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Example of Package Specification: comm_pkg

The example in the slide creates a package called `comm_pkg` used to manage business processing rules for commission calculations.

The `v_std_comm` public (global) variable is declared to hold a maximum allowable percentage commission for the user session, and it is initialized to 0.10 (that is, 10%).

The `reset_comm` public procedure is declared to accept a new commission percentage that updates the standard commission percentage if the commission validation rules are accepted. The validation rules for resetting the commission are not made public and do not appear in the package specification. The validation rules are managed by using a private function in the package body.

Creating the Package Body

```
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.

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Creating the Package Body

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

- Specify the OR REPLACE option to overwrite an existing 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.
- Complete the implementation for all procedures or functions declared in the package specification within the package body.

The following are 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 specification** 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.

Example of a Package Body: comm_pkg

```
CREATE OR REPLACE PACKAGE BODY comm_pkg IS
  FUNCTION validate(p_comm NUMBER) RETURN BOOLEAN IS
    v_max_comm      employees.commission_pct%type;
  BEGIN
    SELECT MAX(commission_pct) INTO v_max_comm
    FROM   employees;
    RETURN (p_comm BETWEEN 0.0 AND v_max_comm);
  END validate;

  PROCEDURE reset_comm (p_new_comm NUMBER) IS BEGIN
    IF validate(p_new_comm) THEN
      v_std_comm := p_new_comm; -- reset public var
    ELSE RAISE_APPLICATION_ERROR(
      -20210, 'Bad Commission');
    END IF;
  END reset_comm;
END comm_pkg;
```

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Example of a Package Body: comm_pkg

The slide shows the complete package body for `comm_pkg`, with a private function called `validate` to check for a valid commission. The validation requires that the commission be positive and less than the highest commission among existing employees. The `reset_comm` procedure invokes the private validation function before changing the standard commission in `v_std_comm`. In the example, note the following:

- The `v_std_comm` variable referenced in the `reset_comm` procedure is a public variable. Variables declared in the package specification, such as `v_std_comm`, can be directly referenced without qualification.
- The `reset_comm` procedure implements the public definition in the specification.
- In the `comm_pkg` body, the `validate` function is private and is directly referenced from the `reset_comm` procedure without qualification.

Note: The `validate` function appears before the `reset_comm` procedure because the `reset_comm` procedure references the `validate` function. It is possible to create forward declarations for subprograms in the package body if their order of appearance needs to be changed. If a package specification declares only types, constants, variables, and exceptions without any subprogram specifications, then the package body is unnecessary. However, the body can be used to initialize items declared in the package specification.

Invoking the Package Subprograms: Examples

```
-- Invoke a function within the same packages:
CREATE OR REPLACE PACKAGE BODY comm_pkg IS ...
  PROCEDURE reset_comm(p_new_comm NUMBER) IS
  BEGIN
    IF validate(p_new_comm) THEN
      v_std_comm := p_new_comm;
    ELSE ...
    END IF;
  END reset_comm;
END comm_pkg;
```

```
-- Invoke a package procedure from SQL*Plus:
EXECUTE comm_pkg.reset_comm(0.15)
```

```
-- Invoke a package procedure in a different schema:
EXECUTE scott.comm_pkg.reset_comm(0.15)
```

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Invoking Package Subprograms

After the package is stored in the database, you can invoke public or private subprograms within the same package, or public subprograms if external to the package. Fully qualify the subprogram with its package name when invoked externally from the package. Use the `package_name.subprogram` syntax.

Fully qualifying a subprogram when invoked within the same package is optional.

Example 1: Invokes the `validate` function from the `reset_comm` procedure within the same package. The package name prefix is not required; it is optional.

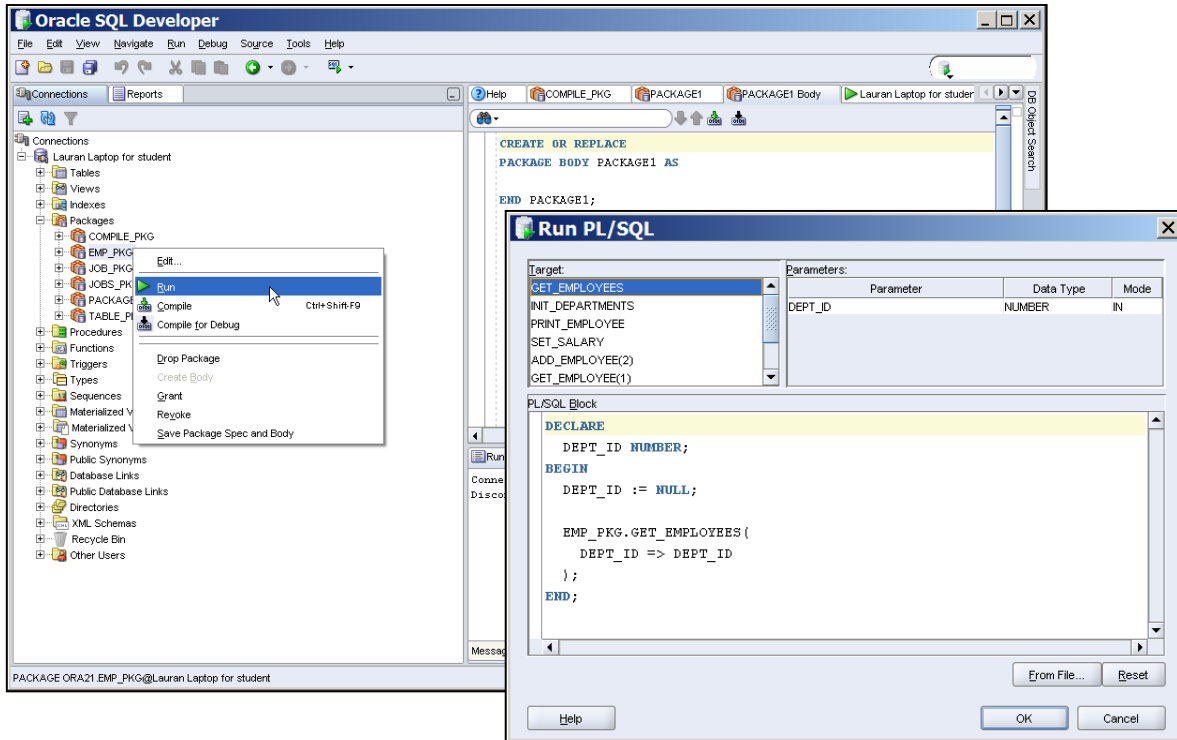
Example 2: Calls the `reset_comm` procedure from SQL*Plus (an environment external to the package) to reset the prevailing commission to 0.15 for the user session.

Example 3: Calls the `reset_comm` procedure that is owned in a schema user called SCOTT. Using SQL*Plus, the qualified package procedure is prefixed with the schema name. This can be simplified by using a synonym that references the `schema.package_name`.

Assume that a database link named NY has been created for a remote database in which the `reset_comm` package procedure is created. To invoke the remote procedure, use:

```
EXECUTE comm_pkg.reset_comm@NY(0.15)
```


Invoking the Package Subprograms: Using SQL Developer



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Invoking the Package Subprograms: Using SQL Developer

Use the **Run PL/SQL** window to specify parameter values for running a PL/SQL function or procedure. (If you specify a package, select a function or procedure in the package.) Specify the following:

Target: Select the name of the function or procedure to run.

Parameters: This section lists each parameter for the specified target. The mode of each parameter can be IN (the value is passed in), OUT (the value is returned), or IN/OUT (the value is passed in, and the result of the function or procedure's action is stored in the parameter).

PL/SQL Block: This is a block of PL/SQL code created by SQL Developer. You should change the formal IN and IN/OUT parameter specifications in this block to actual values that you want to use for running the function or procedure. For example, to specify 10 as the value for an input parameter named DEPT_ID, change DEPT_ID => DEPT_ID to DEPT_ID => 10. When you click OK, SQL Developer runs the function or procedure.

Creating and Using Bodiless Packages

```
CREATE OR REPLACE PACKAGE global_consts IS
  c_mile_2_kilo      CONSTANT  NUMBER  :=  1.6093;
  c_kilo_2_mile      CONSTANT  NUMBER  :=  0.6214;
  c_yard_2_meter     CONSTANT  NUMBER  :=  0.9144;
  c_meter_2_yard     CONSTANT  NUMBER  :=  1.0936;
END global_consts;
```

```
BEGIN  DBMS_OUTPUT.PUT_LINE('20 miles = ' ||
    20 * global_consts.c_mile_2_kilo || ' km');
END;
```

```
CREATE FUNCTION mtr2yrd(p_m NUMBER) RETURN NUMBER IS
BEGIN
  RETURN (p_m * global_consts.c_meter_2_yard);
END mtr2yrd;
/
EXECUTE DBMS_OUTPUT.PUT_LINE(mtr2yrd(1))
```

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Creating and Using Bodiless Packages

The variables and constants declared within stand-alone subprograms exist only for the duration that the subprogram executes. To provide data that exists for the duration of the user session, create a package specification containing public (global) variables and constant declarations. In this case, create a package specification without a package body, known as a *bodiless package*. As discussed earlier in this lesson, if a specification declares only types, constants, variables, and exceptions, then the package body is unnecessary.

Examples

The first code box in the slide creates a bodiless package specification with several constants to be used for conversion rates. A package body is not required to support this package specification.

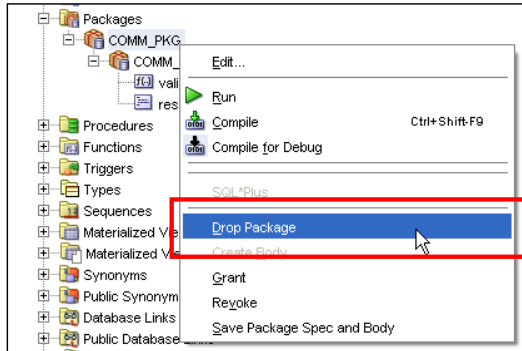
The second code box references the `c_mile_2_kilo` constant in the `global_consts` package by prefixing the package name to the identifier of the constant.

The third example creates a stand-alone function `c_mtr2yrd` to convert meters to yards, and uses the constant conversion rate `c_meter_2_yard` declared in the `global_consts` package. The function is invoked in a `DBMS_OUTPUT.PUT_LINE` parameter.

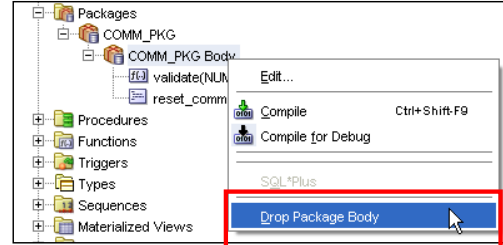
Rule to be followed: When referencing a variable, cursor, constant, or exception from outside the package, you must qualify it with the name of the package.

Removing Packages: Using SQL Developer or the SQL DROP Statement

Drop package specification and body



Drop package body only



```
-- Remove the package specification and body
DROP PACKAGE package_name;
```

```
-- Remove the package body only
DROP PACKAGE BODY package_name;
```

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Removing Packages

When a package is no longer required, you can use a SQL statement in SQL Developer to remove it. A package has two parts; therefore, you can remove the whole package, or you can remove only the package body and retain the package specification.

Viewing Packages Using the Data Dictionary

```
-- View the package specification.  
SELECT text  
FROM   user_source  
WHERE  name = 'COMM_PKG' AND type = 'PACKAGE';
```

TEXT
1 PACKAGE comm_pkg IS
2 std_comm NUMBER := 0.10; --initialized to 0.10
3 PROCEDURE reset_comm(new_comm NUMBER);
4 END comm_pkg;

```
-- View the package body.  
SELECT text  
FROM   user_source  
WHERE  name = 'COMM_PKG' AND type = 'PACKAGE BODY';
```

TEXT
1 PACKAGE BODY comm_pkg IS
2 FUNCTION validate(comm NUMBER) RETURN BOOLEAN IS
3 max_comm employees.commission_pct%type;
4 BEGIN
5 SELECT MAX(commission_pct) INTO max_comm
6 FROM employees;
7 RETURN (comm BETWEEN 0.0 AND max_comm);

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Viewing Packages in the Data Dictionary

The source code for PL/SQL packages is also stored in the USER_SOURCE and ALL_SOURCE data dictionary views. The USER_SOURCE table is used to display PL/SQL code that you own. The ALL_SOURCE table is used to display PL/SQL code to which you have been granted the EXECUTE right by the owner of that subprogram code and provides an OWNER column in addition to the preceding columns.

When querying the package, use a condition in which the TYPE column is:

- Equal to 'PACKAGE' to display the source code for the package specification
- Equal to 'PACKAGE BODY' to display the source code for the package body

You can also view the package specification and body in SQL Developer using the package name in the Packages node.

Note: You cannot display the source code for Oracle PL/SQL built-in packages, or PL/SQL whose source code has been wrapped by using a WRAP utility or obfuscation. Obfuscating and wrapping PL/SQL source code is covered in a later lesson. Clicking the Execute Statement (F9) icon (instead of the Run Script icon) in the SQL Worksheet toolbar, sometimes displays a better formatted output in the Results tab as shown in the slide examples.

Guidelines for Writing Packages

- Develop packages for general use.
- Define the package specification before the body.
- The package specification should contain only those constructs that you want to be public.
- Place items in the declaration part of the package body when you must maintain them throughout a session or across transactions.
- The fine-grain dependency management reduces the need to recompile referencing subprograms when a package specification changes.
- The package specification should contain as few constructs as possible.

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Guidelines for Writing Packages

Keep your packages as general as possible, so that they can be reused in future applications. Also, avoid writing packages that duplicate features provided by the Oracle server.

Package specifications reflect the design of your application, so define them before defining the package bodies. The package specification should contain only those constructs that must be visible to the users of the package. Thus, other developers cannot misuse the package by basing code on irrelevant details.

Place items in the declaration part of the package body when you must maintain them throughout a session or across transactions. For example, declare a variable called `NUMBER_EMPLOYED` as a private variable if each call to a procedure that uses the variable needs to be maintained. When declared as a global variable in the package specification, the value of that global variable is initialized in a session the first time a construct from the package is invoked.

Before Oracle Database 11g, changes to the package body did not require recompilation of dependent constructs, whereas changes to the package specification required the recompilation of every stored subprogram that references the package. Oracle Database 11g reduces this dependency. Dependencies are now tracked at the level of element within unit. Fine-Grain Dependency Management is covered in a later lesson.

Quiz

The package specification is the interface to your applications. It declares the public types, variables, constants, exceptions, cursors, and subprograms available for use. The package specification may also include PRAGMAs, which are directives to the compiler.

1. True
2. False

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Answer: 1

Summary

In this lesson, you should have learned how to:

- Describe packages and list their components
- Create a package to group related variables, cursors, constants, exceptions, procedures, and functions
- Designate a package construct as either public or private
- Invoke a package construct
- Describe the use of a bodiless package

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Summary

You group related procedures and functions in a package. Packages improve organization, management, security, and performance.

A package consists of a package specification and a package body. You can change a package body without affecting its package specification.

Packages enable you to hide source code from users. When you invoke a package for the first time, the entire package is loaded into memory. This reduces the disk access for subsequent calls.

Practice 4 Overview: Creating and Using Packages

This practice covers the following topics:

- Creating packages
- Invoking package program units

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Practice 4: Overview

In this practice, you create package specifications and package bodies. You then invoke the constructs in the packages by using sample data.

Note: If you are using SQL Developer, your compile time errors are displayed in the Message Log tab. If you are using SQL*Plus to create your stored code, use `SHOW ERRORS` to view compile errors.

Practice 4

1. Create a package specification and body called `JOB_PKG`, containing a copy of your `ADD_JOB`, `UPD_JOB`, and `DEL_JOB` procedures as well as your `GET_JOB` function.

Note: Use the code from your previously saved procedures and functions when creating the package. You can copy the code in a procedure or function, and then paste the code into the appropriate section of the package.

- a. Create the package specification including the procedures and function headings as public constructs.
- b. Create the package body with the implementations for each of the subprograms.
- c. Delete the following stand-alone procedures and function you just packaged using the Procedures and Functions nodes in the Object Navigation tree:
 - i. The `ADD_JOB`, `UPD_JOB`, and `DEL_JOB` procedures
 - ii. The `GET_JOB` function
- d. Invoke your `ADD_JOB` package procedure by passing the values `IT_SYSAN` and `SYSTEMS ANALYST` as parameters.
- e. Query the `JOBS` table to see the result.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_SYSAN	Systems Analyst		
1 rows selected			

2. Create and invoke a package that contains private and public constructs.
 - a. Create a package specification and a package body called `EMP_PKG` that contains the following procedures and function that you created earlier:
 - `ADD_EMPLOYEE` procedure as a *public* construct
 - `GET_EMPLOYEE` procedure as a *public* construct
 - `VALID_DEPTID` function as a *private* construct
 - b. Invoke the `EMP_PKG.ADD_EMPLOYEE` procedure, using department ID 15 for the employee Jane Harris with the email ID `JAHARRIS`. Because department ID 15 does not exist, you should get an error message as specified in the exception handler of your procedure.
 - c. Invoke the `ADD_EMPLOYEE` package procedure by using department ID 80 for employee David Smith with the email ID `DASMITH`.
 - d. Query the `EMPLOYEES` table to verify that the new employee was added.

5

Working with Packages

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Objectives

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

- Overload package procedures and functions
- Use forward declarations
- Create an initialization block in a package body
- Manage persistent package data states for the life of a session
- Use PL/SQL tables and records in packages

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Lesson Aim

This lesson introduces the more advanced features of PL/SQL, including overloading, forward referencing, one-time-only procedures, and the persistency of variables, constants, exceptions, and cursors. It also explains the effect of packaging functions that are used in SQL statements.

Lesson Agenda

- Overloading package subprograms, using forward declarations, and creating an initialization block in a package body
- Managing persistent package data states for the life of a session and using PL/SQL tables and records in packages

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Overloading Subprograms in PL/SQL

- Enables you to create two or more subprograms with the same name
- Requires that the subprogram's formal parameters differ in number, order, or data type family
- Enables you to build flexible ways for invoking subprograms with different data
- Provides a way to extend functionality without loss of existing code; that is, adding new parameters to existing subprograms
- Provides a way to overload local subprograms, package subprograms, and type methods, but not stand-alone subprograms

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Overloading Subprograms

The overloading feature in PL/SQL enables you to develop two or more packaged subprograms with the same name. Overloading is useful when you want a subprogram to accept similar sets of parameters that have different data types. For example, the `TO_CHAR` function has more than one way to be called, enabling you to convert a number or a date to a character string.

PL/SQL allows overloading of package subprogram names and object type methods.

The key rule is that you can use the same name for different subprograms as long as their formal parameters differ in *number*, *order*, or *data type* family.

Consider using overloading when:

- Processing rules for two or more subprograms are similar, but the type or number of parameters used varies
- Providing alternative ways for finding different data with varying search criteria. For example, you may want to find employees by their employee ID and also provide a way to find employees by their last name. The logic is intrinsically the same, but the parameters or search criteria differ.
- Extending functionality when you do not want to replace existing code

Note: Stand-alone subprograms cannot be overloaded. Writing local subprograms in object type methods is not discussed in this course.

Overloading Subprograms (continued)

Restrictions

You cannot overload:

- Two subprograms if their formal parameters differ only in data type and the different data types are in the same family (NUMBER and DECIMAL belong to the same family.)
- Two subprograms if their formal parameters differ only in subtype and the different subtypes are based on types in the same family (VARCHAR and STRING are PL/SQL subtypes of VARCHAR2.)
- Two functions that differ only in return type, even if the types are in different families

You get a run-time error when you overload subprograms with the preceding features.

Note: The preceding restrictions apply if the names of the parameters are also the same.

If you use different names for the parameters, you can invoke the subprograms by using named notation for the parameters.

Resolving Calls

The compiler tries to find a declaration that matches the call. It searches first in the current scope and then, if necessary, in successive enclosing scopes. The compiler stops searching if it finds one or more subprogram declarations in which the name matches the name of the called subprogram. For similarly named subprograms at the same level of scope, the compiler needs an exact match in number, order, and data type between the actual and formal parameters.

Overloading Procedures Example: Creating the Package Specification

```
CREATE OR REPLACE PACKAGE dept_pkg IS
  PROCEDURE add_department
    (p_deptno departments.department_id%TYPE,
     p_name departments.department_name%TYPE := 'unknown',
     p_loc departments.location_id%TYPE := 1700);

  PROCEDURE add_department
    (p_name departments.department_name%TYPE := 'unknown',
     p_loc departments.location_id%TYPE := 1700);
END dept_pkg;
/
```

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Overloading: Example

The slide shows the dept_pkg package specification with an overloaded procedure called add_department. The first declaration takes three parameters that are used to provide data for a new department record inserted into the department table. The second declaration takes only two parameters because this version internally generates the department ID through an Oracle sequence.

It is better to specify data types using the %TYPE attribute for variables that are used to populate columns in database tables, as shown in the slide example; however, you can also specify the data types as follows:

```
CREATE OR REPLACE PACKAGE dept_pkg IS
  PROCEDURE add_department(p_deptno NUMBER,
    p_name VARCHAR2 := 'unknown', p_loc NUMBER := 1700);
  PROCEDURE add_department(
    p_name VARCHAR2 := 'unknown', p_loc NUMBER := 1700);
END dept_pkg;
/
```

Overloading Procedures Example: Creating the Package Body

```
CREATE OR REPLACE PACKAGE BODY dept_pkg IS
PROCEDURE add_department -- First procedure's declaration
(p_deptno departments.department_id%TYPE,
 p_name    departments.department_name%TYPE := 'unknown',
 p_loc     departments.location_id%TYPE := 1700) IS
BEGIN
    INSERT INTO departments (department_id,
                             department_name, location_id)
    VALUES (p_deptno, p_name, p_loc);
END add_department;

PROCEDURE add_department -- Second procedure's declaration
(p_name    departments.department_name%TYPE := 'unknown',
 p_loc     departments.location_id%TYPE := 1700) IS
BEGIN
    INSERT INTO departments (department_id,
                             department_name, location_id)
    VALUES (departments_seq.NEXTVAL, p_name, p_loc);
END add_department;
END dept_pkg; /
```

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Overloading: Example (continued)

If you call `add_department` with an explicitly provided department ID, then PL/SQL uses the first version of the procedure. Consider the following example:

```
EXECUTE dept_pkg.add_department(980, 'Education', 2500)
SELECT * FROM departments
WHERE department_id = 980;
```

DEPARTMENT_ID	DEPARTMENT_NAME	MANAGER_ID	LOCATION_ID
980	Education		2500
1 rows selected			

If you call `add_department` with no department ID, PL/SQL uses the second version:

```
EXECUTE dept_pkg.add_department ('Training', 2400)
SELECT * FROM departments
WHERE department_name = 'Training';
```

DEPARTMENT_ID	DEPARTMENT_NAME	MANAGER_ID	LOCATION_ID
280	Training		2400
1 rows selected			

Overloading and the STANDARD Package

- A package named `STANDARD` defines the PL/SQL environment and built-in functions.
- Most built-in functions are overloaded. An example is the `TO_CHAR` function:

```
FUNCTION TO_CHAR (p1 DATE) RETURN VARCHAR2;
FUNCTION TO_CHAR (p2 NUMBER) RETURN VARCHAR2;
FUNCTION TO_CHAR (p1 DATE, P2 VARCHAR2) RETURN VARCHAR2;
FUNCTION TO_CHAR (p1 NUMBER, P2 VARCHAR2) RETURN
    VARCHAR2;
. . .
```

- A PL/SQL subprogram with the same name as a built-in subprogram overrides the standard declaration in the local context, unless qualified by the package name.

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Overloading and the STANDARD Package

A package named `STANDARD` defines the PL/SQL environment and globally declares types, exceptions, and subprograms that are available automatically to PL/SQL programs. Most of the built-in functions that are found in the `STANDARD` package are overloaded. For example, the `TO_CHAR` function has four different declarations, as shown in the slide. The `TO_CHAR` function can take either the `DATE` or the `NUMBER` data type and convert it to the character data type. The format to which the date or number has to be converted can also be specified in the function call.

If you re-declare a built-in subprogram in another PL/SQL program, then your local declaration overrides the standard or built-in subprogram. To be able to access the built-in subprogram, you must qualify it with its package name. For example, if you re-declare the `TO_CHAR` function to access the built-in function, you refer to it as `STANDARD.TO_CHAR`.

If you re-declare a built-in subprogram as a stand-alone subprogram, then, to access your subprogram, you must qualify it with your schema name: for example, `SCOTT.TO_CHAR`.

In the slide example, PL/SQL resolves a call to `TO_CHAR` by matching the number and data types of the formal and actual parameters.

Illegal Procedure Reference

- Block-structured languages such as PL/SQL must declare identifiers before referencing them.
- Example of a referencing problem:

```
CREATE OR REPLACE PACKAGE BODY forward_pkg IS
  PROCEDURE award_bonus(. . .) IS
  BEGIN
    calc_rating(. . .);    --illegal reference
  END;

  PROCEDURE calc_rating(. . .) IS
  BEGIN
    ...
  END;
END forward_pkg;
/
```

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Using Forward Declarations

In general, PL/SQL is like other block-structured languages and does not allow forward references. You must declare an identifier before using it. For example, a subprogram must be declared before you can call it.

Coding standards often require that subprograms be kept in alphabetical sequence to make them easy to find. In this case, you may encounter problems, as shown in the slide example, where the `calc_rating` procedure cannot be referenced because it has not yet been declared.

You can solve the illegal reference problem by reversing the order of the two procedures. However, this easy solution does not work if the coding rules require subprograms to be declared in alphabetical order.

The solution in this case is to use forward declarations provided in PL/SQL. A forward declaration enables you to declare the heading of a subprogram, that is, the subprogram specification terminated by a semicolon.

Note: The compilation error for `calc_rating` occurs only if `calc_rating` is a private packaged procedure. If `calc_rating` is declared in the package specification, it is already declared as if it is a forward declaration, and its reference can be resolved by the compiler.

Using Forward Declarations to Solve Illegal Procedure Reference

In the package body, a forward declaration is a private subprogram specification terminated by a semicolon.

```
CREATE OR REPLACE PACKAGE BODY forward_pkg IS
  PROCEDURE calc_rating (...); -- forward declaration
  -- Subprograms defined in alphabetical order
  PROCEDURE award_bonus(...) IS
  BEGIN
    calc_rating (...);          -- reference resolved!
    . . .
  END;
  PROCEDURE calc_rating (...) IS -- implementation
  BEGIN
    . . .
  END;
END forward_pkg;
```

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Using Forward Declarations (continued)

As previously mentioned, PL/SQL enables you to create a special subprogram declaration called a forward declaration. A forward declaration may be required for private subprograms in the package body, and consists of the subprogram specification terminated by a semicolon. Forward declarations help to:

- Define subprograms in logical or alphabetical order
- Define mutually recursive subprograms. Mutually recursive programs are programs that call each other directly or indirectly.
- Group and logically organize subprograms in a package body

When creating a forward declaration:

- The formal parameters must appear in both the forward declaration and the subprogram body
- The subprogram body can appear anywhere after the forward declaration, but both must appear in the same program unit

Forward Declarations and Packages

Typically, the subprogram specifications go in the package specification, and the subprogram bodies go in the package body. The public subprogram declarations in the package specification do not require forward declarations.

Initializing Packages

The block at the end of the package body executes once and is used to initialize public and private package variables.

```
CREATE OR REPLACE PACKAGE taxes IS
  v_tax  NUMBER;
  ... -- declare all public procedures/functions
END taxes;
/
CREATE OR REPLACE PACKAGE BODY taxes IS
  ... -- declare all private variables
  ... -- define public/private procedures/functions
  BEGIN
    SELECT  rate_value INTO v_tax
    FROM    tax_rates
    WHERE   rate_name = 'TAX';
  END taxes;
/
```

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Package Initialization Block

The first time a component in a package is referenced, the entire package is loaded into memory for the user session. By default, the initial value of variables is NULL (if not explicitly initialized). To initialize package variables, you can:

- Use assignment operations in their declarations for simple initialization tasks
- Add code block to the end of a package body for more complex initialization tasks

Consider the block of code at the end of a package body as a package initialization block that executes once, when the package is first invoked within the user session.

The example in the slide shows the `v_tax` public variable being initialized to the value in the `tax_rates` table the first time the `taxes` package is referenced.

Note: If you initialize the variable in the declaration by using an assignment operation, it is overwritten by the code in the initialization block at the end of the package body. The initialization block is terminated by the `END` keyword for the package body.

Using Package Functions in SQL

- You use package functions in SQL statements.
- To execute a SQL statement that calls a member function, the Oracle database must know the function's purity level.
- Purity level is the extent to which the function is free of side effects, which refers to accessing database tables, package variables, and so on, for reading or writing.
- It is important to control side effects because they can:
 - Prevent the proper parallelization of a query
 - Produce order-dependent and, therefore, indeterminate results
 - Require impermissible actions such as the maintenance of package state across user sessions

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Using Package Functions in SQL and Restrictions

To execute a SQL statement that calls a stored function, the Oracle Server must know the purity level of the function, or the extent to which the function is free of side effects. The term *side effect* refers to accessing database tables, package variables, and so forth for reading or writing. It is important to control side effects because they can prevent the proper parallelization of a query, produce order-dependent and therefore indeterminate results, or require impermissible actions such as the maintenance of package state across user sessions.

In general, restrictions are changes to database tables or public package variables (those declared in a package specification). Restrictions can delay the execution of a query, yield order-dependent (therefore indeterminate) results, or require that the package state variables be maintained across user sessions. Various restrictions are not allowed when a function is called from a SQL query or a DML statement.

Controlling Side Effects of PL/SQL Subprograms

To be callable from SQL statements, a stored function must obey the following purity rules to control side effects:

- When called from a `SELECT` or a parallelized DML statement, the function cannot modify any database tables.
- When called from a DML statement, the function cannot query or modify any database tables modified by that statement.
- When called from a `SELECT` or DML statement, the function cannot execute SQL transaction control, session control, or system control statements.

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Controlling Side Effects of PL/SQL Subprograms

The fewer side effects a function has, the better it can be optimized within a query, particularly when the `PARALLEL_ENABLE` or `DETERMINISTIC` hints are used.

To be callable from SQL statements, a stored function (and any subprograms that it calls) must obey the purity rules listed in the slide. The purpose of those rules is to control side effects.

If any SQL statement inside the function body violates a rule, you get an error at run time (when the statement is parsed).

To check for purity rule violations at compile time, use the `RESTRICT_REFERENCES` pragma to assert that a function does not read or write database tables or package variables.

Note

- In the slide, a DML statement refers to an `INSERT`, `UPDATE`, or `DELETE` statement.
- For information about using the `RESTRICT_REFERENCES` pragma, refer to the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)*.

Package Function in SQL: Example

```
CREATE OR REPLACE PACKAGE taxes_pkg IS
    FUNCTION tax (p_value IN NUMBER) RETURN NUMBER;
END taxes_pkg;
/
CREATE OR REPLACE PACKAGE BODY taxes_pkg IS
    FUNCTION tax (p_value IN NUMBER) RETURN NUMBER IS
        v_rate NUMBER := 0.08;
    BEGIN
        RETURN (p_value * v_rate);
    END tax;
END taxes_pkg;
/
```

```
SELECT taxes_pkg.tax(salary), salary, last_name
FROM employees;
```

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Package Function in SQL: Example

The first code example in the slide shows how to create the package specification and the body encapsulating the tax function in the `taxes_pkg` package. The second code example shows how to call the packaged tax function in the `SELECT` statement. The results are as follows:

TAXES_PKG.TAX(SALARY)	SALARY	LAST_NAME
1920	24000	King
1360	17000	Kochhar
1360	17000	De Haan
720	9000	Hunold
480	6000	Ernst
384	4800	Austin
384	4800	Pataballa
336	4200	Lorentz
960	12000	Greenberg

...

107 rows selected

Lesson Agenda

- Overloading package subprograms, using forward declarations, and creating an initialization block in a package body
- Managing persistent package data states for the life of a session and using PL/SQL tables and records in packages

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Persistent State of Packages

The collection of package variables and the values define the package state. The package state is:

- Initialized when the package is first loaded
- Persistent (by default) for the life of the session:
 - Stored in the User Global Area (UGA)
 - Unique to each session
 - Subject to change when package subprograms are called or public variables are modified
- Not persistent for the session but persistent for the life of a subprogram call when using `PRAGMA SERIALLY_REUSABLE` in the package specification

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Persistent State of Packages

The collection of public and private package variables represents the package state for the user session. That is, the package state is the set of values stored in all the package variables at a given point in time. In general, the package state exists for the life of the user session.

Package variables are initialized the first time a package is loaded into memory for a user session. The package variables are, by default, unique to each session and hold their values until the user session is terminated. In other words, the variables are stored in the User Global Area (UGA) memory allocated by the database for each user session. The package state changes when a package subprogram is invoked and its logic modifies the variable state. Public package state can be directly modified by operations appropriate to its type.

`PRAGMA` signifies that the statement is a compiler directive. `PRAGMAS` are processed at compile time, not at run time. They do not affect the meaning of a program; they simply convey information to the compiler. If you add `PRAGMA SERIALLY_REUSABLE` to the package specification, then the database stores package variables in the System Global Area (SGA) shared across user sessions. In this case, the package state is maintained for the life of a subprogram call or a single reference to a package construct. The `SERIALLY_REUSABLE` directive is useful if you want to conserve memory and if the package state does not need to persist for each user session.

Persistent State of Packages (continued)

This PRAGMA is appropriate for packages that declare large temporary work areas that are used once and not needed during subsequent database calls in the same session.

You can mark a bodiless package as serially reusable. If a package has a spec and body, you must mark both. You cannot mark only the body.

The global memory for serially reusable packages is pooled in the System Global Area (SGA), not allocated to individual users in the User Global Area (UGA). That way, the package work area can be reused. When the call to the server ends, the memory is returned to the pool. Each time the package is reused, its public variables are initialized to their default values or to NULL.

Note: Serially reusable packages cannot be accessed from database triggers or other PL/SQL subprograms that are called from SQL statements. If you try, the Oracle server generates an error.

Persistent State of Package Variables: Example

Time	Events	State for Scott		State for Jones	
		v_std_commission	MAX (comm_pc)	v_std_commission	MAX (comm_pc)
		[variable]	[column]	[variable]	[Column]
9:00	Scott> EXECUTE comm_pkg.reset_comm(0.25)	0.10 0.25	0.4	-	0.4
9:30	Jones> INSERT INTO employees(last_name, commission_pct) VALUES('Madonna', 0.8);	0.25	0.4		0.8
9:35	Jones> EXECUTE comm_pkg.reset_comm (0.5)	0.25	0.4	0.1 0.5	0.8
10:00	Scott> EXECUTE comm_pkg.reset_comm(0.6) Err -20210 'Bad Commission'	0.25	0.4	0.5	0.8
11:00	Jones> ROLLBACK;	0.25	0.4	0.5	0.4
11:01	EXIT ...	0.25	0.4	-	0.4
12:00	EXEC comm_pkg.reset_comm(0.2)	0.25	0.4	0.2	0.4

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Persistent State of Package Variables: Example

The slide sequence is based on two different users, Scott and Jones, executing comm_pkg (covered in the lesson titled “Creating Packages”), in which the reset_comm procedure invokes the validate function to check the new commission. The example shows how the persistent state of the v_std_comm package variable is maintained in each user session.

At 9:00: Scott calls reset_comm with a new commission value of 0.25, the package state for v_std_comm is initialized to 0.10 and then set to 0.25, which is validated because it is less than the database maximum value of 0.4.

At 9:30: Jones inserts a new row into the EMPLOYEES table with a new maximum v_commission_pct value of 0.8. This is not committed, so it is visible to Jones only. Scott’s state is unaffected.

At 9:35: Jones calls reset_comm with a new commission value of 0.5. The state for Jones’s v_std_comm is first initialized to 0.10 and then set to the new value 0.5 that is valid for his session with the database maximum value of 0.8.

At 10:00: Scott calls with reset_comm with a new commission value of 0.6, which is greater than the maximum database commission visible to his session, that is, 0.4. (Jones did not commit the 0.8 value.)

Between 11:00 and 12:00: Jones rolls back the transaction and exits the session. Jones logs in at 11:45 and successfully executes the procedure, setting his state to 0.2.

Persistent State of a Package Cursor: Example

```
CREATE OR REPLACE PACKAGE curs_pkg IS -- Package spec
  PROCEDURE open;
  FUNCTION next(p_n NUMBER := 1) RETURN BOOLEAN;
  PROCEDURE close;
END curs_pkg;

CREATE OR REPLACE PACKAGE BODY curs_pkg IS
-- Package body
  CURSOR cur_c IS
    SELECT employee_id FROM employees;
  PROCEDURE open IS
  BEGIN
    IF NOT cur_c%ISOPEN THEN
      OPEN cur_c;
    END IF;
  END open;
  . . . -- code continued on next slide
```

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Persistent State of a Package Cursor: Example

The example in the slide shows the CURS_PKG package specification and body. The body declaration is continued in the next slide.

To use this package, perform the following steps to process the rows:

1. Call the open procedure to open the cursor.

Persistent State of a Package Cursor: Example

```
. . .  
FUNCTION next(p_n NUMBER := 1) RETURN BOOLEAN IS  
    v_emp_id employees.employee_id%TYPE;  
BEGIN  
    FOR count IN 1 .. p_n LOOP  
        FETCH cur_c INTO v_emp_id;  
        EXIT WHEN cur_c%NOTFOUND;  
        DBMS_OUTPUT.PUT_LINE('Id: ' || (v_emp_id));  
    END LOOP;  
    RETURN cur_c%FOUND;  
END next;  
PROCEDURE close IS  
BEGIN  
    IF cur_c%ISOPEN THEN  
        CLOSE cur_c;  
    END IF;  
END close;  
END curs_pkg;
```

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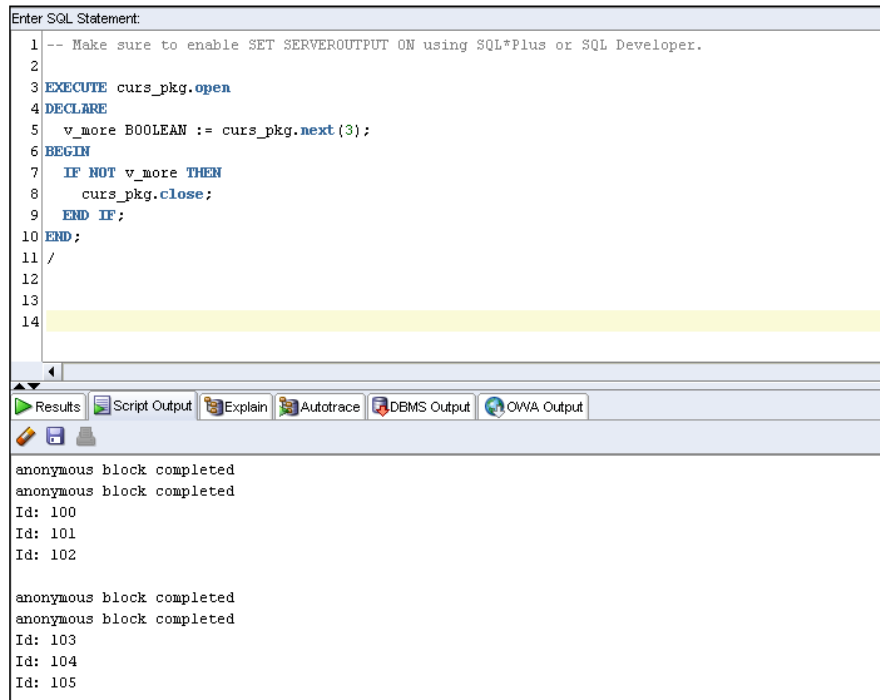
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Persistent State of a Package Cursor: Example (continued)

2. Call the `next` procedure to fetch one or a specified number of rows. If you request more rows than actually exist, the procedure successfully handles termination. It returns `TRUE` if more rows need to be processed; otherwise it returns `FALSE`.
3. Call the `close` procedure to close the cursor, before or at the end of processing the rows.

Note: The cursor declaration is private to the package. Therefore, the cursor state can be influenced by invoking the package procedure and functions listed in the slide.

Executing the CURS_PKG Package



```
Enter SQL Statement:
1 -- Make sure to enable SET SERVEROUTPUT ON using SQL*Plus or SQL Developer.
2
3 EXECUTE curs_pkg.open
4 DECLARE
5   v_more BOOLEAN := curs_pkg.next(3);
6 BEGIN
7   IF NOT v_more THEN
8     curs_pkg.close;
9   END IF;
10 END;
11 /
12
13
14
```

Results | Script Output | Explain | Autotrace | DBMS Output | OWA Output

anonymous block completed
anonymous block completed
Id: 100
Id: 101
Id: 102

anonymous block completed
anonymous block completed
Id: 103
Id: 104
Id: 105

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Executing CURS_PKG

Recall that the state of a package variable or cursor persists across transactions within a session. However, the state does not persist across different sessions for the same user. The database tables hold data that persists across sessions and users. The call to `curs_pkg.open` opens the cursor, which remains open until the session is terminated, or the cursor is explicitly closed. The anonymous block executes the `next` function in the Declaration section, initializing the `BOOLEAN` variable `b_more` to `TRUE`, as there are more than three rows in the `EMPLOYEES` table. The block checks for the end of the result set and closes the cursor, if appropriate. When the block executes, it displays the first three rows:

```
Id :100
Id :101
Id :102
```

If you click the Run Script (F5) icon again, the next three rows are displayed:

```
Id :103
Id :104
Id :105
```

To close the cursor, you can issue the following command to close the cursor in the package, or exit the session:

```
EXECUTE curs_pkg.close
```

Using PL/SQL Tables of Records in Packages

```
CREATE OR REPLACE PACKAGE emp_pkg IS
  TYPE emp_table_type IS TABLE OF employees%ROWTYPE
    INDEX BY BINARY_INTEGER;
  PROCEDURE get_employees(p_emps OUT emp_table_type);
END emp_pkg;
```

```
CREATE OR REPLACE PACKAGE BODY emp_pkg IS
  PROCEDURE get_employees(p_emps OUT emp_table_type) IS
    v_i BINARY_INTEGER := 0;
  BEGIN
    FOR emp_record IN (SELECT * FROM employees)
    LOOP
      emps(v_i) := emp_record;
      v_i := v_i + 1;
    END LOOP;
  END get_employees;
END emp_pkg;
```

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Using Tables of Records of Procedures or Functions in Packages

The emp_pkg package contains a get_employees procedure that reads rows from the EMPLOYEES table and returns the rows using the OUT parameter, which is a PL/SQL table of records. The key points include the following:

- employee_table_type is declared as a public type.
- employee_table_type is used for a formal output parameter in the procedure, and the employees variable in the calling block (shown below).

In SQL Developer, you can invoke the get_employees procedure in an anonymous PL/SQL block by using the v_employees variable, as shown in the following example:

```
DECLARE
  v_employees emp_pkg.emp_table_type;
BEGIN
  emp_pkg.get_employees(v_employees);
  DBMS_OUTPUT.PUT_LINE('Emp 4: ' || v_employees(4).last_name);
END;
```

This results in the following output:

```
anonymous block completed
Emp 4: Fay
```

Quiz

Overloading subprograms in PL/SQL:

1. Enables you to create two or more subprograms with the same name
2. Requires that the subprogram's formal parameters differ in number, order, or data type family
3. Enables you to build flexible ways for invoking subprograms with different data
4. Provides a way to extend functionality without loss of existing code; that is, adding new parameters to existing subprograms

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Answer: 1, 2, 3, 4

The overloading feature in PL/SQL enables you to develop two or more packaged subprograms with the same name. Overloading is useful when you want a subprogram to accept similar sets of parameters that have different data types. For example, the `TO_CHAR` function has more than one way to be called, enabling you to convert a number or a date to a character string.

PL/SQL allows overloading of package subprogram names and object type methods.

The key rule is that you can use the same name for different subprograms as long as their formal parameters differ in *number*, *order*, or *data type* family.

Consider using overloading when:

- Processing rules for two or more subprograms are similar, but the type or number of parameters used varies
- Providing alternative ways for finding different data with varying search criteria. For example, you may want to find employees by their employee ID and also provide a way to find employees by their last name. The logic is intrinsically the same, but the parameters or search criteria differ.
- Extending functionality when you do not want to replace existing code

Summary

In this lesson, you should have learned how to:

- Create and call overloaded subprograms
- Use forward declarations for subprograms
- Write package initialization blocks
- Maintain persistent package state

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Summary

Overloading is a feature that enables you to define different subprograms with the same name. It is logical to give two subprograms the same name when the processing in both the subprograms is the same but the parameters passed to them vary.

PL/SQL permits a special subprogram declaration called a forward declaration. A forward declaration enables you to define subprograms in logical or alphabetical order, define mutually recursive subprograms, and group subprograms in a package.

A package initialization block is executed only when the package is first invoked within the other user session. You can use this feature to initialize variables only once per session.

You can keep track of the state of a package variable or cursor, which persists throughout the user session, from the time the user first references the variable or cursor to the time the user disconnects.

Using the PL/SQL wrapper, you can obscure the source code stored in the database to protect your intellectual property.

Practice 5: Overview

This practice covers the following topics:

- Using overloaded subprograms
- Creating a package initialization block
- Using a forward declaration

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Practice 5: Overview

In this practice, you modify an existing package to contain overloaded subprograms and you use forward declarations. You also create a package initialization block within a package body to populate a PL/SQL table.

Practice 5

1. Modify the code for the EMP_PKG package that you created in Practice 4 step 2, and overload the ADD_EMPLOYEE procedure.
 - a. In the package specification, add a new procedure called ADD_EMPLOYEE that accepts the following three parameters:
 - i. First name
 - ii. Last name
 - iii. Department ID
 - b. Click Run Script to create the package. Compile the package.
 - c. Implement the new ADD_EMPLOYEE procedure in the package body as follows:
 - i. Format the email address in uppercase characters, using the first letter of the first name concatenated with the first seven letters of the last name.
 - ii. The procedure should call the existing ADD_EMPLOYEE procedure to perform the actual INSERT operation using its parameters and formatted email to supply the values.
 - iii. Click Run Script to create the package. Compile the package.
 - d. Invoke the new ADD_EMPLOYEE procedure using the name Samuel Joplin to be added to department 30.
 - e. Confirm that the new employee was added to the EMPLOYEES table.
2. In the EMP_PKG package, create two overloaded functions called GET_EMPLOYEE:
 - a. In the package specification, add the following functions:
 - i. The GET_EMPLOYEE function that accepts the parameter called p_emp_id based on the employees.employee_id%TYPE type. This function should return an EMPLOYEES%ROWTYPE.
 - ii. The GET_EMPLOYEE function that accepts the parameter called p_family_name of type employees.last_name%TYPE. This function should return an EMPLOYEES%ROWTYPE.
 - b. Click the Run Script (F5) icon to re-create the package. Compile the package.
 - c. In the package body:
 - i. Implement the first GET_EMPLOYEE function to query an employee using the employee's ID.
 - ii. Implement the second GET_EMPLOYEE function to use the equality operator on the value supplied in the p_family_name parameter.

Practice 5 (continued)

- d. Click Run Script to re-create the package. Compile the package.
 - e. Add a utility procedure `PRINT_EMPLOYEE` to the `EMP_PKG` package as follows:
 - i. The procedure accepts an `EMPLOYEES%ROWTYPE` as a parameter.
 - ii. The procedure displays the following for an employee on one line, using the `DBMS_OUTPUT` package:
 - `department_id`
 - `employee_id`
 - `first_name`
 - `last_name`
 - `job_id`
 - `salary`
 - f. Click Run Script to re-create the package. Compile the package.
 - g. Use an anonymous block to invoke the `EMP_PKG.GET_EMPLOYEE` function with an employee ID of 100 and family name of 'Joplin'. Use the `PRINT_EMPLOYEE` procedure to display the results for each row returned.
3. Because the company does not frequently change its departmental data, you can improve the performance of your `EMP_PKG` by adding a public procedure, `INIT_DEPARTMENTS`, to populate a private PL/SQL table of valid department IDs. Modify the `VALID_DEPTID` function to use the private PL/SQL table contents to validate department ID values.

Note: The `sol_05_03.sql` solution file script contains the code for steps a, b, and c.

- a. In the package specification, create a procedure called `INIT_DEPARTMENTS` with no parameters by adding the following to the package specification section before the `PRINT_EMPLOYEES` specification:


```
PROCEDURE init_departments;
```
- b. In the package body, implement the `INIT_DEPARTMENTS` procedure to store all department IDs in a private PL/SQL index-by table named `valid_departments` containing `BOOLEAN` values.
 - i. Declare the `valid_departments` variable and its type definition `boolean_tab_type` before all procedures in the body. Enter the following at the beginning of the package body:


```
TYPE boolean_tab_type IS TABLE OF BOOLEAN
INDEX BY BINARY_INTEGER;
valid_departments boolean_tab_type;
```

Practice 5 (continued)

- ii. Use the `department_id` column value as the index to create the entry in the index-by table to indicate its presence, and assign the entry a value of `TRUE`. Enter the `INIT_DEPARTMENTS` procedure declaration at the end of the package body (right after the `print_employees` procedure) as follows:

```
PROCEDURE init_departments IS
BEGIN
    FOR rec IN (SELECT department_id FROM departments)
    LOOP
        valid_departments(rec.department_id) := TRUE;
    END LOOP;
END;
```

- c. In the body, create an initialization block that calls the `INIT_DEPARTMENTS` procedure to initialize the table as follows:

```
BEGIN
    init_departments;
END;
```

- d. Click Run Script to create the package. Compile the package.

4. Change the `VALID_DEPTID` validation processing function to use the private PL/SQL table of department IDs.
 - a. Modify the `VALID_DEPTID` function to perform its validation by using the PL/SQL table of department ID values. Click Run Script to create the package. Compile the package.
 - b. Test your code by calling `ADD_EMPLOYEE` using the name James Bond in department 15. What happens?
 - c. Insert a new department. Specify 15 for the department ID and Security for the department name. Commit and verify the changes.
 - d. Test your code again, by calling `ADD_EMPLOYEE` using the name James Bond in department 15. What happens?
 - e. Execute the `EMP_PKG.INIT_DEPARTMENTS` procedure to update the internal PL/SQL table with the latest departmental data.
 - f. Test your code by calling `ADD_EMPLOYEE` using the employee name James Bond, who works in department 15. What happens?
 - g. Delete employee James Bond and department 15 from their respective tables, commit the changes, and refresh the department data by invoking the `EMP_PKG.INIT_DEPARTMENTS` procedure.

Practice 5 (continued)

5. Reorganize the subprograms in the package specification and the body so that they are in alphabetical sequence.
 - a. Edit the package specification and reorganize subprograms alphabetically. Click Run Script to re-create the package specification. Compile the package specification. What happens?
 - b. Edit the package body and reorganize all subprograms alphabetically. Click Run Script to re-create the package specification. Recompile the package specification. What happens?
 - c. Correct the compilation error using a forward declaration in the body for the appropriate subprogram reference. Click Run Script to re-create the package, and then recompile the package. What happens?

6

Using Oracle-Supplied Packages in Application Development

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Objectives

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

- Describe how the DBMS_OUTPUT package works
- Use UTL_FILE to direct output to operating system files
- Describe the main features of UTL_MAIL

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Lesson Aim

In this lesson, you learn how to use some of the Oracle-supplied packages and their capabilities.

Lesson Agenda

- Identifying the benefits of using the Oracle-supplied packages and listing some of those packages
- Using the following Oracle-supplied packages:
 - DBMS_OUTPUT
 - UTL_FILE
 - UTL_MAIL

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Using Oracle-Supplied Packages

- The 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.

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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`. The `DBMS_OUTPUT` package is the one that you will be most familiar with during this course. You should already be familiar with this package if you attended the *Oracle Database 11g: PL/SQL Fundamentals* course.

Examples of Some Oracle-Supplied Packages

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

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

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List of Some 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 *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)*. This lesson covers the first three packages in the slide.

The following is a brief description about all the listed packages:

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

Lesson Agenda

- Identifying the benefits of using the Oracle-supplied packages and listing some of those packages
- Using the following Oracle-supplied packages:
 - DBMS_OUTPUT
 - UTL_FILE
 - UTL_MAIL

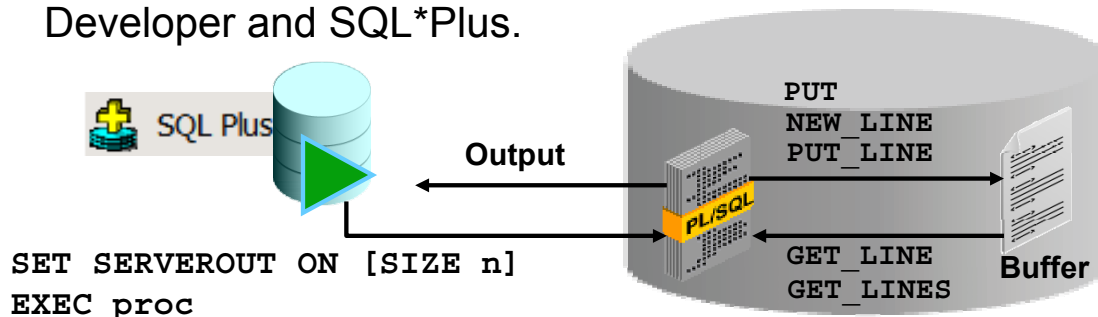
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How the DBMS_OUTPUT Package Works

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.
- Messages are not sent until the sending subprogram or trigger completes.
- Use SET SERVEROUTPUT ON to display messages in SQL Developer and SQL*Plus.



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How the DBMS_OUTPUT Package Works

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

- PUT appends text from the procedure to the current line of the line output buffer.
- NEW_LINE places an end-of-line marker in the output buffer.
- PUT_LINE combines the action of PUT and NEW_LINE (to trim leading spaces).
- GET_LINE retrieves the current line from the buffer into a procedure variable.
- GET_LINES retrieves an array of lines into a procedure-array variable.
- ENABLE/DISABLE enables and disables calls to 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 the number of characters. The minimum is 2,000 and the maximum is unlimited. The default is 20,000.
- An integer parameter between 2,000 and 1,000,000 in the ENABLE procedure

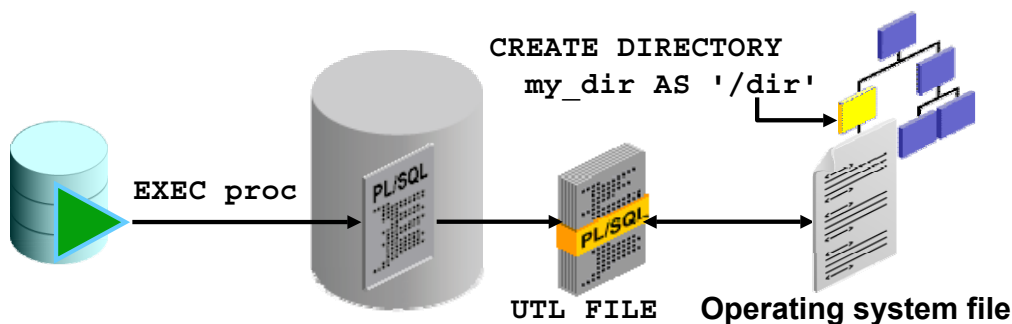
You can output results to the window for debugging purposes. You can trace a code execution path for a function or procedure. You can send messages between subprograms and triggers.

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

Using the UTL_FILE Package to Interact with Operating System Files

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

- Provides a restricted version of operating system stream file I/O for text files
- Can access files in operating system directories defined by a CREATE DIRECTORY statement



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Interacting with Operating System Files

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 my_dir TO public.
```

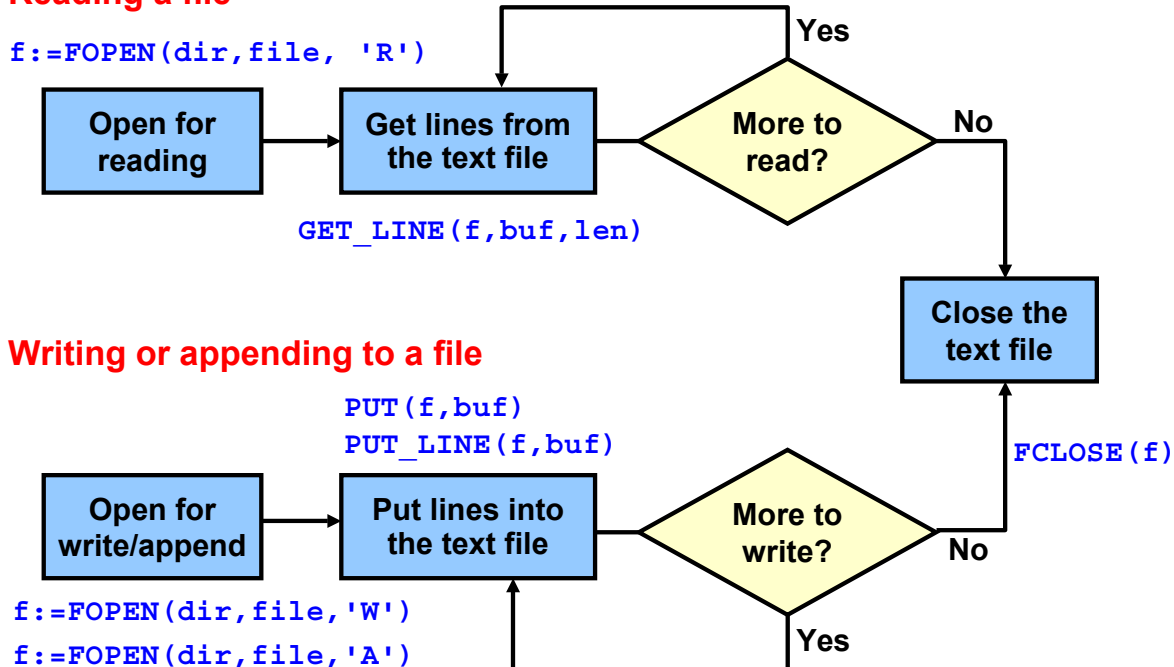
- The paths specified in the utl_file_dir database initialization parameter

Oracle recommends that you use the CREATE DIRECTORY feature instead of UTL_FILE_DIR for directory access verification. Directory objects offer more flexibility and granular control to the UTL_FILE application administrator, can be maintained dynamically (that is, without shutting down the database), and are consistent with other Oracle tools. The CREATE DIRECTORY privilege is granted only to SYS and SYSTEM by default.

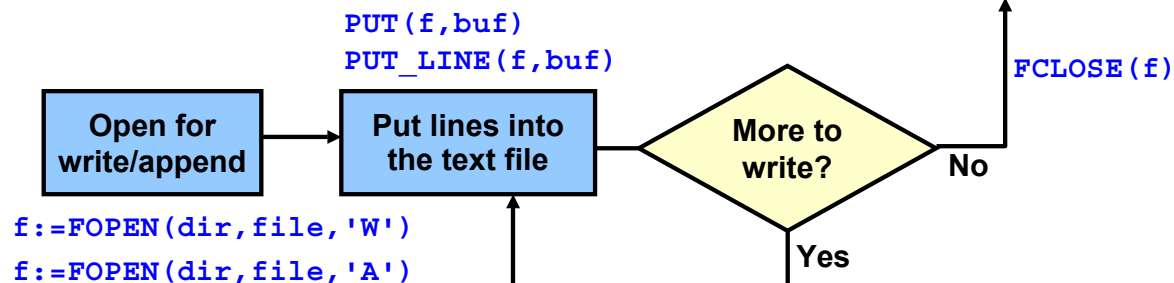
The operating system directories specified by using either of these techniques should be accessible to and on the same machine as the database server processes. The path (directory) names may be case-sensitive for some operating systems.

File Processing Using the UTL_FILE Package: Overview

Reading a file



Writing or appending to a file



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File Processing Using the UTL_FILE Package

You can use the procedures and functions in the UTL_FILE package to open files with the FOPEN function. You can then either read from or write or append to the file until processing is done. After completing processing the file, close the file by using the FCLOSE procedure. The following are the subprograms:

- The FOPEN function opens a file in a specified directory for input/output (I/O) and returns a file handle used in subsequent I/O operations.
- The IS_OPEN function returns a Boolean value whenever a file handle refers to an open file. Use IS_OPEN to check whether the file is already open before opening the file.
- The GET_LINE procedure reads a line of text from the file into an output buffer parameter. (The maximum input record size is 1,023 bytes unless you specify a larger size in the overloaded version of FOPEN.)
- The PUT and PUT_LINE procedures write text to the opened file.
- The PUTF procedure provides formatted output with two format specifiers: %s to substitute a value into the output string and \n for a new line character.
- The NEW_LINE procedure terminates a line in an output file.
- The FFLUSH procedure writes all data buffered in memory to a file.
- The FCLOSE procedure closes an opened file.
- The FCLOSE_ALL procedure closes all opened file handles for the session.

Using the Available Declared Exceptions in the UTL_FILE Package

Exception Name	Description
INVALID_PATH	File location invalid
INVALID_MODE	The open_mode parameter in FOPEN is invalid
INVALID_FILEHANDLE	File handle invalid
INVALID_OPERATION	File could not be opened or operated on as requested
READ_ERROR	Operating system error occurred during the read operation
WRITE_ERROR	Operating system error occurred during the write operation
INTERNAL_ERROR	Unspecified PL/SQL error

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Exceptions in the UTL_FILE Package

The UTL_FILE package declares fifteen exceptions that indicate an error condition in the operating system file processing. You may have to handle one of these exceptions when using UTL_FILE subprograms.

A subset of the exceptions are displayed in the slide. For additional information about the remaining exceptions, refer to the *Oracle Database PL/SQL Packages and Types Reference 11g Release 1* guide.

Note: These exceptions must always be prefixed with the package name. UTL_FILE procedures can also raise predefined PL/SQL exceptions such as NO_DATA_FOUND or VALUE_ERROR.

The NO_DATA_FOUND exception is raised when reading past the end of a file by using UTL_FILE.GET_LINE or UTL_FILE.GET_LINES.

FOPEN and IS_OPEN Functions: Example

- This FOPEN function opens a file for input or output.

```
FUNCTION FOPEN (p_location IN VARCHAR2,  
               p_filename  IN VARCHAR2,  
               p_open_mode IN VARCHAR2)  
RETURN UTL_FILE.FILE_TYPE;
```

- The IS_OPEN function determines whether a file handle refers to an open file.

```
FUNCTION IS_OPEN (p_file IN FILE_TYPE)  
RETURN BOOLEAN;
```

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FOPEN and IS_OPEN Function Parameters: Example

The parameters include the following:

- p_location parameter: Specifies the name of a directory alias defined by a CREATE DIRECTORY statement, or an operating system-specific path specified by using the utl_file_dir database parameter
- p_filename parameter: Specifies the name of the file, including the extension, without any path information
- open_mode string: Specifies how the file is to be opened. Values are:
 - 'R' for reading text (use GET_LINE)
 - 'W' for writing text (PUT, PUT_LINE, NEW_LINE, PUTF, FFLUSH)
 - 'A' for appending text (PUT, PUT_LINE, NEW_LINE, PUTF, FFLUSH)

The return value from FOPEN is a file handle whose type is UTL_FILE.FILE_TYPE. The handle must be used on subsequent calls to routines that operate on the opened file.

The IS_OPEN function parameter is the file handle. The IS_OPEN function tests a file handle to see whether it identifies an opened file. It returns a Boolean value of TRUE if the file has been opened; otherwise it returns a value of FALSE indicating that the file has not been opened. The slide example shows how to combine the use of the two subprograms. For the full syntax, refer to the *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)* guide.

FOPEN and IS_OPEN Function Parameters: Example (continued)

```

CREATE OR REPLACE PROCEDURE read_file(p_dir VARCHAR2,
p_filename VARCHAR2) IS
  f_file UTL_FILE.FILE_TYPE;
  v_buffer VARCHAR2(200);
  v_lines PLS_INTEGER := 0;
BEGIN
  DBMS_OUTPUT.PUT_LINE(' Start ');
  IF NOT UTL_FILE.IS_OPEN(f_file) THEN
    DBMS_OUTPUT.PUT_LINE(' Open ');
    f_file := UTL_FILE.FOPEN (p_dir, p_filename, 'R');
    DBMS_OUTPUT.PUT_LINE(' Opened ');
  BEGIN
    LOOP
      UTL_FILE.GET_LINE(f_file, v_buffer);
      v_lines := v_lines + 1;
      DBMS_OUTPUT.PUT_LINE(TO_CHAR(v_lines, '099')||'
      '||buffer);
    END LOOP;
  EXCEPTION
    WHEN NO_DATA_FOUND THEN
      DBMS_OUTPUT.PUT_LINE(' ** End of File **');
  END; -- ends Begin
  DBMS_OUTPUT.PUT_LINE(v_lines||' lines read from file');
  UTL_FILE.FCLOSE(f_file);
END IF;
END read_file;
/
SHOW ERRORS
EXECUTE read_file('UTL_FILE', 'instructor.txt')

```

The partial output of the above code is as follows:

```

PROCEDURE read_file(dir Compiled.
No Errors.
line 27: SQLPLUS Command Skipped: set serveroutput on
anonymous block completed
Start
Open
Opened
001 SALARY REPORT: GENERATED ON
002                               08-MAR-01
003
004 DEPARTMENT: 10
005  EMPLOYEE: Whalen earns: 4400

```

...

```

120 DEPARTMENT: 110
121  EMPLOYEE: Higgins earns: 12000
122  EMPLOYEE: Gietz earns: 8300
123  EMPLOYEE: Grant earns: 7000
124 *** END OF REPORT ***
** End of File **
124 lines read from file

```

Using UTL_FILE: Example

```
CREATE OR REPLACE PROCEDURE sal_status(  
  p_dir IN VARCHAR2, p_filename IN VARCHAR2) IS  
  f_file UTL_FILE.FILE_TYPE;  
  CURSOR cur_emp IS  
    SELECT last_name, salary, department_id  
    FROM employees ORDER BY department_id;  
  v_newdeptno employees.department_id%TYPE;  
  v_olddeptno employees.department_id%TYPE := 0;  
BEGIN  
  f_file:= UTL_FILE.FOPEN (p_dir, p_filename, 'W');  
  UTL_FILE.PUT_LINE(f_file,  
    'REPORT: GENERATED ON ' || SYSDATE);  
  UTL_FILE.NEW_LINE (f_file);  
  . . .
```

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Using UTL_FILE: Example

In the slide example, the `sal_status` procedure creates a report of employees for each department, along with their salaries. The data is written to a text file by using the `UTL_FILE` package. In the code example, the file variable is declared as `UTL_FILE.FILE_TYPE`, a package type that is a record with a field called `ID` of the `BINARY_INTEGER` data type. For example:

```
TYPE file_type IS RECORD (id BINARY_INTEGER);
```

The field of `FILE_TYPE` record is private to the `UTL_FILE` package and should never be referenced or changed. The `sal_status` procedure accepts two parameters:

- The `p_dir` parameter for the name of the directory in which to write the text file
- The `p_filename` parameter to specify the name of the file

For example, to call the procedure, use the following:

```
EXECUTE sal_status('UTL_FILE', 'salreport.txt')
```

Note: The directory location used (`UTL_FILE`) must be in uppercase characters if it is a directory alias created by a `CREATE DIRECTORY` statement. When reading a file in a loop, the loop should exit when it detects the `NO_DATA_FOUND` exception. The `UTL_FILE` output is sent synchronously. A `DBMS_OUTPUT` procedure does not produce an output until the procedure is completed.

Using UTL_FILE: Example

```
...
FOR emp_rec IN cur_emp LOOP
  IF emp_rec.department_id <> v_olddeptno THEN
    UTL_FILE.PUT_LINE (f_file,
      'DEPARTMENT: ' || emp_rec.department_id);
    UTL_FILE.NEW_LINE (f_file);
  END IF;
  UTL_FILE.PUT_LINE (f_file,
    '  EMPLOYEE: ' || emp_rec.last_name ||
    '  earns: ' || emp_rec.salary);
  v_olddeptno := emp_rec.department_id;
  UTL_FILE.NEW_LINE (f_file);
END LOOP;
UTL_FILE.PUT_LINE(f_file, '*** END OF REPORT ***');
UTL_FILE.FCLOSE (f_file);
EXCEPTION
  WHEN UTL_FILE.INVALID_FILEHANDLE THEN
    RAISE_APPLICATION_ERROR(-20001, 'Invalid File.');
```

```
  WHEN UTL_FILE.WRITE_ERROR THEN
    RAISE_APPLICATION_ERROR (-20002, 'Unable to write to file');
END sal_status;/
```

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Using UTL_FILE: Example (continued)

The following is a sample of the salreport.txt output file:

```
REPORT: GENERATED ON 27-JUN-07

DEPARTMENT: 10

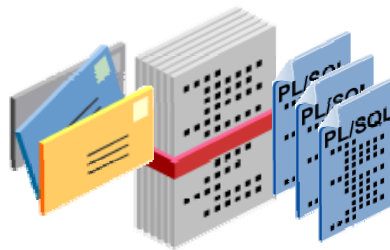
  EMPLOYEE: Whalen earns: 4400
DEPARTMENT: 20

  EMPLOYEE: Hartstein earns: 13000
  EMPLOYEE: Fay earns: 6000
DEPARTMENT: 30

  EMPLOYEE: Raphaely earns: 11000
  EMPLOYEE: Colmenares earns: 2500
  EMPLOYEE: Khoo earns: 3100
  EMPLOYEE: Baida earns: 2900
  EMPLOYEE: Tobias earns: 2800
  EMPLOYEE: Himuro earns: 2600
DEPARTMENT: 40
```

What Is the UTL_MAIL Package?

- A utility for managing email
- Requires the setting of the SMTP_OUT_SERVER database initialization parameter
- Provides the following procedures:
 - SEND for messages without attachments
 - SEND_ATTACH_RAW for messages with binary attachments
 - SEND_ATTACH_VARCHAR2 for messages with text attachments



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Using UTL_MAIL

The UTL_MAIL package is a utility for managing email that includes commonly used email features such as attachments, CC, BCC, and return receipt.

The UTL_MAIL package is not installed by default because of the SMTP_OUT_SERVER configuration requirement and the security exposure this involves. When installing UTL_MAIL, you should take steps to prevent the port defined by SMTP_OUT_SERVER being swamped by data transmissions. To install UTL_MAIL, log in as a DBA user in SQL*Plus and execute the following scripts:

```
@$ORACLE_HOME/rdbms/admin/utlmail.sql  
@$ORACLE_HOME/rdbms/admin/prvtmail.plb
```

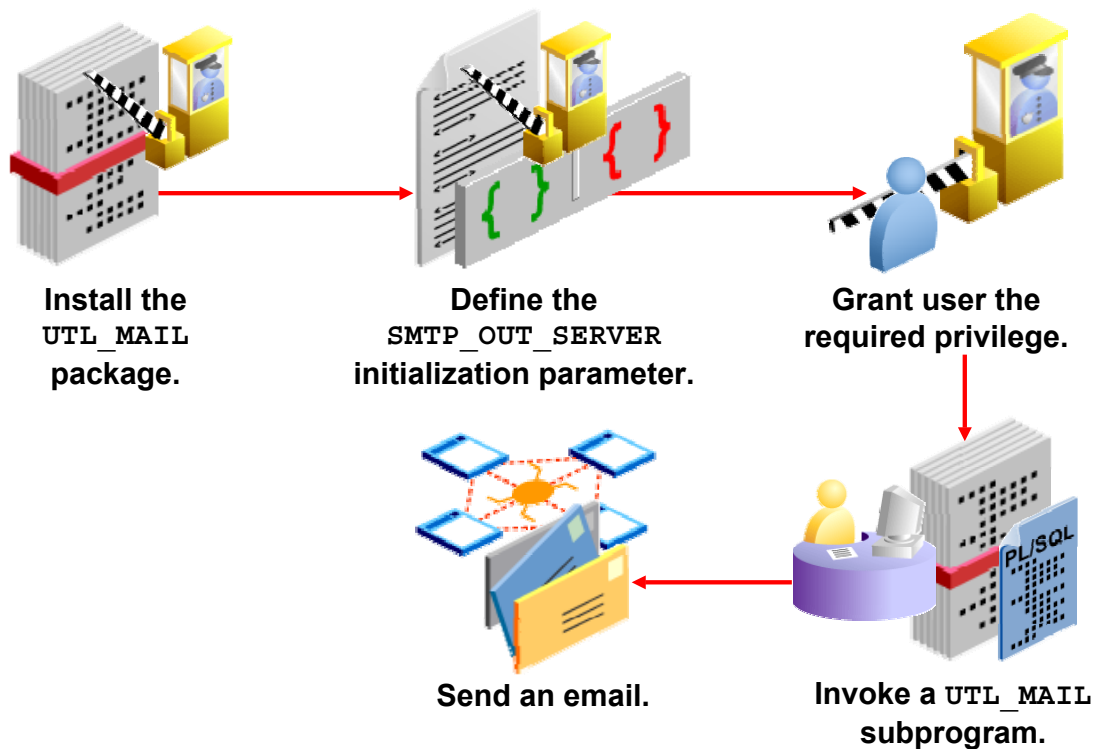
You should define the SMTP_OUT_SERVER parameter in the init.ora file database initialization file:

```
SMTP_OUT_SERVER=mystmpserver.mydomain.com
```

The SMTP_OUT_SERVER parameter specifies the SMTP host and port to which UTL_MAIL delivers outbound email. Multiple servers can be specified, separated by commas. If the first server in the list is unavailable, then UTL_MAIL tries the second server, and so on. If SMTP_OUT_SERVER is not defined, then this invokes a default setting derived from DB_DOMAIN, which is a database initialization parameter specifying the logical location of the database within the network structure. For example:

```
db_domain=mydomain.com
```

Setting Up and Using the UTL_MAIL: Overview



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Setting Up and Using the UTL_MAIL: Overview

In Oracle Database 11g, the UTL_MAIL package is now an invoker's rights package and the invoking user will need the connect privilege granted in the access control list assigned to the remote network host to which he wants to connect. The Security Administrator performs this task.

Note

- For information about how a user with SYSDBA capabilities grants a user the required fine-grained privileges required for using this package, refer to the "Managing Fine-Grained Access to External Network Services" topic in the *Oracle Database Security Guide 11g Release 1 (11.1)* guide and the *Oracle Database 11g Advanced PL/SQL* instructor-led training course.
- Due to firewall restrictions, the UTL_MAIL examples in this lesson cannot be demonstrated; therefore, no labs were designed to use UTL_MAIL.

Summary of UTL_MAIL Subprograms

Subprogram	Description
SEND procedure	Packages an email message, locates SMTP information, and delivers the message to the SMTP server for forwarding to the recipients
SEND_ATTACH_RAW Procedure	Represents the SEND procedure overloaded for RAW attachments
SEND_ATTACH_VARCHAR2 Procedure	Represents the SEND procedure overloaded for VARCHAR2 attachments

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Installing and Using UTL_MAIL

- As SYSDBA, using SQL Developer or SQL*Plus:
 - Install the UTL_MAIL package

```
@?/rdbms/admin/utlmail.sql
@?/rdbms/admin/prvtmail.plb
```

- Set the SMTP_OUT_SERVER

```
ALTER SYSTEM SET SMTP_OUT_SERVER='smtp.server.com'
SCOPE=SPFILE
```

- As a developer, invoke a UTL_MAIL procedure:

```
BEGIN
  UTL_MAIL.SEND('otn@oracle.com','user@oracle.com',
    message => 'For latest downloads visit OTN',
    subject => 'OTN Newsletter');
END;
```

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Installing and Using UTL_MAIL

The slide shows how to configure the SMTP_OUT_SERVER parameter to the name of the SMTP host in your network, and how to install the UTL_MAIL package that is not installed by default. Changing the SMTP_OUT_SERVER parameter requires restarting the database instance. These tasks are performed by a user with SYSDBA capabilities.

The last example in the slide shows the simplest way to send a text message by using the UTL_MAIL.SEND procedure with at least a subject and a message. The first two required parameters are the following :

- The sender email address (in this case, otn@oracle.com)
- The recipients email address (for example, user@oracle.com). The value can be a comma-separated list of addresses.

The UTL_MAIL.SEND procedure provides several other parameters, such as cc, bcc, and priority with default values, if not specified. In the example, the message parameter specifies the text for the email, and the subject parameter contains the text for the subject line. To send an HTML message with HTML tags, add the mime_type parameter (for example, mime_type=>'text/html').

Note: For details about all the UTL_MAIL procedure parameters, refer to the *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)* guide.

The SEND Procedure Syntax

Packages an email message into the appropriate format, locates SMTP information, and delivers the message to the SMTP server for forwarding to the recipients.

```
UTL_MAIL.SEND (  
  sender      IN      VARCHAR2 CHARACTER SET ANY_CS,  
  recipients  IN      VARCHAR2 CHARACTER SET ANY_CS,  
  cc          IN      VARCHAR2 CHARACTER SET ANY_CS  
                DEFAULT NULL,  
  bcc         IN      VARCHAR2 CHARACTER SET ANY_CS  
                DEFAULT NULL,  
  subject     IN      VARCHAR2 CHARACTER SET ANY_CS  
                DEFAULT NULL,  
  message     IN      VARCHAR2 CHARACTER SET ANY_CS,  
  mime_type   IN      VARCHAR2  
                DEFAULT 'text/plain; charset=us-ascii',  
  priority    IN      PLS_INTEGER DEFAULT NULL);
```

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The SEND Procedure

This procedure packages an email message into the appropriate format, locates SMTP information, and delivers the message to the SMTP server for forwarding to the recipients. It hides the SMTP API and exposes a one-line email facility for ease of use.

The SEND Procedure Parameters

- **sender:** The email address of the sender.
- **recipients:** The email addresses of the recipient(s), separated by commas.
- **cc:** The email addresses of the CC recipient(s), separated by commas. The default is NULL.
- **bcc:** The email addresses of the BCC recipient(s), separated by commas. The default is NULL.
- **subject:** A string to be included as email subject string. The default is NULL.
- **message:** A text message body.
- **mime_type:** The mime type of the message, default is 'text/plain; charset=us-ascii'.
- **priority:** The message priority. The default is NULL.

The SEND_ATTACH_RAW Procedure

This procedure is the SEND procedure overloaded for RAW attachments.

```
UTL_MAIL.SEND_ATTACH_RAW (
  sender          IN      VARCHAR2 CHARACTER SET ANY_CS,
  recipients      IN      VARCHAR2 CHARACTER SET ANY_CS,
  cc              IN      VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,
  bcc             IN      VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,
  subject         IN      VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,
  message         IN      VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,
  mime_type       IN      VARCHAR2 DEFAULT CHARACTER SET ANY_CS
                    DEFAULT 'text/plain; charset=us-ascii',
  priority        IN      PLS_INTEGER DEFAULT 3,
  attachment      IN      RAW,
  att_inline      IN      BOOLEAN DEFAULT TRUE,
  att_mime_type   IN      VARCHAR2 CHARACTER SET ANY_CS
                    DEFAULT 'text/plain; charset=us-ascii',
  att_filename    IN      VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL);
```

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The SEND_ATTACH_RAW Procedure Parameters

- **sender:** The email address of the sender.
- **recipients:** The email addresses of the recipient(s), separated by commas.
- **cc:** The email addresses of the CC recipient(s), separated by commas. The default is NULL.
- **bcc:** The email addresses of the BCC recipient(s), separated by commas. The default is NULL.
- **subject:** A string to be included as email subject string. The default is NULL.
- **message:** A text message body.
- **mime_type:** The mime type of the message, default is 'text/plain; charset=us-ascii'.
- **priority:** The message priority. The default is NULL.
- **attachment:** A RAW attachment.
- **att_inline:** Specifies whether the attachment is viewable inline with the message body. The default is TRUE.
- **att_mime_type:** The mime type of the attachment, default is 'application/octet'.
- **att_filename:** The string specifying a file name containing the attachment. The default is NULL.

Sending Email with a Binary Attachment: Example

```
CREATE OR REPLACE PROCEDURE send_mail_logo IS
BEGIN
    UTL_MAIL.SEND_ATTACH_RAW(
        sender => 'me@oracle.com',
        recipients => 'you@somewhere.net',
        message =>
            '<HTML><BODY>See attachment</BODY></HTML>',
        subject => 'Oracle Logo',
        mime_type => 'text/html'
        attachment => get_image('oracle.gif'),
        att_inline => true,
        att_mime_type => 'image/gif',
        att_filename => 'oralogo.gif');
END;
/
```

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Sending Email with a Binary Attachment: Example

The slide shows a procedure calling the `UTL_MAIL.SEND_ATTACH_RAW` procedure to send a textual or an HTML message with a binary attachment. In addition to the `sender`, `recipients`, `message`, `subject`, and `mime_type` parameters that provide values for the main part of the email message, the `SEND_ATTACH_RAW` procedure has the following highlighted parameters:

- The `attachment` parameter (required) accepts a RAW data type, with a maximum size of 32,767 binary characters.
- The `att_inline` parameter (optional) is Boolean (default TRUE) to indicate that the attachment is viewable with the message body.
- The `att_mime_type` parameter (optional) specifies the format of the attachment. If not provided, it is set to `application/octet`.
- The `att_filename` parameter (optional) assigns any file name to the attachment. It is NULL by default, in which case, the name is assigned a default name.

The `get_image` function in the example uses a BFILE to read the image data. Using a BFILE requires creating a logical directory name in the database by using the `CREATE DIRECTORY` statement. The code for `get_image` is shown on the following page.

Sending Email with a Binary Attachment: Example (continued)

The `get_image` function uses the `DBMS_LOB` package to read a binary file from the operating system:

```
CREATE OR REPLACE FUNCTION get_image(  
    filename VARCHAR2, dir VARCHAR2 := 'TEMP')  
RETURN RAW IS  
    image RAW(32767);  
    file BFILE := BFILENAME(dir, filename);  
BEGIN  
    DBMS_LOB.FILEOPEN(file, DBMS_LOB.FILE_READONLY);  
    image := DBMS_LOB.SUBSTR(file);  
    DBMS_LOB.CLOSE(file);  
    RETURN image;  
END;  
/
```

To create the directory called `TEMP`, execute the following statement in SQL Developer or SQL*Plus:

```
CREATE DIRECTORY temp AS 'd:\temp';
```

Note

- You need the `CREATE ANY DIRECTORY` system privilege to execute this statement.
- Due to firewall restrictions at the Oracle Education Center, the examples on this page and the previous page are not available for demonstration.

The SEND_ATTACH_VARCHAR2 Procedure

This procedure is the SEND procedure overloaded for VARCHAR2 attachments.

```
UTL_MAIL.SEND_ATTACH_VARCHAR2 (  
  sender          IN    VARCHAR2 CHARACTER SET ANY_CS,  
  recipients      IN    VARCHAR2 CHARACTER SET ANY_CS,  
  cc              IN    VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,  
  bcc             IN    VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,  
  subject         IN    VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,  
  message        IN    VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL,  
  mime_type       IN    VARCHAR2 CHARACTER SET ANY_CS  
                  DEFAULT 'text/plain; charset=us-ascii',  
  priority        IN    PLS_INTEGER DEFAULT 3,  
  attachment      IN    VARCHAR2 CHARACTER SET ANY_CS,  
  att_inline      IN    BOOLEAN DEFAULT TRUE,  
  att_mime_type   IN    VARCHAR2 CHARACTER SET ANY_CS  
                  DEFAULT 'text/plain; charset=us-ascii',  
  att_filename    IN    VARCHAR2 CHARACTER SET ANY_CS DEFAULT NULL);
```

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The SEND_ATTACH_VARCHAR2 Procedure Parameters

- **sender:** The email address of the sender.
- **recipients:** The email addresses of the recipient(s), separated by commas.
- **cc:** The email addresses of the CC recipient(s), separated by commas. The default is NULL.
- **bcc:** The email addresses of the BCC recipient(s), separated by commas. The default is NULL.
- **subject:** A string to be included as email subject string. The default is NULL.
- **Message:** A text message body.
- **mime_type:** The mime type of the message, default is 'text/plain; charset=us-ascii'.
- **priority:** The message priority. The default is NULL.
- **attachment:** A text attachment.
- **att_inline:** Specifies whether the attachment is inline. The default is TRUE.
- **att_mime_type:** The mime type of the attachment, default is 'text/plain; charset=us-ascii'.
- **att_filename:** The string specifying a file name containing the attachment. The default is NULL.

Sending Email with a Text Attachment: Example

```
CREATE OR REPLACE PROCEDURE send_mail_file IS
BEGIN
  UTL_MAIL.SEND_ATTACH_VARCHAR2(
    sender => 'me@oracle.com',
    recipients => 'you@somewhere.net',
    message =>
      '<HTML><BODY>See attachment</BODY></HTML>',
    subject => 'Oracle Notes',
    mime_type => 'text/html'
    attachment => get_file('notes.txt'),
    att_inline => false,
    att_mime_type => 'text/plain',
    att_filename => 'notes.txt');
END;
/
```

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Sending Email with a Text Attachment

The slide shows a procedure that calls the `UTL_MAIL.SEND_ATTACH_VARCHAR2` procedure to send a textual or an HTML message with a text attachment. In addition to the `sender`, `recipients`, `message`, `subject`, and `mime_type` parameters that provide values for the main part of the e-mail message, the `SEND_ATTACH_VARCHAR2` procedure has the following parameters highlighted:

- The `attachment` parameter (required) accepts a `VARCHAR2` data type with a maximum size of 32,767 binary characters.
- The `att_inline` parameter (optional) is a Boolean (default `TRUE`) to indicate that the attachment is viewable with the message body.
- The `att_mime_type` parameter (optional) specifies the format of the attachment. If not provided, it is set to `application/octet`.
- The `att_filename` parameter (optional) assigns any file name to the attachment. It is `NULL` by default, in which case, the name is assigned a default name.

The `get_file` function in the example uses a `BFILE` to read a text file from the operating system directories for the value of the `attachment` parameter, which could simply be populated from a `VARCHAR2` variable. The code for `get_file` is shown on the following page.

Sending Email with a Text Attachment (continued)

The `get_file` function uses the `DBMS_LOB` package to read a binary file from the operating system, and uses the `UTL_RAW` package to convert the RAW binary data into readable text data in the form of a `VARCHAR2` data type:

```
CREATE OR REPLACE FUNCTION get_file(
    filename VARCHAR2, dir VARCHAR2 := 'TEMP')
RETURN VARCHAR2 IS
    contents VARCHAR2(32767);
    file BFILE := BFILENAME(dir, filename);
BEGIN
    DBMS_LOB.FILEOPEN(file, DBMS_LOB.FILE_READONLY);
    contents := UTL_RAW.CAST_TO_VARCHAR2(
        DBMS_LOB.SUBSTR(file));
    DBMS_LOB.CLOSE(file);
    RETURN contents;
END;
/
```

Note: Alternatively, you could read the contents of the text file into a `VARCHAR2` variable by using the `UTL_FILE` package functionality.

The preceding example requires the `TEMP` directory to be created similar to the following statement in SQL*Plus:

```
CREATE DIRECTORY temp AS 'd:\temp';
```

Note

- The `CREATE ANY DIRECTORY` system privilege is required to execute this statement.
- Due to firewall restrictions at the Oracle Education Center, the examples on this page and the previous page are not available for demonstration.

Quiz

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.

1. True
2. False

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Answer: 1

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.
- The paths specified in the `utl_file_dir` database initialization parameter

Summary

In this lesson, you should have learned:

- How the DBMS_OUTPUT package works
- How to use UTL_FILE to direct output to operating system files
- About the main features of UTL_MAIL

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Summary

This lesson covers a small subset of packages provided with the Oracle database. You have extensively used DBMS_OUTPUT for debugging purposes and displaying procedurally generated information on the screen in SQL*Plus.

In this lesson, you should have learned how to use the power features provided by the database to create text files in the operating system by using UTL_FILE. You also learned how to send email with or without binary or text attachments by using the UTL_MAIL package.

Note: For more information about all PL/SQL packages and types, refer to *PL/SQL Packages and Types Reference*.

Practice 6: Overview

This practice covers how to use `UTL_FILE` to generate a text report.

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Practice 6: Overview

In this practice, you use `UTL_FILE` to generate a text file report of employees in each department.

Practice 6

1. By using the UTL_FILE package, create a procedure called EMPLOYEE_REPORT that generates an employee report in a file in the operating system. The report should generate a list of employees who have exceeded the average salary of their departments.
 - a. Your program should accept two parameters. The first parameter is the output directory. The second parameter is the name of the text file that is written.
Note: Use the directory location value UTL_FILE. Add an exception-handling section to handle errors that may be encountered when using the UTL_FILE package.
 - b. Click Run Script (F5) to create the package. Compile the package.
2. Invoke the program, using the second parameter with a name such as sal_rptxx.txt, where xx represents your user number (for example, 61, 62, ..., 80 and so on).
3. Transfer the generated output text file from the host to your client machine as follows:
 - a. Double-click the Putty-SFTP icon on your desktop. The Putty SFTP command window is displayed.
 - b. At the psftp> prompt, enter the following command substituting host_name with the host name provided to you by your instructor:

```
open host_name
```

For example, if you are connecting to a host named vx0114.us.oracle.com, enter the following at the prompt:

```
open vx0114.us.oracle.com
```
 - c. Enter oracle as both your username and password.
Note: After you enter the username, if you get a message about the host key not being cached in, enter **y** at the following prompt: “Store key in cache? <y/n> _”.
 - c. To display the list of folders and files in the current directory, issue the ls command.
 - d. Change your directory to UTL_FILE by using the cd UTL_FILE command.
 - e. List the contents of the current directory using the ls command.
 - f. Transfer the output file from the host to your client machine by issuing the following command (for a user account ora61, for example):

```
get sal_rpt61.txt
```
 - h. Exit **Putty-SFTP** by entering bye at the command line or by clicking the close control on title bar.
 - i. Open the transferred file, such as sal_rpt61.txt, which you can find in the D:\Other\putty folder using WordPad.
Note: The data displays the employee’s last name, department ID, and salary. Ask your instructor to provide instructions on how to obtain the report file from the server using the Putty PSFTP utility.

Using Dynamic SQL

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Objectives

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

- Describe the execution flow of SQL statements
- Build and execute SQL statements dynamically using Native Dynamic SQL (NDS)
- Identify situations when you must use the DBMS_SQL package instead of NDS to build and execute SQL statements dynamically

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Lesson Aim

In this lesson, you learn to construct and execute SQL statements dynamically—that is, at run time using the Native Dynamic SQL statements in PL/SQL.

Lesson Agenda

- Using Native Dynamic SQL (NDS)
- Using the `DBMS_SQL` package

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Execution Flow of SQL

- All SQL statements go through some or all of the following stages:
 - Parse
 - Bind
 - Execute
 - Fetch
- Some stages may not be relevant for all statements:
 - The fetch phase is applicable to queries.
 - For embedded SQL statements such as `SELECT`, `DML`, `MERGE`, `COMMIT`, `SAVEPOINT`, and `ROLLBACK`, the parse and bind phases are done at compile time.
 - For dynamic SQL statements, all phases are performed at run time.

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Steps to Process SQL Statements

All SQL statements have to go through various stages. However, some stages may not be relevant for all statements. The following are the key stages:

- **Parse:** Every SQL statement must be parsed. Parsing the statement includes checking the statement's syntax and validating the statement, ensuring that all references to objects are correct and that the relevant privileges to those objects exist.
- **Bind:** After parsing, the Oracle server may need values from or for any bind variable in the statement. The process of obtaining these values is called binding variables. This stage may be skipped if the statement does not contain bind variables.
- **Execute:** At this point, the Oracle server has all necessary information and resources, and the statement is executed. For non-query statements, this is the last phase.
- **Fetch:** In the fetch stage, which is applicable to queries, the rows are selected and ordered (if requested by the query), and each successive fetch retrieves another row of the result, until the last row has been fetched.

Working With Dynamic SQL

Use dynamic SQL to create a SQL statement whose structure may change during run time. Dynamic SQL:

- Is constructed and stored as a character string, string variable, or string expression within the application.
- Is a SQL statement with varying column data, or different conditions with or without placeholders (bind variables).
- Enables DDL, DCL, or session-control statements to be written and executed from PL/SQL.
- Is executed with Native Dynamic SQL statements or the DBMS_SQL package.

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Dynamic SQL

The embedded SQL statements available in PL/SQL are limited to SELECT, INSERT, UPDATE, DELETE, MERGE, COMMIT, and ROLLBACK, all of which are parsed at compile time—that is, they have a fixed structure. You need to use dynamic SQL functionality if you require:

- The structure of a SQL statement to be altered at run time
- Access to data definition language (DDL) statements and other SQL functionality in PL/SQL

To perform these kinds of tasks in PL/SQL, you must construct SQL statements dynamically in character strings and execute them using either of the following:

- Native Dynamic SQL statements with EXECUTE IMMEDIATE
- The DBMS_SQL package

The process of using SQL statements that are not embedded in your source program and are constructed in strings and executed at run time is known as “dynamic SQL.” The SQL statements are created dynamically at run time and can access and use PL/SQL variables. For example, you create a procedure that uses dynamic SQL to operate on a table whose name is not known until run time, or execute a DDL statement (such as CREATE TABLE), a data control statement (such as GRANT), or a session control statement (such as ALTER SESSION).

Using Dynamic SQL

- Use dynamic SQL when the full text of the dynamic SQL statement is unknown until run time; therefore, its syntax is checked at *run time* rather than at *compile time*.
- Use dynamic SQL when one of the following items is unknown at precompile time:
 - Text of the SQL statement such as commands, clauses, and so on
 - The number and data types of host variables
 - References to database objects such as tables, columns, indexes, sequences, usernames, and views
- Use dynamic SQL to make your PL/SQL programs more general and flexible.

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Using Dynamic SQL

In PL/SQL, you need dynamic SQL to execute the following SQL statements where the full text is unknown at compile time such as:

- A SELECT statement that includes an identifier that is unknown at compile time (such as a table name)
- A WHERE clause in which the column name is unknown at compile time

Note

For additional information about dynamic SQL, see the following resources:

- *Pro*C/C++ Programmer's Guide 11g Release 1 (11.1)* documentation guide
 - *Lesson 13, Oracle Dynamic SQL*, covers the four available methods that you can use to define dynamic SQL statements. It briefly describes the capabilities and limitations of each method, and then offers guidelines for choosing the right method. Later sections in the same guide show you how to use the methods, and include example programs that you can study.
 - *Lesson 15, Oracle Dynamic SQL: Method 4*, contains very detailed information about Method 4 when defining dynamic SQL statements.
- *Oracle PL/SQL Programming* book by Steven Feuerstein and Bill Pribyl. *Lesson 16, Dynamic SQL and Dynamic PL/SQL*, contains additional information about dynamic SQL.

Native Dynamic SQL (NDS)

- Provides native support for dynamic SQL directly in the PL/SQL language.
- Provides the ability to execute SQL statements whose structure is unknown until execution time.
- If the dynamic SQL statement is a `SELECT` statement that returns multiple rows, NDS gives you the following choices:
 - Use the `EXECUTE IMMEDIATE` statement with the `BULK COLLECT INTO` clause
 - Use the `OPEN-FOR`, `FETCH`, and `CLOSE` statements
- In Oracle Database 11g, NDS supports statements larger than 32 KB by accepting a `CLOB` argument.

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Native Dynamic SQL

Native Dynamic SQL provides the ability to dynamically execute SQL statements whose structure is constructed at execution time. The following statements have been added or extended in PL/SQL to support Native Dynamic SQL:

- **EXECUTE IMMEDIATE:** Prepares a statement, executes it, returns variables, and then deallocates resources
- **OPEN-FOR:** Prepares and executes a statement using a cursor variable
- **FETCH:** Retrieves the results of an opened statement by using the cursor variable
- **CLOSE:** Closes the cursor used by the cursor variable and deallocates resources

You can use bind variables in the dynamic parameters in the `EXECUTE IMMEDIATE` and `OPEN` statements. Native Dynamic SQL includes the following capabilities:

- Define a dynamic SQL statement.
- Handle `IN`, `IN OUT`, and `OUT` bind variables that are bound by position, not by name.

Using the EXECUTE IMMEDIATE Statement

Use the EXECUTE IMMEDIATE statement for NDS or PL/SQL anonymous blocks:

```
EXECUTE IMMEDIATE dynamic_string
  [INTO {define_variable
        [, define_variable] ... | record}]
  [USING [IN|OUT|IN OUT] bind_argument
        [, [IN|OUT|IN OUT] bind_argument] ... ];
```

- INTO is used for single-row queries and specifies the variables or records into which column values are retrieved.
- USING is used to hold all bind arguments. The default parameter mode is IN.

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Using the EXECUTE IMMEDIATE Statement

The EXECUTE IMMEDIATE statement can be used to execute SQL statements or PL/SQL anonymous blocks. The syntactical elements include the following:

- *dynamic_string* is a string expression that represents a dynamic SQL statement (without terminator) or a PL/SQL block (with terminator).
- *define_variable* is a PL/SQL variable that stores the selected column value.
- *record* is a user-defined or %ROWTYPE record that stores a selected row.
- *bind_argument* is an expression whose value is passed to the dynamic SQL statement or PL/SQL block.
- The INTO clause specifies the variables or record into which column values are retrieved. It is used only for single-row queries. For each value retrieved by the query, there must be a corresponding, type-compatible variable or field in the INTO clause.
- The USING clause holds all bind arguments. The default parameter mode is IN.

You can use numeric, character, and string literals as bind arguments, but you cannot use Boolean literals (TRUE, FALSE, and NULL).

Note: Use OPEN-FOR, FETCH, and CLOSE for a multirow query. The syntax shown in the slide is not complete because support exists for bulk-processing operations (which is a topic that is not covered in this course).

Available Methods for Using NDS

Method #	SQL Statement Type	NDS SQL Statements Used
Method 1	Non-query without host variables	EXECUTE IMMEDIATE without the USING and INTO clauses
Method 2	Non-query with known number of input host variables	EXECUTE IMMEDIATE with a USING clause
Method 3	Query with known number of select-list items and input host variables	EXECUTE IMMEDIATE with the USING and INTO clauses
Method 4	Query with unknown number of select-list items or input host variables	Use the DBMS_SQL package

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Available Methods for Using NDS

The four available methods for NDS that are listed in the slide are increasingly general. That is, Method 2 encompasses Method 1, Method 3 encompasses Methods 1 and 2, and Method 4 encompasses Methods 1, 2, and 3. However, each method is most useful for handling a certain kind of SQL statement, as follows:

Method 1:

This method lets your program accept or build a dynamic SQL statement, then immediately execute it using the EXECUTE IMMEDIATE command. The SQL statement must not be a query (SELECT statement) and must not contain any placeholders for input host variables. For example, the following host strings qualify:

- DELETE FROM EMPLOYEES WHERE DEPTNO = 20
- GRANT SELECT ON EMPLOYEES TO scott

With Method 1, the SQL statement is parsed every time it is executed.

Note

- Examples of non-queries include data definition language (DDLs) statements, UPDATES, INSERTs, or DELETEs.
- The term *select-list item* includes column names and expressions such as SAL * 1.10 and MAX (SAL) .

Available Methods for Using NDS (continued)

Method 2:

This method lets your program accept or build a dynamic SQL statement, then process it using the PREPARE and EXECUTE commands. The SQL statement must not be a query. The number of placeholders for input host variables and the data types of the input host variables must be known at precompile time. For example, the following host strings fall into this category:

- `INSERT INTO EMPLOYEES (FIRST_NAME, LAST_NAME, JOB_ID) VALUES (:emp_first_name, :emp_last_name, :job_id)`
- `DELETE FROM EMPLOYEES WHERE EMPLOYEE_ID = :emp_number`

With Method 2, the SQL statement is parsed just once, but can be executed many times with different values for the host variables. SQL data definition statements such as CREATE and GRANT are executed when they are PREPARED.

Method 3:

This method lets your program accept or build a dynamic query, then process it using the PREPARE command with the DECLARE, OPEN, FETCH, and CLOSE cursor commands. The number of select-list items, the number of placeholders for input host variables, and the data types of the input host variables must be known at precompile time. For example, the following host strings qualify:

- `SELECT DEPARTMENT_ID, MIN(SALARY), MAX(SALARY)
FROM EMPLOYEES
GROUP BY DEPARTMENT_ID`
- `SELECT LAST_NAME, EMPLOYEE_ID
FROM EMPLOYEES
WHERE DEPARTMENT_ID = :dept_number`

Method 4:

This method lets your program accept or build a dynamic SQL statement, then process it using descriptors. A descriptor is an area of memory used by your program and Oracle to hold a complete description of the variables in a dynamic SQL statement. The number of select-list items, the number of placeholders for input host variables, and the data types of the input host variables can be unknown until run time. For example, the following host strings fall into this category:

- `INSERT INTO EMPLOYEES (<unknown>) VALUES (<unknown>)`
- `SELECT <unknown> FROM EMPLOYEES WHERE DEPARTMENT_ID = 20`

Method 4 is required for dynamic SQL statements that contain an unknown number of select-list items or input host variables. With this method, you use the DBMS_SQL package, which is covered later in this lesson. Situations that require using Method 4 are rare.

Note:

For additional information about the four dynamic SQL methods, see the following lessons in the *Pro*C/C++ Programmer's Guide 11g Release 1 (11.1)* documentation guide.

- *Lesson 13, Oracle Dynamic SQL*
- *Lesson 15, Oracle Dynamic SQL: Method 4*

Dynamic SQL with a DDL Statement: Examples

```
-- Create a table using dynamic SQL

CREATE OR REPLACE PROCEDURE create_table(
  p_table_name VARCHAR2, p_col_specs VARCHAR2) IS
BEGIN
  EXECUTE IMMEDIATE 'CREATE TABLE ' || p_table_name ||
    ' (' || p_col_specs || ')';
END;
/
```

```
-- Call the procedure

BEGIN
  create_table('EMPLOYEE_NAMES',
    'id NUMBER(4) PRIMARY KEY, name VARCHAR2(40)');
END;
/
```

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Dynamic SQL with a DDL Statement

The code examples show the creation of a `create_table` procedure that accepts the table name and column definitions (specifications) as parameters.

The procedure call shows the creation of a table called `EMPLOYEE_NAMES` with two columns:

- An ID column with a `NUMBER` data type used as a primary key
- A name column of up to 40 characters for the employee name

Any DDL statement can be executed by using the syntax shown in the slide, whether the statement is dynamically constructed or specified as a literal string. You can create and execute a statement that is stored in a PL/SQL string variable, as in the following example:

```
CREATE OR REPLACE PROCEDURE add_col(p_table_name VARCHAR2,
                                     p_col_spec   VARCHAR2) IS
  v_stmt VARCHAR2(100) := 'ALTER TABLE ' || p_table_name ||
    ' ADD ' || p_col_spec;
BEGIN
  EXECUTE IMMEDIATE v_stmt;
END;
/
```

To add a new column to a table, enter the following:

```
EXECUTE add_col('employee_names', 'salary number(8,2)')
```

Dynamic SQL with DML Statements

```
-- Delete rows from any table:
CREATE FUNCTION del_rows(p_table_name VARCHAR2)
RETURN NUMBER IS
BEGIN
    EXECUTE IMMEDIATE 'DELETE FROM ' || p_table_name;
    RETURN SQL%ROWCOUNT;
END;
/
BEGIN DBMS_OUTPUT.PUT_LINE(
    del_rows('EMPLOYEE_NAMES') || ' rows deleted. ');
END;
/
```

```
-- Insert a row into a table with two columns:
CREATE PROCEDURE add_row(p_table_name VARCHAR2,
    p_id NUMBER, p_name VARCHAR2) IS
BEGIN
    EXECUTE IMMEDIATE 'INSERT INTO ' || p_table_name ||
        ' VALUES (:1, :2)' USING p_id, p_name;
END;
```

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Dynamic SQL with DML Statements

The first slide code example defines a dynamic SQL statement using Method 1—that is, nonquery without host variables. The examples in the slide demonstrate the following:

- The `del_rows` function deletes rows from a specified table and returns the number of rows deleted by using the implicit SQL cursor `%ROWCOUNT` attribute. Executing the function is shown below the example for creating a function.
- The `add_row` procedure shows how to provide input values to a dynamic SQL statement with the `USING` clause. The bind variable names `:1` and `:2` are not important; however, the order of the parameter names (`p_id` and `p_name`) in the `USING` clause is associated with the bind variables by position, in the order of their respective appearance. Therefore, the PL/SQL parameter `p_id` is assigned to the `:1` placeholder, and the `p_name` parameter is assigned to the `:2` placeholder. Placeholder or bind variable names can be alphanumeric but must be preceded with a colon.

Note: The `EXECUTE IMMEDIATE` statement prepares (parses) and immediately executes the dynamic SQL statement. Dynamic SQL statements are always parsed.

Also, note that a `COMMIT` operation is not performed in either of the examples. Therefore, the operations can be undone with a `ROLLBACK` statement.

Dynamic SQL with a Single-Row Query: Example

```
CREATE FUNCTION get_emp(p_emp_id NUMBER)
RETURN employees%ROWTYPE IS
  v_stmt VARCHAR2(200);
  v_emprec employees%ROWTYPE;
BEGIN
  v_stmt := 'SELECT * FROM employees ' ||
            'WHERE employee id = :p_emp_id';
  EXECUTE IMMEDIATE v_stmt INTO v_emprec USING p_emp_id;
  RETURN v_emprec;
END;
/
DECLARE
  v_emprec employees%ROWTYPE := get_emp(100);
BEGIN
  DBMS_OUTPUT.PUT_LINE('Emp: ' || v_emprec.last_name);
END;
/
```

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Dynamic SQL with a Single-Row Query

The code example in the slide is an example of defining a dynamic SQL statement using Method 3 with a single row queried—that is, query with a known number of select-list items and input host variables.

The single-row query example demonstrates the `get_emp` function that retrieves an `EMPLOYEES` record into a variable specified in the `INTO` clause. It also shows how to provide input values for the `WHERE` clause.

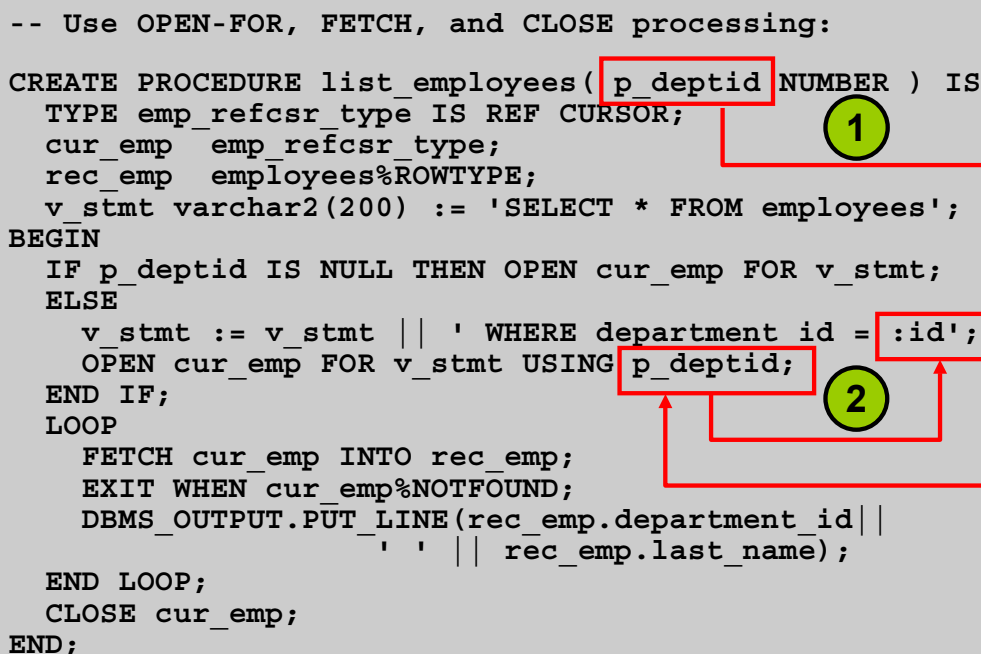
The anonymous block is used to execute the `get_emp` function and return the result into a local `EMPLOYEES` record variable.

The example could be enhanced to provide alternative `WHERE` clauses depending on input parameter values, making it more suitable for dynamic SQL processing.

Dynamic SQL with a Multirow Query: Example

```
-- Use OPEN-FOR, FETCH, and CLOSE processing:

CREATE PROCEDURE list_employees( p_deptid NUMBER ) IS
  TYPE emp_refcsr_type IS REF CURSOR;
  cur_emp emp_refcsr_type;
  rec_emp employees%ROWTYPE;
  v_stmt varchar2(200) := 'SELECT * FROM employees';
BEGIN
  IF p_deptid IS NULL THEN OPEN cur_emp FOR v_stmt;
  ELSE
    v_stmt := v_stmt || ' WHERE department id = :id';
    OPEN cur_emp FOR v_stmt USING p_deptid;
  END IF;
  LOOP
    FETCH cur_emp INTO rec_emp;
    EXIT WHEN cur_emp%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE(rec_emp.department_id ||
      ' ' || rec_emp.last_name);
  END LOOP;
  CLOSE cur_emp;
END;
```



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Dynamic SQL with a Multirow Query

The code example in the slide is an example of using Method 3 with multiple rows queried. The example shows how to execute a multirow query by performing the following programming steps:

- Declaring a REF CURSOR type
- Declaring a cursor variable based on the REF CURSOR type name that you declare
- Executing an OPEN-FOR statement that uses the cursor variable
- Using a FETCH statement referencing the cursor variable until all records are processed
- Executing the CLOSE statement by using the cursor variable

This process is the same as using static cursor definitions. However, the OPEN-FOR syntax accepts a string literal or variable specifying the SELECT statement, which can be dynamically constructed.

Note: The next page provides a brief introduction to the REF CURSOR type and cursor variables. An alternative to this is using the BULK COLLECT syntax supported by native dynamic SQL statements (a topic that is not covered in this course).

Declaring Cursor Variables

```
-- Declare two cursor types as REF CURSORS:

CREATE OR REPLACE FUNCTION process_data
RETURN employees%ROWTYPE IS
    TYPE cur_ref_type      IS REF CURSOR; -- weak ref. cursor
    TYPE cur_ref_emp_type IS REF CURSOR; -- weak ref. cursor
    . . .

-- Declare a cursor variable using the cursor type:
    v_dept_csr cur_ref_type;
    v_emp_csr  cur_ref_emp_type;

BEGIN
    OPEN v_dept_csr FOR SELECT * FROM departments;
    OPEN v_emp_csr  FOR SELECT * FROM employees;

-- Then use as normal cursors
    . . .

END;
```

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Declaring Cursor Variables

A cursor variable is a PL/SQL identifier whose type name has been declared as a REF CURSOR type. Creating a cursor variable involves two steps:

- Declaring a type name as a REF CURSOR type
- Declaring a PL/SQL variable by using the type name declared as a REF CURSOR type

The slide examples create two reference cursor types:

- The `cur_ref_type` is a generic reference cursor, known as a weak reference cursor. A weak reference cursor can be associated with any query.
- The `cur_ref_emp_type` is a weak reference cursor type since there is no RETURN type clause included.

After a cursor variable is declared by using a reference cursor type name, the cursor variable that is associated with a query is opened by using the OPEN-FOR syntax shown in the slide. The standard FETCH, cursor attributes, and CLOSE operations used with explicit cursors are also applicable with cursor variables. To compare cursor variables with explicit cursors:

- A cursor variable can be associated with more than one query at run time
- An explicit cursor is associated with one query at compilation time

Executing a PL/SQL Anonymous Block Dynamically

```
CREATE FUNCTION annual_sal(p_emp_id NUMBER)
RETURN NUMBER IS
  v_plsql varchar2(200) :=
    'DECLARE ' ||
    ' rec_emp employees%ROWTYPE; ' ||
    'BEGIN ' ||
    ' rec_emp := get_emp(:empid); ' ||
    ' :res := rec_emp.salary * 12; ' ||
    'END;';
  v_result NUMBER;
BEGIN
  EXECUTE IMMEDIATE v_plsql
    USING IN p_emp_id, OUT v_result;
  RETURN v_result;
END;
/
EXECUTE DBMS_OUTPUT.PUT_LINE(annual_sal(100))
```

The diagram illustrates the execution of the PL/SQL block. A red box highlights the dynamic SQL construction and execution. Numbered circles 1 and 2 indicate specific steps: 1 points to the 'get_emp(:empid)' call, and 2 points to the 'EXECUTE IMMEDIATE' statement.

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Dynamically Executing a PL/SQL Block

The `annual_sal` function dynamically constructs an anonymous PL/SQL block. The PL/SQL block contains bind variables for:

- The input of the employee ID using the `:empid` placeholder
- The output result computing the annual employees' salary using the placeholder called `:res`

Note: This example demonstrates how to use the OUT result syntax (in the USING clause of the EXECUTE IMMEDIATE statement) to obtain the result calculated by the PL/SQL block. The procedure output variables and function return values can be obtained in a similar way from a dynamically executed anonymous PL/SQL block.

```
FUNCTION annual_sal(emp_id Compiled.
anonymous block completed
316800
```

Using Native Dynamic SQL to Compile PL/SQL Code

Compile PL/SQL code with the ALTER statement:

- ALTER PROCEDURE name COMPILE
- ALTER FUNCTION name COMPILE
- ALTER PACKAGE name COMPILE SPECIFICATION
- ALTER PACKAGE name COMPILE BODY

```
CREATE PROCEDURE compile_plsql(p_name VARCHAR2,  
    p_plsql_type VARCHAR2, p_options VARCHAR2 := NULL) IS  
    v_stmt varchar2(200) := 'ALTER ' || p_plsql_type ||  
        ' ' || p_name || ' COMPILE';  
  
BEGIN  
    IF p_options IS NOT NULL THEN  
        v_stmt := v_stmt || ' ' || p_options;  
    END IF;  
    EXECUTE IMMEDIATE v_stmt;  
END;/
```

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Using Native Dynamic SQL to Compile PL/SQL Code

The `compile_plsql` procedure in the example can be used to compile different PL/SQL code using the ALTER DDL statement. Four basic forms of the ALTER statement are shown to compile:

- A procedure
- A function
- A package specification
- A package body

Note: If you leave out the keyword SPECIFICATION or BODY with the ALTER PACKAGE statement, then the specification and body are both compiled.

Here are examples of calling the procedure in the slide for each of the four cases, respectively:

```
EXEC compile_plsql ('list_employees', 'procedure')  
EXEC compile_plsql ('get_emp', 'function')  
EXEC compile_plsql ('mypack', 'package', 'specification')  
EXEC compile_plsql ('mypack', 'package', 'body')
```

Here is an example of compiling with debug enabled for the `get_emp` function:

```
EXEC compile_plsql ('get_emp', 'function', 'debug')
```

Lesson Agenda

- Using Native Dynamic SQL (NDS)
- Using the DBMS_SQL package

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Using the DBMS_SQL Package

- The DBMS_SQL package is used to write dynamic SQL in stored procedures and to parse DDL statements.
- You must use the DBMS_SQL package to execute a dynamic SQL statement that has an unknown number of input or output variables, also known as Method 4.
- In most cases, NDS is easier to use and performs better than DBMS_SQL except when dealing with Method 4.
- For example, you must use the DBMS_SQL package in the following situations:
 - You do not know the SELECT list at compile time
 - You do not know how many columns a SELECT statement will return, or what their data types will be

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Using the DBMS_SQL Package

Using DBMS_SQL, you can write stored procedures and anonymous PL/SQL blocks that use dynamic SQL, such as executing DDL statements in PL/SQL—for example, executing a DROP TABLE statement. The operations provided by this package are performed under the current user, not under the package owner SYS.

Method 4: Method 4 refers to situations where, in a dynamic SQL statement, the number of columns selected for a query or the number of bind variables set is not known until run time. In this case, you should use the DBMS_SQL package.

Using the DBMS_SQL Package Subprograms

Examples of the package procedures and functions:

- OPEN_CURSOR
- PARSE
- BIND_VARIABLE
- EXECUTE
- FETCH_ROWS
- CLOSE_CURSOR

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Using the DBMS_SQL Package Subprograms

The DBMS_SQL package provides the following subprograms to execute dynamic SQL:

- OPEN_CURSOR to open a new cursor and return a cursor ID number
- PARSE to parse the SQL statement. Every SQL statement must be parsed by calling the PARSE procedures. Parsing the statement checks the statement's syntax and associates it with the cursor in your program. You can parse any DML or DDL statement. DDL statements are immediately executed when parsed.
- BIND_VARIABLE to bind a given value to a bind variable identified by its name in the statement being parsed. This is not needed if the statement does not have bind variables.
- EXECUTE to execute the SQL statement and return the number of rows processed
- FETCH_ROWS to retrieve the next row for a query (use in a loop for multiple rows)
- CLOSE_CURSOR to close the specified cursor

Note: Using the DBMS_SQL package to execute DDL statements can result in a deadlock. For example, the most likely reason is that the package is being used to drop a procedure that you are still using.

Using the DBMS_SQL Package Subprograms (continued)

The PARSE Procedure Parameters

The LANGUAGE_FLAG parameter of the PARSE procedure determines how Oracle handles the SQL statement—that is, using behavior associated with a specific Oracle database version. Using NATIVE (or 1) for this parameter specifies using the normal behavior associated with the database to which the program is connected.

If the LANGUAGE_FLAG parameter is set to V6 (or 0), that specifies version 6 behavior. If the LANGUAGE_FLAG parameter is set to V7 (or 2), that specifies Oracle database version 7 behavior.

Note: For additional information, see the *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)* guide.

Using DBMS_SQL with a DML Statement: Deleting Rows

```
CREATE OR REPLACE FUNCTION delete_all_rows
(p_table_name VARCHAR2) RETURN NUMBER IS
  v_cur_id      INTEGER;
  v_rows_del    NUMBER;
BEGIN
  v_cur_id := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(v_cur_id,
    'DELETE FROM ' || p_table_name, DBMS_SQL.NATIVE);
  v_rows_del := DBMS_SQL.EXECUTE (v_cur_id);
  DBMS_SQL.CLOSE_CURSOR(v_cur_id);
  RETURN v_rows_del;
END;
/
```

```
CREATE TABLE temp_emp AS SELECT * FROM employees;
BEGIN
  DBMS_OUTPUT.PUT_LINE('Rows Deleted: ' ||
delete_all_rows('temp_emp'));
END; /
```

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Using DBMS_SQL with a DML Statement

In the slide, the table name is passed into the `delete_all_rows` function. The function uses dynamic SQL to delete rows from the specified table, and returns a count representing the number of rows that are deleted after successful execution of the statement.

To process a DML statement dynamically, perform the following steps:

1. Use `OPEN_CURSOR` to establish an area in memory to process a SQL statement.
2. Use `PARSE` to establish the validity of the SQL statement.
3. Use the `EXECUTE` function to run the SQL statement. This function returns the number of rows processed.
4. Use `CLOSE_CURSOR` to close the cursor.

The steps to execute a DDL statement are similar; but step 3 is optional because a DDL statement is immediately executed when the `PARSE` is successfully done—that is, the statement syntax and semantics are correct. If you use the `EXECUTE` function with a DDL statement, then it does not do anything and returns a value of 0 for the number of rows processed because DDL statements do not process rows.

```
CREATE TABLE succeeded.
anonymous block completed
Rows Deleted: 107

DROP TABLE temp_emp succeeded.
```

Using DBMS_SQL with a Parameterized DML Statement

```
CREATE PROCEDURE insert_row (p_table_name VARCHAR2,
  p_id VARCHAR2, p_name VARCHAR2, p_region NUMBER) IS
  v_cur_id      INTEGER;
  v_stmt        VARCHAR2(200);
  v_rows_added  NUMBER;
BEGIN
  v_stmt := 'INSERT INTO ' || p_table_name ||
    ' VALUES (:cid, :cname, :rid)';
  v_cur_id := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(v_cur_id, v_stmt, DBMS_SQL.NATIVE);
  DBMS_SQL.BIND_VARIABLE(v_cur_id, ':cid', p_id);
  DBMS_SQL.BIND_VARIABLE(v_cur_id, ':cname', p_name);
  DBMS_SQL.BIND_VARIABLE(v_cur_id, ':rid', p_region);
  rows_added := DBMS_SQL.EXECUTE(v_cur_id);
  DBMS_SQL.CLOSE_CURSOR(v_cur_id);
  DBMS_OUTPUT.PUT_LINE(v_rows_added || ' row added');
END; /
```

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Using DBMS_SQL with a Parameterized DML Statement

The example in the slide performs the DML operation to insert a row into a specified table. The example demonstrates the extra step required to associate values to bind variables that exist in the SQL statement. For example, a call to the procedure shown in the slide is:

```
EXECUTE insert_row('countries', 'LB', 'Lebanon', 4)
```

After the statement is parsed, you must call the `DBMS_SQL.BIND_VARIABLE` procedure to assign values for each bind variable that exists in the statement. The binding of values must be done before executing the code. To process a `SELECT` statement dynamically, perform the following steps after opening and before closing the cursor:

1. Execute `DBMS_SQL.DEFINE_COLUMN` for each column selected.
2. Execute `DBMS_SQL.BIND_VARIABLE` for each bind variable in the query.
3. For each row, perform the following steps:
 - a. Execute `DBMS_SQL.FETCH_ROWS` to retrieve a row and return the number of rows fetched. Stop additional processing when a zero value is returned.
 - b. Execute `DBMS_SQL.COLUMN_VALUE` to retrieve each selected column value into each PL/SQL variable for processing.

Although this coding process is not complex, it is more time consuming to write and is prone to error compared with using the Native Dynamic SQL approach.

Dynamic SQL Functional Completeness

For functional completeness, interoperability between native dynamic SQL and `DBMS_SQL` is supported in Oracle Database 11g:

- SQL statements larger than 32 KB are allowed in native dynamic SQL.
- `DBMS_SQL.PARSE()` is overloaded for CLOBs.
- A `REF CURSOR` can be converted to a `DBMS_SQL` cursor and vice versa to support interoperability.
- `DBMS_SQL` supports the full range of data types including collections and object types.

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Dynamic SQL Functional Completeness

When generating dynamic SQL, you can either use the `DBMS_SQL` supplied package when dealing with Method 4 situations, or you can use native dynamic SQL. Before Oracle Database 11g, each of these methods had functional limitations. In Oracle Database 11g, functionality is added to both methods to make them more complete.

The features for executing dynamic SQL from PL/SQL had some restrictions in Oracle Database 10g. `DBMS_SQL` was needed for Method 4 scenarios but it could not handle the full range of data types and its cursor representation was not usable by a client to the database. Native dynamic SQL was more convenient for non-Method 4 scenarios, but it did not support statements bigger than 32 KB. Oracle Database 11g removes these and other restrictions to make the support of dynamic SQL from PL/SQL functionally complete.

Quiz

The full text of the dynamic SQL statement might be unknown until run time; therefore, its syntax is checked at *run time* rather than at *compile time*.

1. True
2. False

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Answer: 1

Summary

In this lesson, you should have learned how to:

- Describe the execution flow of SQL statements
- Build and execute SQL statements dynamically using Native Dynamic SQL (NDS)
- Identify situations when you must use the `DBMS_SQL` package instead of NDS to build and execute SQL statements dynamically

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Summary

In this lesson, you discovered how to dynamically create any SQL statement and execute it using the Native Dynamic SQL statements. Dynamically executing SQL and PL/SQL code extends the capabilities of PL/SQL beyond query and transactional operations. For earlier releases of the database, you could achieve similar results with the `DBMS_SQL` package.

Practice 7 Overview: Using Native Dynamic SQL

This practice covers the following topics:

- Creating a package that uses Native Dynamic SQL to create or drop a table and to populate, modify, and delete rows from a table
- Creating a package that compiles the PL/SQL code in your schema

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Practice 7: Overview

In this practice, you write code to perform the following tasks:

- Create a package that uses Native Dynamic SQL to create or drop a table, and to populate, modify, and delete rows from the table.
- Create a package that compiles the PL/SQL code in your schema, either all the PL/SQL code or only code that has an `INVALID` status in the `USER_OBJECTS` table.

Practice 7

1. Create a package called TABLE_PKG that uses Native Dynamic SQL to create or drop a table, and to populate, modify, and delete rows from the table. The subprograms should manage optional default parameters with NULL values.

- a. Create a package specification with the following procedures:

```
PROCEDURE make(p_table_name VARCHAR2, p_col_specs
              VARCHAR2)
PROCEDURE add_row(p_table_name VARCHAR2, p_col_values
                 VARCHAR2, p_cols VARCHAR2 := NULL)
PROCEDURE upd_row(p_table_name VARCHAR2, p_set_values
                 VARCHAR2, p_conditions VARCHAR2 := NULL)
PROCEDURE del_row(p_table_name VARCHAR2,
                 p_conditions VARCHAR2 := NULL);
PROCEDURE remove(p_table_name VARCHAR2)
```

- b. Create the package body that accepts the parameters and dynamically constructs the appropriate SQL statements that are executed using Native Dynamic SQL, except for the remove procedure. This procedure should be written using the DBMS_SQL package.

- c. Execute the MAKE package procedure to create a table as follows:

```
make('my_contacts', 'id number(4), name varchar2(40)');
```

- d. Describe the MY_CONTACTS table structure.

- e. Execute the ADD_ROW package procedure to add the following rows:

```
add_row('my_contacts', '1, ''Lauran Serhal'', 'id, name');
add_row('my_contacts', '2, ''Nancy'', 'id, name');
add_row('my_contacts', '3, ''Sunitha Patel'', 'id, name');
add_row('my_contacts', '4, ''Valli Pataballa'', 'id, name');
```

- f. Query the MY_CONTACTS table contents to verify the additions.

- g. Execute the DEL_ROW package procedure to delete a contact with ID value 3.

- h. Execute the UPD_ROW procedure with the following row data:

```
upd_row('my_contacts', 'name= ''Nancy Greenberg'', 'id=2');
```

- i. Query the MY_CONTACTS table contents to verify the changes.

- j. Drop the table by using the remove procedure and describe the MY_CONTACTS table.

Practice 7 (continued)

2. Create a `COMPILE_PKG` package that compiles the PL/SQL code in your schema.
 - a. In the specification, create a package procedure called `MAKE` that accepts the name of a PL/SQL program unit to be compiled.
 - b. In the package body, include the following:
 - i. The `EXECUTE` procedure used in the `TABLE_PKG` procedure in step 1 of this practice.
 - ii. A private function named `GET_TYPE` to determine the PL/SQL object type from the data dictionary.
 - The function returns the type name (use `PACKAGE` for a package with a body) if the object exists; otherwise, it should return a `NULL`.
 - In the `WHERE` clause condition, add the following to the condition to ensure only one row is returned if the name represents a `PACKAGE`, which may also have a `PACKAGE BODY`. In this case, you can only compile the complete package, but not the specification or body as separate components:
`rownum = 1`
 - iii. Create the `MAKE` procedure using the following information:
 - The `MAKE` procedure accepts one argument, `name`, which represents the object name.
 - The `MAKE` procedure should call the `GET_TYPE` function. If the object exists, `MAKE` dynamically compiles it with the `ALTER` statement.
 - c. Use the `COMPILE_PKG.MAKE` procedure to compile the following:
 - The `EMPLOYEE_REPORT` procedure
 - The `EMP_PKG` package
 - A nonexistent object called `EMP_DATA`

8

Design Considerations for PL/SQL Code

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Objectives

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

- Create standard constants and exceptions
- Write and call local subprograms
- Control the run-time privileges of a subprogram
- Perform autonomous transactions
- Pass parameters by reference using a `NOCOPY` hint
- Use the `PARALLEL ENABLE` hint for optimization
- Use the cross-session PL/SQL function result cache
- Use the `DETERMINISTIC` clause with functions
- Use bulk binding and the `RETURNING` clause with DML

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Lesson Aim

In this lesson, you learn to use package specifications to standardize names for constant values and exceptions. You learn how to create subprograms in the `Declaration` section of any PL/SQL block for using locally in the block. The `AUTHID` compiler directive is discussed to show how you can manage run-time privileges of the PL/SQL code, and create independent transactions by using the `AUTONOMOUS TRANSACTION` directive for subprograms.

This lesson also covers some performance considerations that can be applied to PL/SQL applications, such as bulk binding operations with a single SQL statement, the `RETURNING` clause, and the `NOCOPY` and `PARALLEL ENABLE` hints.

Lesson Agenda

- Standardizing constants and exceptions, using local subprograms, controlling the run-time privileges of a subprogram, and performing autonomous transactions
- Using the `NOCOPY` and the `PARALLEL ENABLE` hints, the cross-session PL/SQL function result cache, and the `DETERMINISTIC` clause
- Using bulk binding and the `RETURNING` clause with DML

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Standardizing Constants and Exceptions

Constants and exceptions are typically implemented using a bodiless package (that is, a package specification).

- Standardizing helps to:
 - Develop programs that are consistent
 - Promote a higher degree of code reuse
 - Ease code maintenance
 - Implement company standards across entire applications
- Start with standardization of:
 - Exception names
 - Constant definitions

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Standardizing Constants and Exceptions

When several developers are writing their own exception handlers in an application, there could be inconsistencies in the handling of error situations. Unless certain standards are adhered to, the situation can become confusing because of the different approaches followed in handling the same error or because of the display of conflicting error messages that confuse users. To overcome these, you can:

- Implement company standards that use a consistent approach to error handling across the entire application
- Create predefined, generic exception handlers that produce consistency in the application
- Write and call programs that produce consistent error messages

All good programming environments promote naming and coding standards. In PL/SQL, a good place to start implementing naming and coding standards is with commonly used constants and exceptions that occur in the application domain.

The PL/SQL package specification construct is an excellent component to support standardization because all identifiers declared in the package specification are public. They are visible to the subprograms that are developed by the owner of the package and all code with EXECUTE rights to the package specification.

Standardizing Exceptions

Create a standardized error-handling package that includes all named and programmer-defined exceptions to be used in the application.

```
CREATE OR REPLACE PACKAGE error_pkg IS
    e_fk_err      EXCEPTION;
    e_seq_nbr_err EXCEPTION;
    PRAGMA EXCEPTION_INIT (e_fk_err, -2292);
    PRAGMA EXCEPTION_INIT (e_seq_nbr_err, -2277);
    ...
END error_pkg;
/
```

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Standardizing Exceptions

In the example in the slide, the `error_pkg` package is a standardized exception package. It declares a set of programmer-defined exception identifiers. Because many of the Oracle database predefined exceptions do not have identifying names, the example package shown in the slide uses the `PRAGMA EXCEPTION_INIT` directive to associate selected exception names with an Oracle database error number. This enables you to refer to any of the exceptions in a standard way in your applications, as in the following example:

```
BEGIN
    DELETE FROM departments
    WHERE department_id = deptno;
    ...
EXCEPTION
    WHEN error_pkg.e_fk_err THEN
    ...
    WHEN OTHERS THEN
    ...
END;
/
```

Standardizing Exception Handling

Consider writing a subprogram for common exception handling to:

- Display errors based on `SQLCODE` and `SQLERRM` values for exceptions
- Track run-time errors easily by using parameters in your code to identify:
 - The procedure in which the error occurred
 - The location (line number) of the error
 - `RAISE_APPLICATION_ERROR` using stack trace capabilities, with the third argument set to `TRUE`

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Standardizing Exception Handling

Standardized exception handling can be implemented either as a stand-alone subprogram or a subprogram added to the package that defines the standard exceptions. Consider creating a package with:

- Every named exception that is to be used in the application
- All unnamed, programmer-defined exceptions that are used in the application. These are error numbers `-20000` through `-20999`.
- A program to call `RAISE_APPLICATION_ERROR` based on package exceptions
- A program to display an error based on the values of `SQLCODE` and `SQLERRM`
- Additional objects, such as error log tables, and programs to access the tables

A common practice is to use parameters that identify the name of the procedure and the location in which the error has occurred. This enables you to keep track of run-time errors more easily. An alternative is to use the `RAISE_APPLICATION_ERROR` built-in procedure to keep a stack trace of exceptions that can be used to track the call sequence leading to the error. To do this, set the third optional argument to `TRUE`. For example:

```
RAISE_APPLICATION_ERROR(-20001, 'My first error', TRUE);
```

This is meaningful when more than one exception is raised in this manner.

Standardizing Constants

For programs that use local variables whose values should not change:

- Convert the variables to constants to reduce maintenance and debugging
- Create one central package specification and place all constants in it

```
CREATE OR REPLACE PACKAGE constant_pkg IS
  c_order_received CONSTANT VARCHAR(2) := 'OR';
  c_order_shipped   CONSTANT VARCHAR(2) := 'OS';
  c_min_sal          CONSTANT NUMBER(3) := 900;
END constant_pkg;
```

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Standardizing Constants

By definition, a variable's value changes, whereas a constant's value cannot be changed. If you have programs that use local variables whose values should not and do not change, then convert the variables to constants. This can help with the maintenance and debugging of your code.

Consider creating a single shared package with all your constants in it. This makes maintenance and change of the constants much easier. This procedure or package can be loaded on system startup for better performance.

The example in the slide shows the `constant_pkg` package containing a few constants. Refer to any of the package constants in your application as required. Here is an example:

```
BEGIN
  UPDATE employees
    SET salary = salary + 200
  WHERE salary <= constant_pkg.c_min_sal;
END;
/
```

Local Subprograms

A local subprogram is a PROCEDURE or FUNCTION defined at the end of the declarative section.

```
CREATE PROCEDURE employee_sal(p_id NUMBER) IS
  v_emp employees%ROWTYPE;
  FUNCTION tax(p_salary VARCHAR2) RETURN NUMBER IS
  BEGIN
    RETURN p_salary * 0.825;
  END tax;
BEGIN
  SELECT * INTO v_emp
  FROM EMPLOYEES WHERE employee_id = p_id;
  DBMS_OUTPUT.PUT_LINE('Tax: ' || tax(v_emp.salary));
END;
/
EXECUTE employee_sal(100)
```

```
PROCEDURE employee_sal(p_id Compiled.
anonymous block completed
Tax: 19800
```

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Local Subprograms

Local subprograms can drive top-down design. They reduce the size of a module by removing redundant code. This is one of the main reasons for creating a local subprogram. If a module needs the same routine several times, but only this module needs the routine, then define it as a local subprogram.

You can define a named PL/SQL block in the declarative section of any PL/SQL program, procedure, function, or anonymous block *provided that it is declared at the end of the Declaration section*. Local subprograms have the following characteristics:

- They are only accessible to the block in which they are defined.
- They are compiled as part of their enclosing blocks.

The benefits of local subprograms are:

- Reduction of repetitive code
- Improved code readability and ease of maintenance
- Less administration because there is one program to maintain instead of two

The concept is simple. The example shown in the slide illustrates this with a basic example of an income tax calculation of an employee's salary.

Definer's Rights Versus Invoker's Rights

Definer's rights:

- Used prior to Oracle8i
- Programs execute with the privileges of the creating user.
- User does not require privileges on underlying objects that the procedure accesses. User requires privilege only to execute a procedure.

Invoker's rights:

- Introduced in Oracle8i
- Programs execute with the privileges of the calling user.
- User requires privileges on the underlying objects that the procedure accesses.

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Definer's Rights Versus Invoker's Rights

Definer's Rights Model

Before Oracle8i, all programs executed with the privileges of the user who created the subprogram. This is known as the definer's rights model, which:

- Allows a caller of the program the privilege to execute the procedure, but no privileges on the underlying objects that the procedure accesses
- Requires the owner to have all the necessary object privileges for the objects that the procedure references

For example, if user Scott creates a PL/SQL subprogram `get_employees` that is subsequently invoked by Sarah, then the `get_employees` procedure runs with the privileges of the definer Scott.

Invoker's Rights Model

In the invoker's rights model, which was introduced in Oracle8i, programs are executed with the privileges of the calling user. A user of a procedure running with invoker's rights requires privileges on the underlying objects that the procedure references.

For example, if Scott's PL/SQL subprogram `get_employees` is invoked by Sarah, then the `get_employees` procedure runs with the privileges of the invoker Sarah.

Specifying Invoker's Rights: Setting AUTHID to CURRENT_USER

```
CREATE OR REPLACE PROCEDURE add_dept(  
    p_id NUMBER, p_name VARCHAR2) AUTHID CURRENT_USER IS  
BEGIN  
    INSERT INTO departments  
    VALUES (p_id, p_name, NULL, NULL);  
END;
```

When used with stand-alone functions, procedures, or packages:

- Names used in queries, DML, Native Dynamic SQL, and DBMS_SQL package are resolved in the invoker's schema
- Calls to other packages, functions, and procedures are resolved in the definer's schema

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Specifying Invoker's Rights

You can set the invoker's rights for different PL/SQL subprogram constructs as follows:

```
CREATE FUNCTION name RETURN type AUTHID CURRENT_USER IS...  
CREATE PROCEDURE name AUTHID CURRENT_USER IS..  
CREATE PACKAGE name AUTHID CURRENT_USER IS..  
CREATE TYPE name AUTHID CURRENT_USER IS OBJECT...
```

The default is AUTHID DEFINER, which specifies that the subprogram executes with the privileges of its owner. Most supplied PL/SQL packages such as DBMS_LOB, DBMS_ROWID, and so on, are invoker-rights packages.

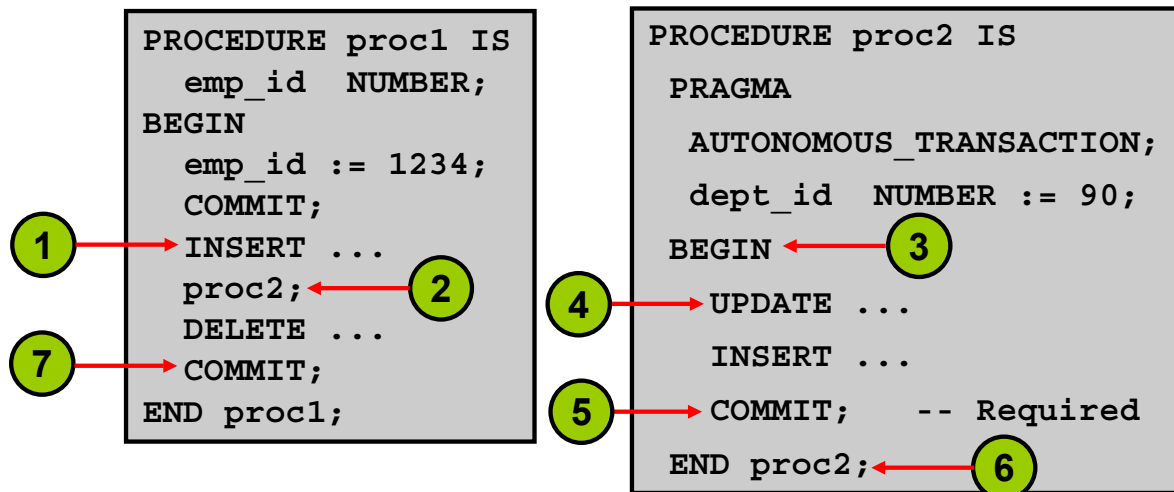
Name Resolution

For a definer's rights procedure, all external references are resolved in the definer's schema. For an invoker's rights procedure, the resolution of external references depends on the kind of statement in which they appear:

- Names used in queries, data manipulation language (DML) statements, dynamic SQL, and DBMS_SQL are resolved in the invoker's schema.
- All other statements, such as calls to packages, functions, and procedures, are resolved in the definer's schema.

Autonomous Transactions

- Are independent transactions started by another main transaction
- Are specified with `PRAGMA AUTONOMOUS_TRANSACTION`



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Autonomous Transactions

A transaction is a series of statements doing a logical unit of work that completes or fails as an integrated unit. Often, one transaction starts another that may need to operate outside the scope of the transaction that started it. That is, in an existing transaction, a required independent transaction may need to commit or roll back changes without affecting the outcome of the starting transaction. For example, in a stock purchase transaction, the customer's information must be committed regardless of whether the overall stock purchase completes. Or, while running that same transaction, you want to log messages to a table even if the overall transaction rolls back.

Since Oracle8i, the autonomous transactions were added to make it possible to create an independent transaction. An autonomous transaction (AT) is an independent transaction started by another main transaction (MT). The slide depicts the behavior of an AT:

1. The main transaction begins.
2. A `proc2` procedure is called to start the autonomous transaction.
3. The main transaction is suspended.
4. The autonomous transactional operation begins.
5. The autonomous transaction ends with a commit or roll back operation.
6. The main transaction is resumed.
7. The main transaction ends.

Features of Autonomous Transactions

- Are independent of the main transaction
- Suspend the calling transaction until the autonomous transactions are completed
- Are not nested transactions
- Do not roll back if the main transaction rolls back
- Enable the changes to become visible to other transactions upon a commit
- Are started and ended by individual subprograms and not by nested or anonymous PL/SQL blocks

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Features of Autonomous Transactions

Autonomous transactions exhibit the following features:

- Although called within a transaction, autonomous transactions are independent of that transaction. That is, they are not nested transactions.
- If the main transaction rolls back, autonomous transactions do not.
- Changes made by an autonomous transaction become visible to other transactions when the autonomous transaction commits.
- With their stack-like functionality, only the “top” transaction is accessible at any given time. After completion, the autonomous transaction is popped, and the calling transaction is resumed.
- There are no limits other than resource limits on how many autonomous transactions can be recursively called.
- Autonomous transactions must be explicitly committed or rolled back; otherwise, an error is returned when attempting to return from the autonomous block.
- You cannot use PRAGMA to mark all subprograms in a package as autonomous. Only individual routines can be marked autonomous.
- You cannot mark a nested or anonymous PL/SQL block as autonomous.

Using Autonomous Transactions: Example

```
PROCEDURE bank_trans(p_cardnbr NUMBER, p_loc NUMBER) IS
BEGIN
    log_usage(p_cardnbr, p_loc);
    INSERT INTO txn VALUES (9001, 1000,...);
END bank_trans;
```

```
PROCEDURE log_usage (p_card_id NUMBER, p_loc NUMBER)
IS
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
    INSERT INTO usage      -- usage is an existing table
    VALUES (p_card_id, p_loc);
    COMMIT;
END log_usage;
```

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Using Autonomous Transactions

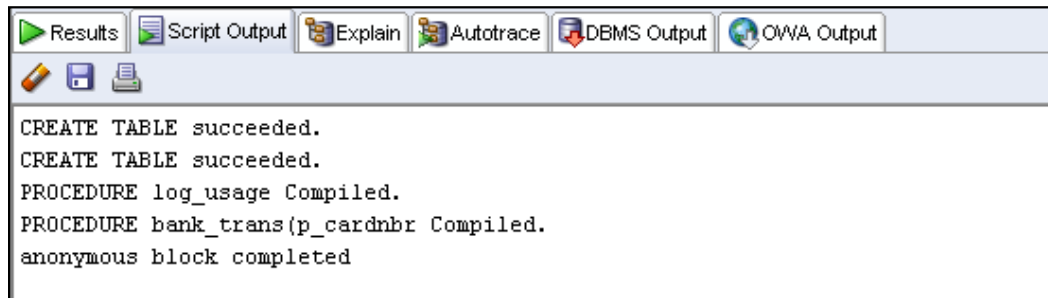
To define autonomous transactions, you use `PRAGMA AUTONOMOUS_TRANSACTION`. `PRAGMA` instructs the PL/SQL compiler to mark a routine as autonomous (independent). In this context, the term “routine” includes top-level (not nested) anonymous PL/SQL blocks; local, stand-alone, and packaged functions and procedures; methods of a SQL object type; and database triggers. You can code `PRAGMA` anywhere in the declarative section of a routine. However, for readability, it is best placed at the top of the `Declaration` section.

In the example in the slide, you track where the bankcard is used, regardless of whether the transaction is successful. The following are the benefits of autonomous transactions:

- After starting, an autonomous transaction is fully independent. It shares no locks, resources, or commit dependencies with the main transaction, so you can log events, increment retry counters, and so on even if the main transaction rolls back.
- More importantly, autonomous transactions help you build modular, reusable software components. For example, stored procedures can start and finish autonomous transactions on their own. A calling application need not know about a procedure’s autonomous operations, and the procedure need not know about the application’s transaction context. That makes autonomous transactions less error-prone than regular transactions and easier to use.

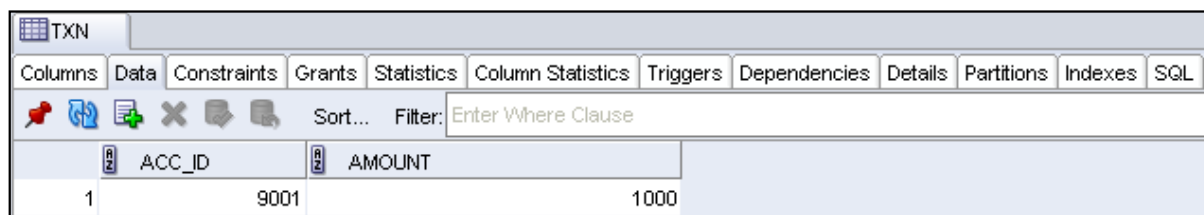
Using Autonomous Transactions (continued)

The output of the previous slide examples, the TXN and USAGE tables are as follows:

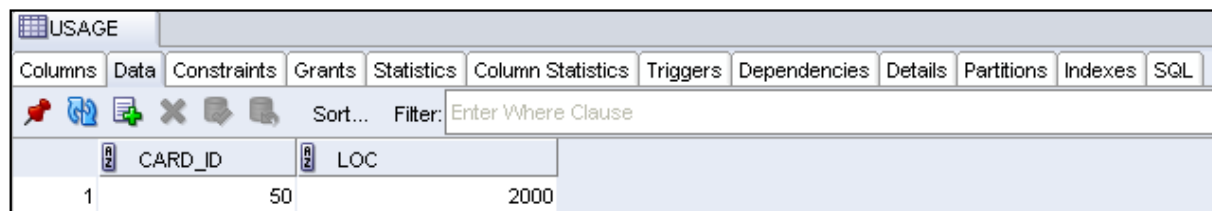


```
Results | Script Output | Explain | Autotrace | DBMS Output | OWA Output
CREATE TABLE succeeded.
CREATE TABLE succeeded.
PROCEDURE log_usage Compiled.
PROCEDURE bank_trans(p_cardnbr Compiled.
anonymous block completed
```

Use the Data tab in the Tables node of the Object Navigator tree to display the values in the TXN and USAGE tables as follows:



TXN		
Columns	Data	Constraints
Sort...	Filter: Enter Where Clause	
ACC_ID	AMOUNT	
1	9001	1000



USAGE		
Columns	Data	Constraints
Sort...	Filter: Enter Where Clause	
CARD_ID	LOC	
1	50	2000

Lesson Agenda

- Standardizing constants and exceptions, using local subprograms, controlling the run-time privileges of a subprogram, and performing autonomous transactions
- **Using the NOCOPY and the PARALLEL ENABLE hints, the cross-session PL/SQL function result cache, and the DETERMINISTIC clause**
- Using bulk binding and the RETURNING clause with DML

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Using the NOCOPY Hint

- Allows the PL/SQL compiler to pass OUT and IN OUT parameters by reference rather than by value
- Enhances performance by reducing overhead when passing parameters

```
DECLARE
  TYPE      rec_emp_type IS TABLE OF employees%ROWTYPE;
  rec_emp   rec_emp_type;
  PROCEDURE populate(p_tab IN OUT NOCOPY emptabtype) IS
  BEGIN
    . . .
  END;
BEGIN
  populate(rec_emp);
END;
/
```

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Using the NOCOPY Hint

Note that PL/SQL subprograms support three parameter-passing modes: IN, OUT, and IN OUT. By default:

- The IN parameter is passed by reference. A pointer to the IN actual parameter is passed to the corresponding formal parameter. So, both the parameters reference the same memory location, which holds the value of the actual parameter.
- The OUT and IN OUT parameters are passed by value. The value of the OUT or IN OUT actual parameter is copied into the corresponding formal parameter. Then, if the subprogram exits normally, the values assigned to the OUT and IN OUT formal parameters are copied into the corresponding actual parameters.

Copying parameters that represent large data structures (such as collections, records, and instances of object types) with OUT and IN OUT parameters slows down execution and uses up memory. To prevent this overhead, you can specify the NOCOPY hint, which enables the PL/SQL compiler to pass OUT and IN OUT parameters by reference.

The slide shows an example of declaring an IN OUT parameter with the NOCOPY hint.

Effects of the NOCOPY Hint

- If the subprogram exits with an exception that is not handled:
 - You cannot rely on the values of the actual parameters passed to a NOCOPY parameter
 - Any incomplete modifications are not “rolled back”
- The remote procedure call (RPC) protocol enables you to pass parameters only by value.

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Effects of the NOCOPY Hint

As a trade-off for better performance, the NOCOPY hint enables you to trade well-defined exception semantics for better performance. Its use affects exception handling in the following ways:

- Because NOCOPY is a hint and not a directive, the compiler can pass NOCOPY parameters to a subprogram by value or by reference. So, if the subprogram exits with an unhandled exception, you cannot rely on the values of the NOCOPY actual parameters.
- By default, if a subprogram exits with an unhandled exception, the values assigned to its OUT and IN OUT formal parameters are not copied to the corresponding actual parameters, and changes appear to roll back. However, when you specify NOCOPY, assignments to the formal parameters immediately affect the actual parameters as well. So, if the subprogram exits with an unhandled exception, the (possibly unfinished) changes are not “rolled back.”
- Currently, the RPC protocol enables you to pass parameters only by value. So, exception semantics can change without notification when you partition applications. For example, if you move a local procedure with NOCOPY parameters to a remote site, those parameters are no longer passed by reference.

When Does the PL/SQL Compiler Ignore the NOCOPY Hint?

The NOCOPY hint has no effect if:

- The actual parameter:
 - Is an element of an index-by table
 - Is constrained (for example, by scale or NOT NULL)
 - And formal parameter are records, where one or both records were declared by using %ROWTYPE or %TYPE, and constraints on corresponding fields in the records differ
 - Requires an implicit data type conversion
- The subprogram is involved in an external or remote procedure call

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When Does the PL/SQL Compiler Ignore the NOCOPY Hint?

In the following cases, the PL/SQL compiler ignores the NOCOPY hint and uses the by-value parameter-passing method (with no error generated):

- The actual parameter is an element of an index-by table. This restriction does not apply to entire index-by tables.
- The actual parameter is constrained (by scale or NOT NULL). This restriction does not extend to constrained elements or attributes. Also, it does not apply to size-constrained character strings.
- The actual and formal parameters are records; one or both records were declared by using %ROWTYPE or %TYPE, and constraints on corresponding fields in the records differ.
- The actual and formal parameters are records; the actual parameter was declared (implicitly) as the index of a cursor FOR loop, and constraints on corresponding fields in the records differ.
- Passing the actual parameter requires an implicit data type conversion.
- The subprogram is involved in an external or remote procedure call.

Using the PARALLEL_ENABLE Hint

- Can be used in functions as an optimization hint
- Indicates that a function can be used in a parallelized query or parallelized DML statement

```
CREATE OR REPLACE FUNCTION f2 (p_p1 NUMBER)
  RETURN NUMBER PARALLEL_ENABLE IS
BEGIN
  RETURN p_p1 * 2;
END f2;
```

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Using the PARALLEL_ENABLE Hint

The PARALLEL_ENABLE keyword can be used in the syntax for declaring a function. It is an optimization hint that indicates that the function can be used in a parallelized query or parallelized DML statement. Oracle's parallel execution feature divides the work of executing a SQL statement across multiple processes. Functions called from a SQL statement that is run in parallel can have a separate copy run in each of these processes, with each copy called for only the subset of rows that are handled by that process.

For DML statements, before Oracle8i, the parallelization optimization looked to see whether a function was noted as having all four of RNDS, WNDS, RNPS, and WNPS specified in a PRAGMA RESTRICT_REFERENCES declaration; those functions that were marked as neither reading nor writing to either the database or package variables could run in parallel. Again, those functions defined with a CREATE FUNCTION statement had their code implicitly examined to determine whether they were actually pure enough; parallelized execution might occur even though a PRAGMA cannot be specified on these functions.

The PARALLEL_ENABLE keyword is placed after the return value type in the declaration of the function, as shown in the example in the slide.

Note: The function should not use session state, such as package variables, because those variables may not be shared among the parallel execution servers.

Using the Cross-Session PL/SQL Function Result Cache

- Each time a result-cached PL/SQL function is called with different parameter values, those parameters and their results are stored in cache.
- The function result cache is stored in a shared global area (SGA), making it available to any session that runs your application.
- Subsequent calls to the same function with the same parameters uses the result from cache.
- Performance and scalability are improved.
- This feature is used with functions that are called frequently and dependent on information that changes infrequently.

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Cross-Session PL/SQL Function Result Cache

Starting in Oracle Database 11g, you can use the PL/SQL cross-session function result caching mechanism. This caching mechanism provides you with a language-supported and system-managed means for storing the results of PL/SQL functions in a shared global area (SGA), which is available to every session that runs your application. The caching mechanism is both efficient and easy to use, and it relieves you of the burden of designing and developing your own caches and cache-management policies.

Each time a result-cached PL/SQL function is called with different parameter values, those parameters and their results are stored in the cache. Subsequently, when the same function is called with the same parameter values, the result is retrieved from the cache, instead of being recomputed. If a database object that was used to compute a cached result is updated, the cached result becomes invalid and must be recomputed.

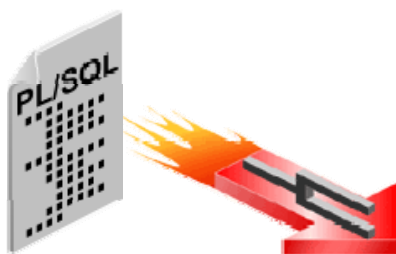
Use the result-caching feature with functions that are called frequently and are dependent on information that never changes or changes infrequently.

Note: For additional information about *Cross-Session PL/SQL Function Result Cache*, refer to the *Oracle Database 11g Advanced PL/SQL* course, the *Oracle Database 11g SQL and PL/SQL New Features* course, or the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)* guide.

Enabling Result-Caching for a Function

You can make a function result-cached as follows:

- Include the `RESULT_CACHE` clause in the following:
 - The function declaration
 - The function definition
- Include an optional `RELIES_ON` clause to specify any tables or views on which the function results depend.



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Enabling Result-Caching for a Function

To enable result-caching for a PL/SQL function, use the `RESULT_CACHE` clause. When a result-cached function is called, the system checks the function result cache. If the cache contains the result from a previous call to the function with the same parameter values, the system returns the cached result to the caller and does not reexecute the function body. If the cache does not contain the result, the system executes the function body and adds the result (for these parameter values) to the cache before returning control to the caller.

The cache can accumulate many results—one result for every unique combination of parameter values with which each result-cached function has been called. If the system needs more memory, it ages out (deletes) one or more cached results.

Note: If function execution results in an unhandled exception, the exception result is not stored in the cache.

Declaring and Defining a Result-Cached Function: Example

```
CREATE OR REPLACE FUNCTION emp_hire_date (p_emp_id
    NUMBER) RETURN VARCHAR
    RESULT_CACHE RELIES_ON (employees) IS
    v_date_hired DATE;
BEGIN
    SELECT hire_date INTO v_date_hired
    FROM HR.Employees
    WHERE Employee_ID = p_emp_ID;
    RETURN to_char(v_date_hired);
END;
```

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Declaring and Defining a Result-Cached Function: Example

If a function depends on settings that might vary from session to session such as `NLS_DATE_FORMAT` and `TIME_ZONE`, make the function result-cached only if you can modify it to handle the various settings.

In the slide example, the `emp_hire_date` function uses the `to_char` function to convert a `DATE` item to a `VARCHAR` item. `emp_hire_date` does not specify a format mask, so the format mask defaults to the one that `NLS_DATE_FORMAT` specifies. If sessions that call `emp_hire_date` have different `NLS_DATE_FORMAT` settings, cached results can have different formats. If a cached result computed by one session ages out, and another session recomputes it, the format might vary even for the same parameter value. If a session gets a cached result whose format differs from its own format, that result will probably be incorrect.

Some possible solutions to this problem are:

- Change the return type of `emp_hire_date` to `DATE` and have each session call the `to_char` function.
- If a common format is acceptable to all sessions, specify a format mask, removing the dependency on `NLS_DATE_FORMAT`—for example, `to_char(date_hired, 'mm/dd/yy')` ;.

Declaring and Defining a Result-Cached Function: Example (continued)

- Add a format mask parameter to HireDate as follows:

```
CREATE OR REPLACE FUNCTION emp_hire_date (p_emp_id NUMBER,  
  fmt VARCHAR) RETURN VARCHAR  
  RESULT_CACHE RELIES_ON (employees) IS  
  v_date_hired DATE;  
BEGIN  
  SELECT hire_date INTO v_date_hired  
  FROM employees  
  WHERE employee_id = p_emp_id;  
  RETURN to_char(v_date_hired, fmt);  
END;
```

Using the DETERMINISTIC Clause with Functions

- Specify `DETERMINISTIC` to indicate that the function returns the same result value whenever it is called with the same values for its arguments.
- This helps the optimizer avoid redundant function calls.
- If a function was called previously with the same arguments, the optimizer can elect to use the previous result.
- Do not specify `DETERMINISTIC` for a function whose result depends on the state of session variables or schema objects.

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Using the DETERMINISTIC Clause with Functions

You can use the `DETERMINISTIC` function clause to indicate that the function returns the same result value whenever it is called with the same values for its arguments.

You must specify this keyword if you intend to call the function in the expression of a function-based index or from the query of a materialized view that is marked `REFRESH FAST` or `ENABLE QUERY REWRITE`. When Oracle Database encounters a deterministic function in one of these contexts, it attempts to use previously calculated results when possible rather than reexecuting the function. If you subsequently change the semantics of the function, you must manually rebuild all dependent function-based indexes and materialized views.

Do not specify this clause to define a function that uses package variables or that accesses the database in any way that might affect the return result of the function. The results of doing so will not be captured if Oracle Database chooses not to reexecute the function.

Note

- Do not specify `DETERMINISTIC` for a function whose result depends on the state of session variables or schema objects because results might vary across calls. Instead, consider making the function result-cached.
- For more information about the `DETERMINISTIC` clause, refer to the *Oracle Database SQL Language Reference 11g Release 1 (11.1)* guide.

Lesson Agenda

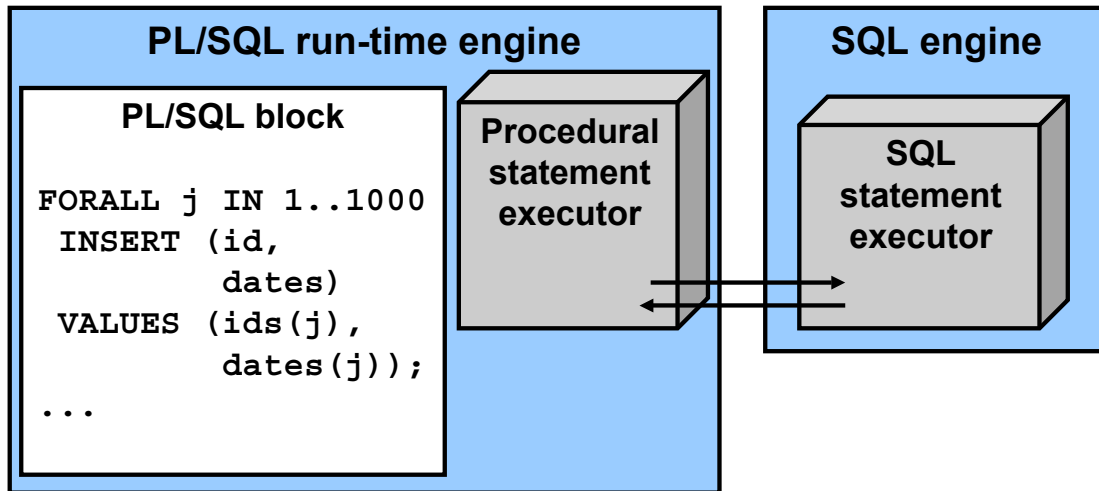
- Standardizing constants and exceptions, using local subprograms, controlling the run-time privileges of a subprogram, and performing autonomous transactions
- Using the `NOCOPY` and the `PARALLEL ENABLE` hints, the cross-session PL/SQL function result cache, and the `DETERMINISTIC` clause
- Using bulk binding and the `RETURNING` clause with DML

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Bulk Binding

Binds whole arrays of values in a single operation, rather than using a loop to perform a `FETCH`, `INSERT`, `UPDATE`, and `DELETE` operation multiple times



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Bulk Binding

The Oracle server uses two engines to run PL/SQL blocks and subprograms:

- The PL/SQL run-time engine, which runs procedural statements but passes the SQL statements to the SQL engine
- The SQL engine, which parses and executes the SQL statement and, in some cases, returns data to the PL/SQL engine

During execution, every SQL statement causes a context switch between the two engines, which results in a performance penalty for excessive amounts of SQL processing. This is typical of applications that have a SQL statement in a loop that uses values from indexed collections. Collections include nested tables, varying arrays, index-by tables, and host arrays.

Performance can be substantially improved by minimizing the number of context switches through the use of bulk binding. Bulk binding causes an entire collection to be bound in one call, a context switch, to the SQL engine. That is, a bulk bind process passes the entire collection of values back and forth between the two engines in a single context switch, compared with incurring a context switch for each collection element in an iteration of a loop. The more rows affected by a SQL statement, the greater the performance gain with bulk binding.

Using Bulk Binding: Syntax and Keywords

- The `FORALL` keyword instructs the *PL/SQL engine* to bulk bind input collections before sending them to the SQL engine.

```
FORALL index IN lower_bound .. upper_bound
  [SAVE EXCEPTIONS]
  sql_statement;
```

- The `BULK COLLECT` keyword instructs the *SQL engine* to bulk bind output collections before returning them to the PL/SQL engine.

```
... BULK COLLECT INTO
    collection_name[,collection_name] ...
```

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Using Bulk Binding

Use bulk binds to improve the performance of:

- DML statements that reference collection elements
- SELECT statements that reference collection elements
- Cursor FOR loops that reference collections and the `RETURNING INTO` clause

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

The `BULK COLLECT` keyword instructs the SQL engine to bulk bind output collections, before returning them to the PL/SQL engine. This enables you to bind locations into which SQL can return the retrieved values in bulk. Thus, you can use these keywords in the `SELECT INTO`, `FETCH INTO`, and `RETURNING INTO` clauses.

The `SAVE EXCEPTIONS` keyword is optional. However, if some of the DML operations succeed and some fail, you would want to track or report on those that fail. Using the `SAVE EXCEPTIONS` keyword causes failed operations to be stored in a cursor attribute called `%BULK_EXCEPTIONS`, which is a collection of records indicating the bulk DML iteration number and corresponding error code.

Using Bulk Binding (continued)

Handling FORALL Exceptions with the %BULK_EXCEPTIONS Attribute

To manage exceptions and have the bulk bind complete despite errors, add the keywords `SAVE EXCEPTIONS` to your `FORALL` statement after the bounds, before the DML statement.

All exceptions raised during the execution are saved in the cursor attribute `%BULK_EXCEPTIONS`, which stores a collection of records. Each record has two fields:

`%BULK_EXCEPTIONS (i) . ERROR_INDEX` holds the “iteration” of the `FORALL` statement during which the exception was raised and `%BULK_EXCEPTIONS (i) . ERROR_CODE` holds the corresponding Oracle error code.

Values stored in `%BULK_EXCEPTIONS` refer to the most recently executed `FORALL` statement. Its subscripts range from 1 to `%BULK_EXCEPTIONS . COUNT`.

Note: For additional information about bulk binding and handling bulk-binding exceptions, refer to the *Oracle Database PL/SQL User's Guide and Reference 11g Release 1 (11.1)*.

Bulk Binding FORALL: Example

```
CREATE PROCEDURE raise_salary(p_percent NUMBER) IS
  TYPE numlist_type IS TABLE OF NUMBER
    INDEX BY BINARY_INTEGER;
  v_id numlist_type; -- collection
BEGIN
  v_id(1) := 100; v_id(2) := 102; v_id(3) := 104; v_id(4) := 110;
  -- bulk-bind the PL/SQL table
  FORALL i IN v_id.FIRST .. v_id.LAST
    UPDATE employees
      SET salary = (1 + p_percent/100) * salary
      WHERE employee_id = v_id(i);
END;
/
```

```
EXECUTE raise_salary(10)
```

```
PL/SQL procedure successfully completed.
```

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Bulk Binding FORALL: Example

Note: Before you can run the example in the slide, you must disable the `update_job_history` trigger as follows:

```
ALTER TRIGGER update_job_history DISABLE;
```

In the example in the slide, the PL/SQL block increases the salary for employees with IDs 100, 102, 104, or 110. It uses the `FORALL` keyword to bulk bind the collection. Without bulk binding, the PL/SQL block would have sent a SQL statement to the SQL engine for each employee record that is updated. If there are many employee records to update, then the large number of context switches between the PL/SQL engine and the SQL engine can affect performance. However, the `FORALL` keyword bulk binds the collection to improve performance.

Note: A looping construct is no longer required when using this feature.

Bulk Binding FORALL: Example (continued)

An Additional Cursor Attribute for DML Operations

Another cursor attribute added to support bulk operations is %BULK_ROWCOUNT. The %BULK_ROWCOUNT attribute is a composite structure designed for use with the FORALL statement. This attribute acts like an index-by table. Its *i*th element stores the number of rows processed by the *i*th execution of an UPDATE or DELETE statement. If the *i*th execution affects no rows, then %BULK_ROWCOUNT(*i*) returns zero.

Here is an example:

```
CREATE TABLE num_table (n NUMBER);
DECLARE
    TYPE num_list_type IS TABLE OF NUMBER
        INDEX BY BINARY_INTEGER;
    v_nums num_list_type;
BEGIN
    v_nums(1) := 1;
    v_nums(2) := 3;
    v_nums(3) := 5;
    v_nums(4) := 7;
    v_nums(5) := 11;
    FORALL i IN v_nums.FIRST .. v_nums.LAST
        INSERT INTO v_num_table (n) VALUES (v_nums(i));
    FOR i IN v_nums.FIRST .. v_nums.LAST
    LOOP
        dbms_output.put_line('Inserted ' ||
            SQL%BULK_ROWCOUNT(i) || ' row(s) '
            || ' on iteration ' || i);
    END LOOP;
END;
/
DROP TABLE num_table;
```

The following results are produced by this example:

```
Inserted 1 row(s) on iteration 1
Inserted 1 row(s) on iteration 2
Inserted 1 row(s) on iteration 3
Inserted 1 row(s) on iteration 4
Inserted 1 row(s) on iteration 5
```

```
PL/SQL procedure successfully completed.
DROP TABLE num_table succeeded.
```


Using BULK COLLECT INTO with Queries

The `SELECT` statement has been enhanced to support the `BULK COLLECT INTO` syntax.

```
CREATE PROCEDURE get_departments(p_loc NUMBER) IS
  TYPE dept_tab_type IS
    TABLE OF departments%ROWTYPE;
  v_depts dept_tab_type;
BEGIN
  SELECT * BULK COLLECT INTO v_depts
  FROM departments
  WHERE location_id = p_loc;
  FOR i IN 1 .. v_depts.COUNT LOOP
    DBMS_OUTPUT.PUT_LINE(v_depts(i).department_id
      || ' ' || v_depts(i).department_name);
  END LOOP;
END;
```

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Using BULK COLLECT INTO with Queries

Starting with Oracle Database 10g, when using a `SELECT` statement in PL/SQL, you can use the bulk collection syntax shown in the example in the slide. Thus, you can quickly obtain a set of rows without using a cursor mechanism.

The example reads all the department rows for a specified region into a PL/SQL table, whose contents are displayed with the `FOR` loop that follows the `SELECT` statement.

Using BULK COLLECT INTO with Cursors

The `FETCH` statement has been enhanced to support the `BULK COLLECT INTO` syntax.

```
CREATE PROCEDURE get_departments(p_loc NUMBER) IS
  CURSOR cur_dept IS
    SELECT * FROM departments
    WHERE location_id = p_loc;
  TYPE dept_tab_type IS TABLE OF cur_dept%ROWTYPE;
  v_depts dept_tab_type;
BEGIN
  OPEN cur_dept;
  FETCH cur_dept BULK COLLECT INTO v_depts;
  CLOSE cur_dept;
  FOR i IN 1 .. v_depts.COUNT LOOP
    DBMS_OUTPUT.PUT_LINE(v_depts(i).department_id
      || ' ' || v_depts(i).department_name);
  END LOOP;
END;
```

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Using BULK COLLECT INTO with Cursors

In Oracle Database 10g, when using cursors in PL/SQL, you can use a form of the `FETCH` statement that supports the bulk collection syntax shown in the example in the slide.

This example shows how `BULK COLLECT INTO` can be used with cursors.

You can also add a `LIMIT` clause to control the number of rows fetched in each operation. The code example in the slide could be modified as follows:

```
CREATE PROCEDURE get_departments(loc NUMBER,
  nrows NUMBER) IS
  CURSOR dept_csr IS SELECT * FROM departments
    WHERE location_id = loc;
  TYPE dept_tabtype IS TABLE OF dept_csr%ROWTYPE;
  depts dept_tabtype;
BEGIN
  OPEN dept_csr;
  FETCH dept_csr BULK COLLECT INTO depts LIMIT nrows;
  CLOSE dept_csr;
  DBMS_OUTPUT.PUT_LINE(depts.COUNT || ' rows read');
END;
```

Using BULK COLLECT INTO with a RETURNING Clause

```
CREATE PROCEDURE raise_salary(p_rate NUMBER) IS
  TYPE emplist_type IS TABLE OF NUMBER;
  TYPE numlist_type IS TABLE OF employees.salary%TYPE
    INDEX BY BINARY_INTEGER;
  v_emp_ids  emplist_type :=
    emplist_type(100,101,102,104);
  v_new_sals numlist_type;
BEGIN
  FORALL i IN v_emp_ids.FIRST .. v_emp_ids.LAST
    UPDATE employees
      SET commission_pct = p_rate * salary
      WHERE employee_id = v_emp_ids(i)
      RETURNING salary BULK COLLECT INTO v_new_sals;
  FOR i IN 1 .. v_new_sals.COUNT LOOP ...
END;
```

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Using BULK COLLECT INTO with a RETURNING Clause

Bulk binds can be used to improve the performance of FOR loops that reference collections and return DML. If you have, or plan to have, PL/SQL code that does this, then you can use the FORALL keyword along with the RETURNING and BULK COLLECT INTO keywords to improve performance.

In the example shown in the slide, the salary information is retrieved from the EMPLOYEES table and collected into the new_sals array. The new_sals collection is returned in bulk to the PL/SQL engine.

The example in the slide shows an incomplete FOR loop that is used to iterate through the new salary data received from the UPDATE operation and then process the results.

FORALL Support for Sparse Collections

```
-- The new INDICES OF syntax allows the bound arrays  
-- themselves to be sparse.
```

```
FORALL index_name IN INDICES OF sparse_array_name  
    BETWEEN LOWER_BOUND AND UPPER_BOUND -- optional  
    SAVE EXCEPTIONS -- optional, but recommended  
    INSERT INTO table_name VALUES  
        sparse_array(index_name);
```

```
-- The new VALUES OF syntax lets you indicate a subset  
-- of the binding arrays.
```

```
FORALL index_name IN VALUES OF index_array_name  
    SAVE EXCEPTIONS -- optional, but recommended  
    INSERT INTO table_name VALUES  
        binding_array_name(index_name);
```

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FORALL Support for Sparse Collections

In earlier releases, PL/SQL did not allow sparse collections to be used with the FORALL statement. If SAVE EXCEPTIONS was not specified, the statement was terminated when the first deleted element was encountered. Even when SAVE EXCEPTION was used, the PL/SQL engine tried to iterate over all elements (existing and nonexistent). This substantially degraded the performance of the DML operation if the relative percentage of the deleted elements was high. In Oracle Database 10g, a new syntax was introduced with the keyword INDICES to allow sparse collection to be used with the FORALL statement. This syntax binds sparse collections more efficiently. The new syntax also supports a more general approach where an index array can be specified to iterate over the collections. Using sparse collection and index arrays in bulk operations improves performance. You use the new INDICES OF and VALUES OF syntax with the FORALL statement. The bulk bind for sparse array syntax can be used in all DML syntaxes. In the syntax, the index array must be dense, and the binding arrays may be dense or sparse and the indicated elements must exist.

Using Bulk Binds in Sparse Collections

The typical application for this feature is an order entry and order processing system where:

- Users enter orders through the Web
- Orders are placed in a staging table before validation
- Data is later validated based on complex business rules (usually implemented programmatically using PL/SQL)
- Invalid orders are separated from valid ones
- Valid orders are inserted into a permanent table for processing

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Using Bulk Binds in Sparse Collections

This feature can be used in any application that starts with a dense PL/SQL table of records or table of scalar that are populated using a bulk collect. This is used as the binding array. A dense array (pointer), whose elements denote the indices of the binding array, is made sparse based on the application logic. This pointer array is then used in the `FORALL` statement to perform bulk DML with the binding arrays. Any exceptions encountered can be saved and further processed in the exception-handling section, perhaps by using another `FORALL` statement.

Using Bulk Bind with Index Array

```
CREATE OR REPLACE PROCEDURE ins_emp2 AS
  TYPE emptab_type IS TABLE OF employees%ROWTYPE;
  v_emp emptab_type;
  TYPE values_of_tab_type IS TABLE OF PLS_INTEGER
    INDEX BY PLS_INTEGER;
  v_num    values_of_tab_type;
  . . .
BEGIN
  . . .
  FORALL k IN VALUES OF v_num
    INSERT INTO new_employees VALUES v_emp(k);
END;
```

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Using Bulk Bind with Index Array

Starting in Oracle Database 10g, you can use an index collection of PLS_INTEGER or BINARY_INTEGER (or one of its subtypes) whose values are the indexes of the collections involved in the bulk-bind DML operation using FORALL. These index collections can then be used in a FORALL statement to process bulk DML using the VALUES OF clause.

In the example shown above, V_NUM is a collection whose type is PLS_INTEGER. In the example, you are creating a procedure INS_EMP2, which identifies only one employee for each occurrence of the first letter of the last name. This procedure then inserts into the NEW_EMPLOYEES table created earlier using the FORALL..IN VALUES OF syntax.

Using the RETURNING Clause

- Improves performance by returning column values with INSERT, UPDATE, and DELETE statements
- Eliminates the need for a SELECT statement

```
CREATE PROCEDURE update_salary(p_emp_id NUMBER) IS
  v_name      employees.last_name%TYPE;
  v_new_sal   employees.salary%TYPE;
BEGIN
  UPDATE employees
    SET salary = salary * 1.1
  WHERE employee_id = p_emp_id
  RETURNING last_name, salary INTO name, v_new_sal;
END update_salary;
/
```

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Using the RETURNING Clause

Often, applications need information about the row affected by a SQL operation—for example, to generate a report or to take a subsequent action. The INSERT, UPDATE, and DELETE statements can include a RETURNING clause, which returns column values from the affected row into PL/SQL variables or host variables. This eliminates the need to SELECT the row after an INSERT or UPDATE, or before a DELETE. As a result, fewer network round trips, less server CPU time, fewer cursors, and less server memory are required.

The example in the slide shows how to update the salary of an employee and, at the same time, retrieve the employee's last name and new salary into a local PL/SQL variable.

Quiz

The `NOCOPY` hint allows the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference rather than by value. This enhances performance by reducing overhead when passing parameters

1. True
2. False

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Answer: 1

PL/SQL subprograms support three parameter-passing modes: `IN`, `OUT`, and `IN OUT`.

By default:

- The `IN` parameter is passed by reference. A pointer to the `IN` actual parameter is passed to the corresponding formal parameter. So, both the parameters reference the same memory location, which holds the value of the actual parameter.
- The `OUT` and `IN OUT` parameters are passed by value. The value of the `OUT` or `IN OUT` actual parameter is copied into the corresponding formal parameter. Then, if the subprogram exits normally, the values assigned to the `OUT` and `IN OUT` formal parameters are copied into the corresponding actual parameters.

Copying parameters that represent large data structures (such as collections, records, and instances of object types) with `OUT` and `IN OUT` parameters slows down execution and uses up memory. To prevent this overhead, you can specify the `NOCOPY` hint, which enables the PL/SQL compiler to pass `OUT` and `IN OUT` parameters by reference.

Summary

In this lesson, you should have learned how to:

- Create standard constants and exceptions
- Write and call local subprograms
- Control the run-time privileges of a subprogram
- Perform autonomous transactions
- Pass parameters by reference using a `NOCOPY` hint
- Use the `PARALLEL_ENABLE` hint for optimization
- Use the cross-session PL/SQL function result cache
- Use the `DETERMINISTIC` clause with functions
- Use bulk binding and the `RETURNING` clause with DML

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Summary

The lesson provides insights into managing your PL/SQL code by defining constants and exceptions in a package specification. This enables a high degree of reuse and standardization of code.

Local subprograms can be used to simplify and modularize a block of code where the subprogram functionality is repeatedly used in the local block.

The run-time security privileges of a subprogram can be altered by using definer's or invoker's rights.

Autonomous transactions can be executed without affecting an existing main transaction.

You should understand how to obtain performance gains by using the `NOCOPY` hint, bulk binding and the `RETURNING` clauses in SQL statements, and the `PARALLEL_ENABLE` hint for optimization of functions.

Practice 8: Overview

This practice covers the following topics:

- Creating a package that uses bulk fetch operations
- Creating a local subprogram to perform an autonomous transaction to audit a business operation

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Practice 8: Overview

In this practice, you create a package that performs a bulk fetch of employees in a specified department. The data is stored in a PL/SQL table in the package. You also provide a procedure to display the contents of the table.

You add an `add_employee` procedure to the package that inserts new employees. The procedure uses a local autonomous subprogram to write a log record each time the `add_employee` procedure is called, whether it successfully adds a record or not.

Practice 8

1. Update the EMP_PKG package with a new procedure to query employees in a specified department.
 - a. In the package specification:
 - i. Declare a get_employees procedure with a parameter called dept_id, which is based on the employees.department_id column type
 - ii. Define an index-by PL/SQL type as a TABLE OF EMPLOYEES%ROWTYPE
 - b. In the package body:
 - i. Define a private variable called emp_table based on the type defined in the specification to hold employee records
 - ii. Implement the get_employees procedure to bulk fetch the data into the table.
 - c. Create a new procedure in the specification and body, called show_employees, that does not take arguments. The procedure displays the contents of the private PL/SQL table variable (if any data exists). Use the print_employee procedure that you created in an earlier practice. To view the results, click the Enable DBMS Output icon in the DBMS Output tab in SQL Developer, if you have not already done so.
 - d. Invoke the emp_pkg.get_employees procedure for department 30, and then invoke emp_pkg.show_employees. Repeat this for department 60.
2. Your manager wants to keep a log whenever the add_employee procedure in the package is invoked to insert a new employee into the EMPLOYEES table.
 - a. First, load and execute the D:\labs\PLPU\solns\sol_08_02_a.sql script to create a log table called LOG_NEWEMP, and a sequence called log_newemp_seq.
 - b. In the EMP_PKG package body, modify the add_employee procedure, which performs the actual INSERT operation. Add a local procedure called audit_newemp as follows:
 - i. The audit_newemp procedure must use an autonomous transaction to insert a log record into the LOG_NEWEMP table.
 - ii. Store the USER, the current time, and the new employee name in the log table row.
 - iii. Use log_newemp_seq to set the entry_id column.

Note: Remember to perform a COMMIT operation in a procedure with an autonomous transaction.

Practice 8 (continued)

- c. Modify the `add_employee` procedure to invoke `audit_emp` before it performs the insert operation.
- d. Invoke the `add_employee` procedure for these new employees: Max Smart in department 20 and Clark Kent in department 10. What happens?
- e. Query the two `EMPLOYEES` records added, and the records in `LOG_NEWEMP` table. How many log records are present?
- f. Execute a `ROLLBACK` statement to undo the insert operations that have not been committed. Use the same queries from step 2 e. as follows:
 - i. Use the first query to check whether the employee rows for Smart and Kent have been removed.
 - ii. Use the second query to check the log records in the `LOG_NEWEMP` table. How many log records are present? Why?

9

Creating Triggers

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Objectives

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

- Describe database triggers and their uses
- Describe the different types of triggers
- Create database triggers
- Describe database trigger-firing rules
- Remove database triggers
- Display trigger information

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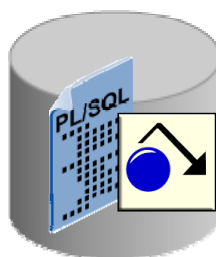
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Lesson Aim

In this lesson, you learn how to create and use database triggers.

What Are Triggers?

- A trigger is a PL/SQL block that is stored in the database and fired (executed) in response to a specified event.
- The Oracle database automatically executes a trigger when specified conditions occur.



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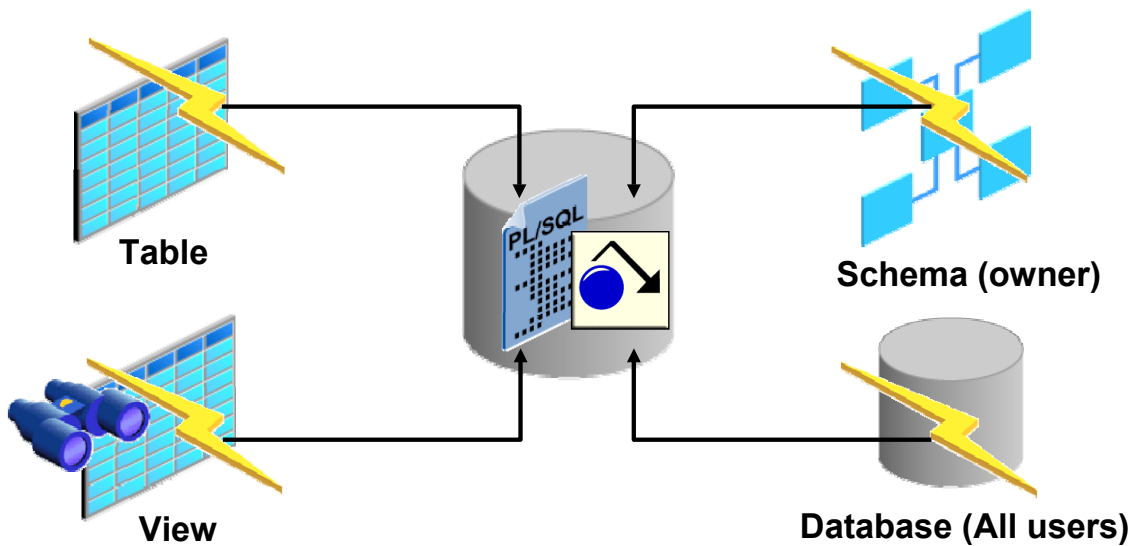
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Working with Triggers: Overview

Triggers are similar to stored procedures. A trigger stored in the database contains PL/SQL in the form of an anonymous block, a call statement, or a compound trigger block. However, procedures and triggers differ in the way that they are invoked. A procedure is explicitly run by a user, application, or trigger. Triggers are implicitly fired by the Oracle database when a triggering event occurs, no matter which user is connected or which application is being used.

Defining Triggers

A trigger can be defined on the table, view, schema (schema owner), or database (all users).



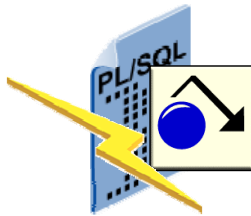
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Trigger Event Types

You can write triggers that fire whenever one of the following operations occurs in the database:

- A database manipulation (DML) statement (DELETE, INSERT, or UPDATE).
- A database definition (DDL) statement (CREATE, ALTER, or DROP).
- A database operation such as SERVERERROR, LOGON, LOGOFF, STARTUP, or SHUTDOWN.



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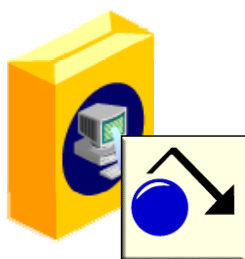
Triggering Event or Statement

A triggering event or statement is the SQL statement, database event, or user event that causes a trigger to fire. A triggering event can be one or more of the following:

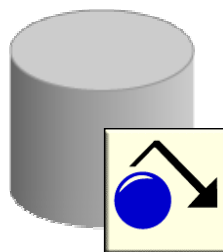
- An INSERT, UPDATE, or DELETE statement on a specific table (or view, in some cases)
- A CREATE, ALTER, or DROP statement on any schema object
- A database startup or instance shutdown
- A specific error message or any error message
- A user logon or logoff

Application and Database Triggers

- Database trigger (covered in this course):
 - Fires whenever a DML, a DLL, or system event occurs on a schema or database
- Application trigger:
 - Fires whenever an event occurs within a particular application



Application Trigger



Database Trigger

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Types of Triggers

Application triggers execute implicitly whenever a particular data manipulation language (DML) event occurs within an application. An example of an application that uses triggers extensively is an application developed with Oracle Forms Developer.

Database triggers execute implicitly when any of the following events occur:

- DML operations on a table
- DML operations on a view, with an `INSTEAD OF` trigger
- DDL statements, such as `CREATE` and `ALTER`

This is the case no matter which user is connected or which application is used. Database triggers also execute implicitly when some user actions or database system actions occur (for example, when a user logs on or the DBA shuts down the database).

Database triggers can be system triggers on a database or a schema (covered in the next lesson). For databases, triggers fire for each event for all users; for a schema, they fire for each event for that specific user. Oracle Forms can define, store, and run triggers of a different sort. However, do not confuse Oracle Forms triggers with the triggers discussed in this lesson.

Business Application Scenarios for Implementing Triggers

You can use triggers for:

- Security
- Auditing
- Data integrity
- Referential integrity
- Table replication
- Computing derived data automatically
- Event logging

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Business Application Scenarios for Implementing Triggers

Develop database triggers in order to enhance features that cannot otherwise be implemented by the Oracle server or as alternatives to those provided by the Oracle server.

- **Security:** The Oracle server allows table access to users or roles. Triggers allow table access according to data values.
- **Auditing:** The Oracle server tracks data operations on tables. Triggers track values for data operations on tables.
- **Data integrity:** The Oracle server enforces integrity constraints. Triggers implement complex integrity rules.
- **Referential integrity:** The Oracle server enforces standard referential integrity rules. Triggers implement nonstandard functionality.
- **Table replication:** The Oracle server copies tables asynchronously into snapshots. Triggers copy tables synchronously into replicas.
- **Derived data:** The Oracle server computes derived data values manually. Triggers compute derived data values automatically.
- **Event logging:** The Oracle server logs events explicitly. Triggers log events transparently.

Available Trigger Types

- Simple DML triggers
 - BEFORE
 - AFTER
 - INSTEAD OF
- Compound triggers
- Non-DML triggers
 - DDL event triggers
 - Database event triggers

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Note

In this lesson, we will discuss the BEFORE, AFTER, and INSTEAD OF triggers. The other trigger types are discussed in the lesson titled “Creating Compound, DDL, and Event Database Triggers.”

Trigger Event Types and Body

- A trigger event type determines which DML statement causes the trigger to execute. The possible events are:
 - INSERT
 - UPDATE [OF column]
 - DELETE
- A trigger body determines what action is performed and is a PL/SQL block or a CALL to a procedure

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Triggering Event Types

The triggering event or statement can be an INSERT, UPDATE, or DELETE statement on a table.

- When the triggering event is an UPDATE statement, you can include a column list to identify which columns must be changed to fire the trigger. You cannot specify a column list for an INSERT or for a DELETE statement because it always affects entire rows.
 - . . . UPDATE OF salary . . .
- The triggering event can contain one, two, or all three of these DML operations.
 - . . . INSERT or UPDATE or DELETE
 - . . . INSERT or UPDATE OF job_id . . .

The trigger body defines the action—that is, what needs to be done when the triggering event is issued. The PL/SQL block can contain SQL and PL/SQL statements, and can define PL/SQL constructs such as variables, cursors, exceptions, and so on. You can also call a PL/SQL procedure or a Java procedure.

Note: The size of a trigger cannot be greater than 32 KB.

Creating DML Triggers Using the CREATE TRIGGER Statement

```
CREATE [OR REPLACE] TRIGGER trigger_name
timing -- when to fire the trigger
event1 [OR event2 OR event3]
ON object_name
[REFERENCING OLD AS old / NEW AS new]
FOR EACH ROW -- default is statement level trigger
WHEN (condition)]
DECLARE]
BEGIN
... trigger_body -- executable statements
[EXCEPTION . . .]
END [trigger_name];
```

`timing` = BEFORE | AFTER | INSTEAD OF

`event` = INSERT | DELETE | UPDATE | UPDATE OF *column_list*

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Creating DML Triggers

The components of the trigger syntax are:

- *trigger_name* uniquely identifies the trigger.
- *timing* indicates when the trigger fires in relation to the triggering event. Values are BEFORE, AFTER, and INSTEAD OF.
- *event* identifies the DML operation causing the trigger to fire. Values are INSERT, UPDATE [OF *column*], and DELETE.
- *object_name* indicates the table or view associated with the trigger.
- For row triggers, you can specify:
 - A REFERENCING clause to choose correlation names for referencing the old and new values of the current row (default values are OLD and NEW)
 - FOR EACH ROW to designate that the trigger is a row trigger
 - A WHEN clause to apply a conditional predicate, in parentheses, which is evaluated for each row to determine whether or not to execute the trigger body
- The *trigger_body* is the action performed by the trigger, implemented as either of the following:
 - An anonymous block with a DECLARE or BEGIN, and an END
 - A CALL clause to invoke a stand-alone or packaged stored procedure, such as:
CALL my_procedure;

Specifying the Trigger Firing (Timing)

You can specify the trigger timing as to whether to run the trigger's action before or after the triggering statement:

- **BEFORE:** Executes the trigger body before the triggering DML event on a table.
- **AFTER:** Execute the trigger body after the triggering DML event on a table.
- **INSTEAD OF:** Execute the trigger body instead of the triggering statement. This is used for views that are not otherwise modifiable.

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Trigger Timing

The **BEFORE** trigger timing is frequently used in the following situations:

- To determine whether the triggering statement should be allowed to complete (This eliminates unnecessary processing and enables a rollback in cases where an exception is raised in the triggering action.)
- To derive column values before completing an INSERT or UPDATE statement
- To initialize global variables or flags, and to validate complex business rules

The **AFTER** triggers are frequently used in the following situations:

- To complete the triggering statement before executing the triggering action
- To perform different actions on the same triggering statement if a BEFORE trigger is already present

The **INSTEAD OF** triggers provide a transparent way of modifying views that cannot be modified directly through SQL DML statements because a view is not always modifiable. You can write appropriate DML statements inside the body of an INSTEAD OF trigger to perform actions directly on the underlying tables of views.

If two or more triggers are defined with the same timing point, and the order in which they fire is important, then you can control the firing order using the **FOLLOWS** clause. If it is practical, you should consider replacing the set of individual triggers for a particular timing point with a single compound trigger that explicitly codes the actions in the order you intend.

Statement-Level Triggers Versus Row-Level Triggers

Statement-Level Triggers	Row-Level Triggers
Is the default when creating a trigger	Use the <code>FOR EACH ROW</code> clause when creating a trigger.
Fires once for the triggering event	Fires once for each row affected by the triggering event
Fires once even if no rows are affected	Does not fire if the triggering event does not affect any rows

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Types of DML Triggers

You can specify that the trigger will be executed once for every row affected by the triggering statement (such as a multiple row `UPDATE`) or once for the triggering statement, no matter how many rows it affects.

Statement Trigger

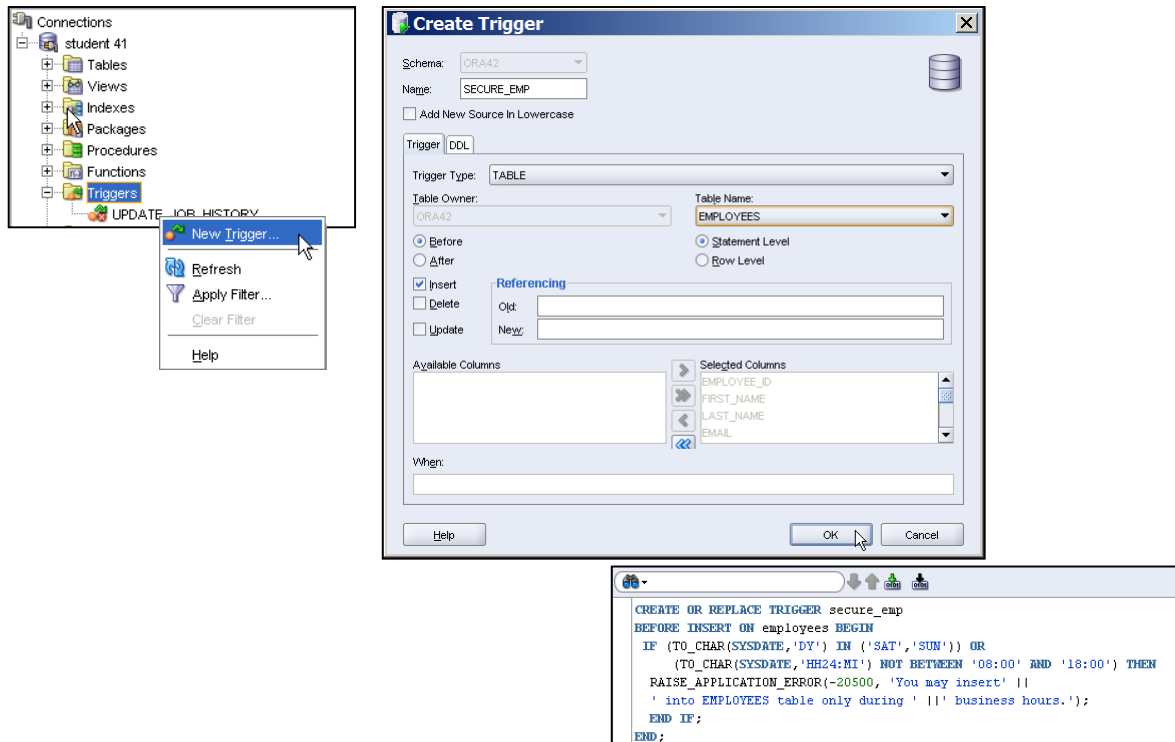
A statement trigger is fired once on behalf of the triggering event, even if no rows are affected at all. Statement triggers are useful if the trigger action does not depend on the data from rows that are affected or on data provided by the triggering event itself (for example, a trigger that performs a complex security check on the current user).

Row Trigger

A row trigger fires each time the table is affected by the triggering event. If the triggering event affects no rows, a row trigger is not executed. Row triggers are useful if the trigger action depends on data of rows that are affected or on data provided by the triggering event itself.

Note: Row triggers use correlation names to access the old and new column values of the row being processed by the trigger.

Creating DML Triggers Using SQL Developer



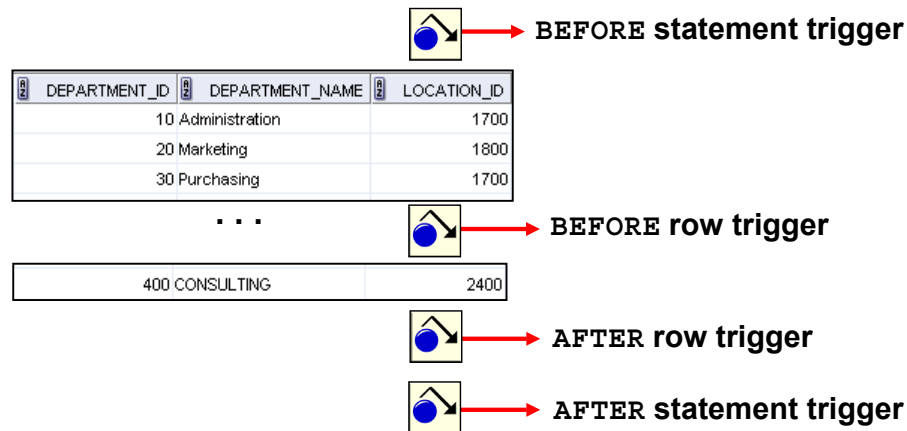
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Trigger-Firing Sequence: Single-Row Manipulation

Use the following firing sequence for a trigger on a table when a single row is manipulated:

```
INSERT INTO departments
  (department_id, department_name, location_id)
VALUES (400, 'CONSULTING', 2400);
```



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Trigger-Firing Sequence: Single-Row Manipulation

Create a statement trigger or a row trigger based on the requirement that the trigger must fire once for each row affected by the triggering statement, or just once for the triggering statement, regardless of the number of rows affected.

When the triggering DML statement affects a single row, both the statement trigger and the row trigger fire exactly once.

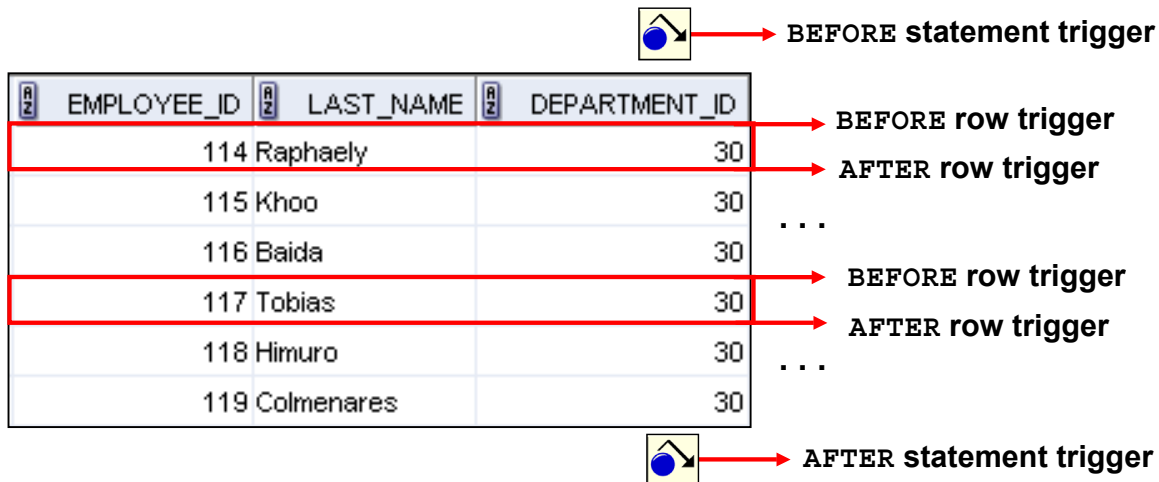
Example

The SQL statement in the slide does not differentiate statement triggers from row triggers because exactly one row is inserted into the table using the syntax for the INSERT statement shown in the slide.

Trigger-Firing Sequence: Multirow Manipulation

Use the following firing sequence for a trigger on a table when many rows are manipulated:

```
UPDATE employees  
  SET salary = salary * 1.1  
  WHERE department_id = 30;
```



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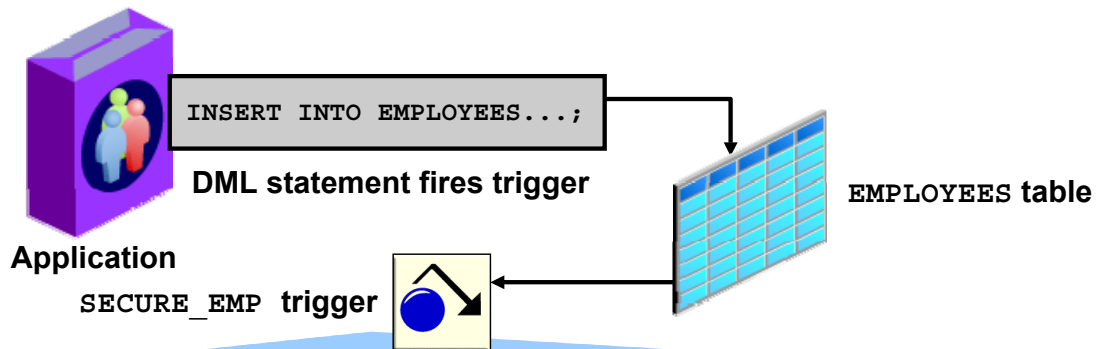
Trigger-Firing Sequence: Multirow Manipulation

When the triggering DML statement affects many rows, the statement trigger fires exactly once, and the row trigger fires once for every row affected by the statement.

Example

The SQL statement in the slide causes a row-level trigger to fire a number of times equal to the number of rows that satisfy the WHERE clause (that is, the number of employees reporting to department 30).

Creating a DML Statement Trigger Example: SECURE_EMP



```
CREATE OR REPLACE TRIGGER secure_emp
BEFORE INSERT ON employees
BEGIN
  IF (TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN')) OR
    (TO_CHAR(SYSDATE,'HH24:MI')
     NOT BETWEEN '08:00' AND '18:00') THEN
    RAISE_APPLICATION_ERROR(-20500, 'You may insert'
      || ' into EMPLOYEES table only during '
      || ' normal business hours.');
```

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Creating a DML Statement Trigger

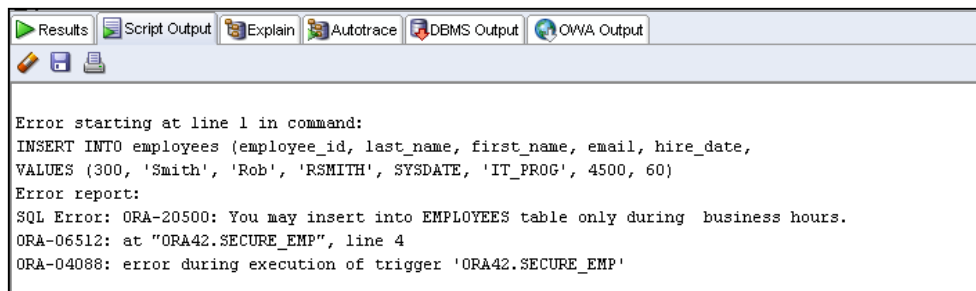
In the slide example, the SECURE_EMP database trigger is a BEFORE statement trigger that prevents the INSERT operation from succeeding if the business condition is violated. In this case, the trigger restricts inserts into the EMPLOYEES table during certain business hours, Monday through Friday.

If a user attempts to insert a row into the EMPLOYEES table on Saturday, then the user sees an error message, the trigger fails, and the triggering statement is rolled back. Remember that the RAISE_APPLICATION_ERROR is a server-side built-in procedure that returns an error to the user and causes the PL/SQL block to fail.

When a database trigger fails, the triggering statement is automatically rolled back by the Oracle server.

Testing Trigger SECURE_EMP

```
INSERT INTO employees (employee_id, last_name,  
    first_name, email, hire_date,  
    job_id, salary, department_id)  
VALUES (300, 'Smith', 'Rob', 'RSMITH', SYSDATE,  
    'IT_PROG', 4500, 60);
```



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Testing SECURE_EMP

To test the trigger, insert a row into the EMPLOYEES table during nonbusiness hours. When the date and time are out of the business hours specified in the trigger, you receive the error message shown in the slide.

Using Conditional Predicates

```
CREATE OR REPLACE TRIGGER secure_emp BEFORE
INSERT OR UPDATE OR DELETE ON employees
BEGIN
    IF (TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN')) OR
       (TO_CHAR(SYSDATE,'HH24')
        NOT BETWEEN '08' AND '18') THEN
        IF DELETING THEN RAISE_APPLICATION_ERROR(
            -20502,'You may delete from EMPLOYEES table' ||
            'only during normal business hours.');
```

```
        ELSIF INSERTING THEN RAISE_APPLICATION_ERROR(
            -20500,'You may insert into EMPLOYEES table' ||
            'only during normal business hours.');
```

```
        ELSIF UPDATING ('SALARY') THEN
            RAISE_APPLICATION_ERROR(-20503, 'You may ' ||
            'update SALARY only normal during business hours.');
```

```
        ELSE RAISE_APPLICATION_ERROR(-20504,'You may' ||
            ' update EMPLOYEES table only during' ||
            ' normal business hours.');
```

```
    END IF;
END IF;
END;
```

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Detecting the DML Operation that Fired a Trigger

If more than one type of DML operation can fire a trigger (for example, ON INSERT OR DELETE OR UPDATE OF Emp_tab), the trigger body can use the conditional predicates INSERTING, DELETING, and UPDATING to check which type of statement fired the trigger.

You can combine several triggering events into one by taking advantage of the special conditional predicates INSERTING, UPDATING, and DELETING within the trigger body.

Example

Create one trigger to restrict all data manipulation events on the EMPLOYEES table to certain business hours, Monday through Friday.

Creating a DML Row Trigger

```
CREATE OR REPLACE TRIGGER restrict_salary
BEFORE INSERT OR UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  IF NOT (:NEW.job_id IN ('AD_PRES', 'AD_VP'))
    AND :NEW.salary > 15000 THEN
    RAISE APPLICATION_ERROR (-20202,
      'Employee cannot earn more than $15,000.');
```

```
END IF;
END;/

UPDATE employees
SET salary = 15500
WHERE last_name = 'Russell';
```

```
Error starting at line 1 in command:
UPDATE employees
SET salary = 15500
WHERE last_name = 'Russell'
Error report:
SQL Error: ORA-20202: Employee cannot earn more than $15,000.
ORA-06512: at "ORA62.RESTRICT_SALARY", line 4
ORA-04088: error during execution of trigger 'ORA62.RESTRICT_SALARY'
```

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Creating a DML Row Trigger

You can create a BEFORE row trigger in order to prevent the triggering operation from succeeding if a certain condition is violated.

In the first slide example, a trigger is created to allow only employees whose job IDs are either AD_PRES or AD_VP to earn a salary of more than 15,000. If you try to update the salary of employee Russell whose employee id is SA_MAN, the trigger raises the exception displayed in the slide.

Using OLD and NEW Qualifiers

- When a row-level trigger fires, the PL/SQL run-time engine creates and populates two data structures:
 - OLD: Stores the original values of the record processed by the trigger
 - NEW: Contains the new values
- NEW and OLD have the same structure as a record declared using the %ROWTYPE on the table to which the trigger is attached.

Data Operations	Old Value	New Value
INSERT	NULL	Inserted value
UPDATE	Value before update	Value after update
DELETE	Value before delete	NULL

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Using OLD and NEW Qualifiers

Within a ROW trigger, you can reference the value of a column before and after the data change by prefixing it with the OLD and NEW qualifiers.

Note

- The OLD and NEW qualifiers are available only in ROW triggers.
- Prefix these qualifiers with a colon (:) in every SQL and PL/SQL statement.
- There is no colon (:) prefix if the qualifiers are referenced in the WHEN restricting condition.
- Row triggers can decrease the performance if you perform many updates on larger tables.

Using OLD and NEW Qualifiers: Example

```
CREATE OR REPLACE TRIGGER audit_emp_values
AFTER DELETE OR INSERT OR UPDATE ON employees
FOR EACH ROW
BEGIN
    INSERT INTO audit_emp(user_name, time_stamp, id,
        old_last_name, new_last_name, old_title,
        new_title, old_salary, new_salary)
    VALUES (USER, SYSDATE, :OLD.employee_id,
        :OLD.last_name, :NEW.last_name, :OLD.job_id,
        :NEW.job_id, :OLD.salary, :NEW.salary);
END;
/
```

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Using OLD and NEW Qualifiers: Example

In the slide example, the AUDIT_EMP_VALUES trigger is created on the EMPLOYEES table. The trigger adds rows to a user table, AUDIT_EMP, logging a user's activity against the EMPLOYEES table. The trigger records the values of several columns both before and after the data changes by using the OLD and NEW qualifiers with the respective column name.

Using OLD and NEW Qualifiers: Example Using AUDIT_EMP

```

INSERT INTO employees (employee_id, last_name, job_id,
salary, email, hire_date)
VALUES (999, 'Temp emp', 'SA_REP', 6000, 'TEMPEMP',
TRUNC(SYSDATE));
/
UPDATE employees
SET salary = 7000, last_name = 'Smith'
WHERE employee_id = 999;
/
SELECT *
FROM audit_emp;

```

	USER_NAME	TIME_STAMP	ID	OLD_LAST_NAME	NEW_LAST_NAME	OLD_TITLE	NEW_TITLE	OLD_SALARY	NEW_SALARY
1	ORA62	27-JUN-07	(null) (null)	Temp emp	(null)	SA_REP	(null)	6000	
2	ORA62	27-JUN-07	999 Temp emp	Smith	SA_REP	SA_REP		6000	7000

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Using OLD and NEW Qualifiers: Example Using AUDIT_EMP

Create a trigger on the EMPLOYEES table to add rows to a user table, AUDIT_EMP, logging a user's activity against the EMPLOYEES table. The trigger records the values of several columns both before and after the data changes by using the OLD and NEW qualifiers with the respective column name.

The following is the result of inserting the employee record into the EMPLOYEES table:

EMPLOYEE_ID	FIRST_NAME	LAST_NAME	PHONE_NUMBER	EMAIL	HIRE_DATE	JOB_ID	SALARY	COMMISSION_PCT	MANAGER_ID	DEPARTMENT_ID
999	(null)	Temp emp	(null)	TEMPEMP	08-MAY-07	SA_REP	6000	(null)	(null)	(null)
206	William	Gietz	515.123.8181	WGIEZT	07-JUN-94	AC_A...	8300	(null)	205	110
205	Shelley	Higgins	515.123.8080	SHIGGINS	07-JUN-94	AC_M...	12000	(null)	101	110

...

The following is the result of updating the salary for employee "Smith":

EMPLOYEE_ID	FIRST_NAME	LAST_NAME	PHONE_NUMBER	EMAIL	HIRE_DATE	JOB_ID	SALARY	COMMISSION_PCT	MANAGER_ID	DEPARTMENT_ID
999	(null)	Smith	(null)	TEMPEMP	08-MAY-07	SA_REP	7000	(null)	(null)	

...

Using the WHEN Clause to Fire a Row Trigger Based on a Condition

```
CREATE OR REPLACE TRIGGER derive_commission_pct
BEFORE INSERT OR UPDATE OF salary ON employees
FOR EACH ROW
WHEN (NEW.job_id = 'SA_REP')
BEGIN
    IF INSERTING THEN
        :NEW.commission_pct := 0;
    ELSIF :OLD.commission_pct IS NULL THEN
        :NEW.commission_pct := 0;
    ELSE
        :NEW.commission_pct := :OLD.commission_pct+0.05;
    END IF;
END;
/
```

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Restricting a Row Trigger: Example

Optionally, you can include a trigger restriction in the definition of a row trigger by specifying a Boolean SQL expression in a WHEN clause. If you include a WHEN clause in the trigger, then the expression in the WHEN clause is evaluated for each row that the trigger affects.

If the expression evaluates to TRUE for a row, then the trigger body executes on behalf of that row. However, if the expression evaluates to FALSE or NOT TRUE for a row (unknown, as with nulls), then the trigger body does not execute for that row. The evaluation of the WHEN clause does not have an effect on the execution of the triggering SQL statement (in other words, the triggering statement is not rolled back if the expression in a WHEN clause evaluates to FALSE).

Note: A WHEN clause cannot be included in the definition of a statement trigger.

In the slide example, a trigger is created on the EMPLOYEES table to calculate an employee's commission when a row is added to the EMPLOYEES table, or when an employee's salary is modified.

The NEW qualifier cannot be prefixed with a colon in the WHEN clause because the WHEN clause is outside the PL/SQL blocks.

Summary of the Trigger Execution Model

1. Execute all BEFORE STATEMENT triggers.
2. Loop *for each row* affected by the SQL statement:
 - a. Execute all BEFORE ROW triggers *for that row*.
 - b. Execute the DML statement and perform integrity constraint checking *for that row*.
 - c. Execute all AFTER ROW triggers *for that row*.
3. Execute all AFTER STATEMENT triggers.

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Trigger Execution Model

A single DML statement can potentially fire up to four types of triggers:

- BEFORE and AFTER statement triggers
- BEFORE and AFTER row triggers

A triggering event or a statement within the trigger can cause one or more integrity constraints to be checked. However, you can defer constraint checking until a COMMIT operation is performed.

Triggers can also cause other triggers—known as cascading triggers—to fire.

All actions and checks performed as a result of a SQL statement must succeed. If an exception is raised within a trigger and the exception is not explicitly handled, then all actions performed because of the original SQL statement are rolled back (including actions performed by firing triggers). This guarantees that integrity constraints can never be compromised by triggers.

When a trigger fires, the tables referenced in the trigger action may undergo changes by other users' transactions. In all cases, a read-consistent image is guaranteed for the modified values that the trigger needs to read (query) or write (update).

Note: Integrity checking can be deferred until the COMMIT operation is performed.

Implementing an Integrity Constraint with an After Trigger

```
-- Integrity constraint violation error -2992 raised.  
UPDATE employees SET department_id = 999  
WHERE employee_id = 170;
```

```
CREATE OR REPLACE TRIGGER employee_dept_fk_trg  
AFTER UPDATE OF department_id  
ON employees FOR EACH ROW  
BEGIN  
    INSERT INTO departments VALUES (:new.department_id,  
                                     'Dept ' || :new.department_id, NULL, NULL);  
EXCEPTION  
    WHEN DUP_VAL_ON_INDEX THEN  
        NULL; -- mask exception if department exists  
END; /
```

```
-- Successful after trigger is fired  
UPDATE employees SET department_id = 999  
WHERE employee_id = 170;
```

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Implementing an Integrity Constraint with an After Trigger

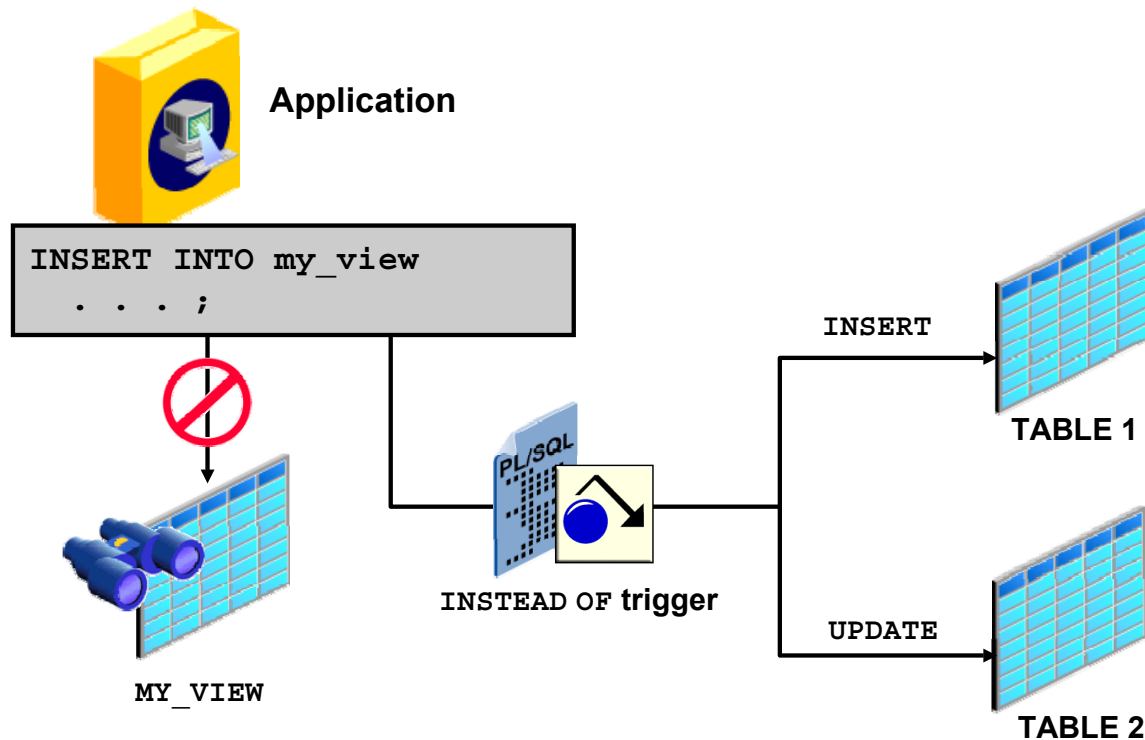
The example in the slide explains a situation in which the integrity constraint can be taken care of by using an After trigger. The EMPLOYEES table has a foreign key constraint on the DEPARTMENT_ID column of the DEPARTMENTS table.

In the first SQL statement, the DEPARTMENT_ID of the employee 170 is modified to 999. Because department 999 does not exist in the DEPARTMENTS table, the statement raises exception -2292 for the integrity constraint violation.

The EMPLOYEE_DEPT_FK_TRG trigger is created that inserts a new row into the DEPARTMENTS table, using :NEW.DEPARTMENT_ID for the value of the new department's DEPARTMENT_ID. The trigger fires when the UPDATE statement modifies the DEPARTMENT_ID of employee 170 to 999. When the foreign key constraint is checked, it is successful because the trigger inserted the department 999 into the DEPARTMENTS table.

Therefore, no exception occurs unless the department already exists when the trigger attempts to insert the new row. However, the EXCEPTION handler traps and masks the exception allowing the operation to succeed.

INSTEAD OF Triggers



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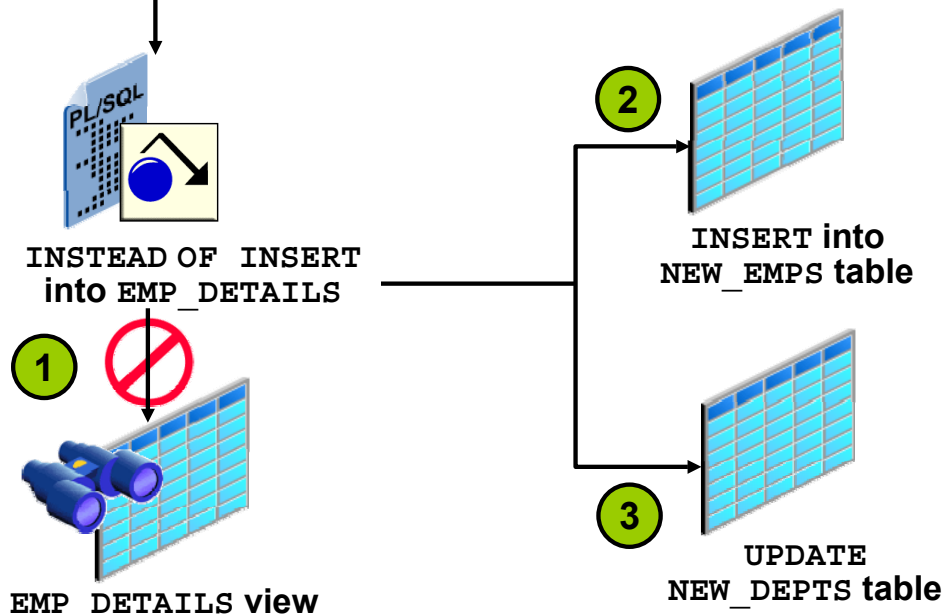
INSTEAD OF Triggers

Use **INSTEAD OF** triggers to modify data in which the DML statement has been issued against an inherently un-updatable view. These triggers are called **INSTEAD OF** triggers because, unlike other triggers, the Oracle server fires the trigger instead of executing the triggering statement. These triggers are used to perform **INSERT**, **UPDATE**, and **DELETE** operations directly on the underlying tables. You can write **INSERT**, **UPDATE**, and **DELETE** statements against a view, and the **INSTEAD OF** trigger works invisibly in the background to make the right actions take place. A view cannot be modified by normal DML statements if the view query contains set operators, group functions, clauses such as **GROUP BY**, **CONNECT BY**, **START**, the **DISTINCT** operator, or joins. For example, if a view consists of more than one table, an insert to the view may entail an insertion into one table and an update to another. So you write an **INSTEAD OF** trigger that fires when you write an insert against the view. Instead of the original insertion, the trigger body executes, which results in an insertion of data into one table and an update to another table.

Note: If a view is inherently updatable and has **INSTEAD OF** triggers, then the triggers take precedence. **INSTEAD OF** triggers are row triggers. The **CHECK** option for views is not enforced when insertions or updates to the view are performed by using **INSTEAD OF** triggers. The **INSTEAD OF** trigger body must enforce the check.

Creating an INSTEAD OF Trigger: Example

```
INSERT INTO emp_details  
VALUES (9001,'ABBOTT',3000, 10, 'Administration');
```



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Creating an INSTEAD OF Trigger

You can create an INSTEAD OF trigger in order to maintain the base tables on which a view is based.

The slide example illustrates an employee being inserted into the view EMP_DETAILS, whose query is based on the EMPLOYEES and DEPARTMENTS tables. The NEW_EMP_DEPT (INSTEAD OF) trigger executes in place of the INSERT operation that causes the trigger to fire. The INSTEAD OF trigger then issues the appropriate INSERT and UPDATE to the base tables used by the EMP_DETAILS view. Therefore, instead of inserting the new employee record into the EMPLOYEES table, the following actions take place:

1. The NEW_EMP_DEPT INSTEAD OF trigger fires.
2. A row is inserted into the NEW_EMPS table.
3. The DEPT_SAL column of the NEW_DEPTS table is updated. The salary value supplied for the new employee is added to the existing total salary of the department to which the new employee has been assigned.

Note: Before you run the slide example, you must create the required structures shown on the next two pages.

Creating an INSTEAD OF Trigger to Perform DML on Complex Views

```
CREATE TABLE new_emps AS
  SELECT employee_id,last_name,salary,department_id
     FROM employees;

CREATE TABLE new_depts AS
  SELECT d.department_id,d.department_name,
         sum(e.salary) dept_sal
     FROM employees e, departments d
    WHERE e.department_id = d.department_id;

CREATE VIEW emp_details AS
  SELECT e.employee_id, e.last_name, e.salary,
         e.department_id, d.department_name
     FROM employees e, departments d
    WHERE e.department_id = d.department_id
  GROUP BY d.department_id,d.department_name;
```

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Creating an INSTEAD OF Trigger (continued)

The example in the slide creates two new tables, NEW_EMPS and NEW_DEPTS, that are based on the EMPLOYEES and DEPARTMENTS tables, respectively. It also creates an EMP_DETAILS view from the EMPLOYEES and DEPARTMENTS tables.

If a view has a complex query structure, then it is not always possible to perform DML directly on the view to affect the underlying tables. The example requires creation of an INSTEAD OF trigger, called NEW_EMP_DEPT, shown on the next page. The NEW_DEPT_EMP trigger handles DML in the following way:

- When a row is inserted into the EMP_DETAILS view, instead of inserting the row directly into the view, rows are added into the NEW_EMPS and NEW_DEPTS tables, using the data values supplied with the INSERT statement.
- When a row is modified or deleted through the EMP_DETAILS view, corresponding rows in the NEW_EMPS and NEW_DEPTS tables are affected.

Note: INSTEAD OF triggers can be written only for views, and the BEFORE and AFTER timing options are not valid.

Creating an INSTEAD OF Trigger (continued)

```

CREATE OR REPLACE TRIGGER new_emp_dept
INSTEAD OF INSERT OR UPDATE OR DELETE ON emp_details
FOR EACH ROW
BEGIN
    IF INSERTING THEN
        INSERT INTO new_emps
        VALUES (:NEW.employee_id, :NEW.last_name,
                :NEW.salary, :NEW.department_id);
        UPDATE new_depts
        SET dept_sal = dept_sal + :NEW.salary
        WHERE department_id = :NEW.department_id;
    ELSIF DELETING THEN
        DELETE FROM new_emps
        WHERE employee_id = :OLD.employee_id;
        UPDATE new_depts
        SET dept_sal = dept_sal - :OLD.salary
        WHERE department_id = :OLD.department_id;
    ELSIF UPDATING ('salary') THEN
        UPDATE new_emps
        SET salary = :NEW.salary
        WHERE employee_id = :OLD.employee_id;
        UPDATE new_depts
        SET dept_sal = dept_sal +
            (:NEW.salary - :OLD.salary)
        WHERE department_id = :OLD.department_id;
    ELSIF UPDATING ('department_id') THEN
        UPDATE new_emps
        SET department_id = :NEW.department_id
        WHERE employee_id = :OLD.employee_id;
        UPDATE new_depts
        SET dept_sal = dept_sal - :OLD.salary
        WHERE department_id = :OLD.department_id;
        UPDATE new_depts
        SET dept_sal = dept_sal + :NEW.salary
        WHERE department_id = :NEW.department_id;
    END IF;
END;
/

```

DEPARTMENT_ID	DEPARTMENT_NAME	DEPT_SAL
10	Administration	7400

1 rows selected

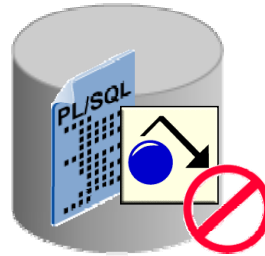
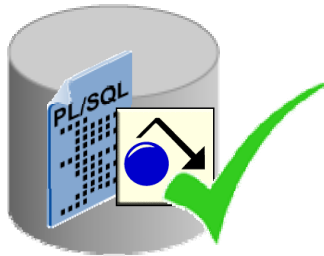
EMPLOYEE_ID	LAST_NAME	SALARY	DEPARTMENT_ID
200	Whalen	4400	10
9001	ABBOTT	3000	10

2 rows selected

The Status of a Trigger

A trigger is in either of two distinct modes:

- Enabled: The trigger runs its trigger action if a triggering statement is issued and the trigger restriction (if any) evaluates to true (default).
- Disabled: The trigger does not run its trigger action, even if a triggering statement is issued and the trigger restriction (if any) would evaluate to true.



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Creating a Disabled Trigger

- Before Oracle Database 11g, if you created a trigger whose body had a PL/SQL compilation error, then DML to the table failed.
- In Oracle Database 11g, you can create a disabled trigger and then enable it only when you know it will be compiled successfully.

```
CREATE OR REPLACE TRIGGER mytrg
  BEFORE INSERT ON mytable FOR EACH ROW
  DISABLE
BEGIN
  :New.ID := my_seq.Nextval;
  . . .
END;
/
```

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Creating a Disabled Trigger

Before Oracle Database 11g, if you created a trigger whose body had a PL/SQL compilation error, then DML to the table failed. The following error message was displayed:

ORA-04098: trigger 'TRG' is invalid and failed re-validation

In Oracle Database 11g, you can create a disabled trigger, and then enable it only when you know it will be compiled successfully.

You can also temporarily disable a trigger in the following situations:

- An object it references is not available.
- You need to perform a large data load, and you want it to proceed quickly without firing triggers.
- You are reloading data.

Note: The slide code example assumes that you have an existing sequence named my_seq.

Managing Triggers Using the ALTER and DROP SQL Statements

```
-- Disable or reenableView a database trigger:
```

```
ALTER TRIGGER trigger_name DISABLE | ENABLE;
```

```
-- Disable or reenableView all triggers for a table:
```

```
ALTER TABLE table_name DISABLE | ENABLE ALL TRIGGERS;
```

```
-- Recompile a trigger for a table:
```

```
ALTER TRIGGER trigger_name COMPILE;
```

```
-- Remove a trigger from the database:
```

```
DROP TRIGGER trigger_name;
```

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Managing Triggers

A trigger has two modes or states: ENABLED and DISABLED. When a trigger is first created, it is enabled by default. The Oracle server checks integrity constraints for enabled triggers and guarantees that triggers cannot compromise them. In addition, the Oracle server provides read-consistent views for queries and constraints, manages the dependencies, and provides a two-phase commit process if a trigger updates remote tables in a distributed database.

Disabling a Trigger

Use the ALTER TRIGGER command to disable a trigger. You can also disable all triggers on a table by using the ALTER TABLE command. You can disable triggers to improve performance or to avoid data integrity checks when loading massive amounts of data with utilities such as SQL*Loader. You might also disable a trigger when it references a database object that is currently unavailable, due to a failed network connection, disk crash, offline data file, or offline tablespace.

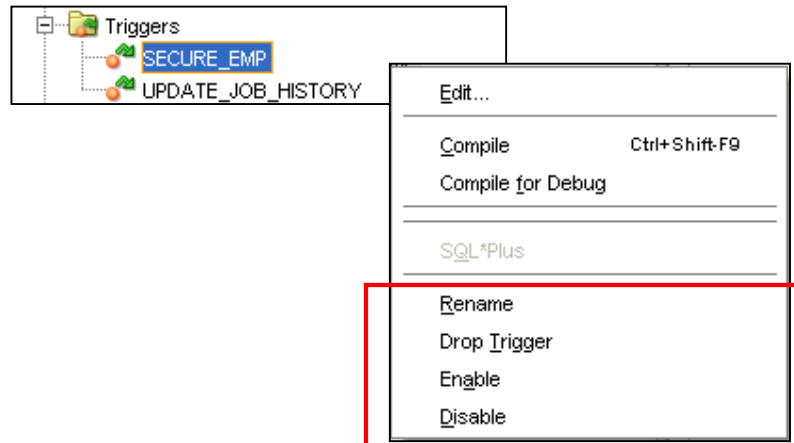
Recompiling a Trigger

Use the ALTER TRIGGER command to explicitly recompile a trigger that is invalid.

Removing Triggers

When a trigger is no longer required, use a SQL statement in SQL Developer or SQL*Plus to remove it. When you remove a table, all triggers on that table are also removed.

Managing Triggers Using SQL Developer



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Managing Triggers Using SQL Developer

You can use the Triggers node in the Connections navigation tree to manage triggers. Right-click a trigger name, and then select one of the following options:

- Edit
- Compile
- Compile for Debug
- Rename
- Drop Trigger
- Enable
- Disable

Testing Triggers

- Test each triggering data operation, as well as non-triggering data operations.
- Test each case of the `WHEN` clause.
- Cause the trigger to fire directly from a basic data operation, as well as indirectly from a procedure.
- Test the effect of the trigger on other triggers.
- Test the effect of other triggers on the trigger.

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Testing Triggers

Testing code can be a time-consuming process. Do the following when testing triggers:

- Ensure that the trigger works properly by testing a number of cases separately:
 - Test the most common success scenarios first.
 - Test the most common failure conditions to see that they are properly managed.
- The more complex the trigger, the more detailed your testing is likely to be. For example, if you have a row trigger with a `WHEN` clause specified, then you should ensure that the trigger fires when the conditions are satisfied. Or, if you have cascading triggers, you need to test the effect of one trigger on the other and ensure that you end up with the desired results.
- Use the `DBMS_OUTPUT` package to debug triggers.

Viewing Trigger Information

You can view the following trigger information:

Data Dictionary View	Description
USER_OBJECTS	Displays object information
USER/ALL/DBA_TRIGGERS	Displays trigger information
USER_ERRORS	Displays PL/SQL syntax errors for a trigger

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Viewing Trigger Information

The slide shows the data dictionary views that you can access to get information regarding the triggers.

The USER_OBJECTS view contains the name and status of the trigger and the date and time when the trigger was created.

The USER_ERRORS view contains the details about the compilation errors that occurred while a trigger was compiling. The contents of these views are similar to those for subprograms.

The USER_TRIGGERS view contains details such as name, type, triggering event, the table on which the trigger is created, and the body of the trigger.

The `SELECT Username FROM USER_USERS;` statement gives the name of the owner of the trigger, not the name of the user who is updating the table.

Using USER_TRIGGERS

```
DESCRIBE user_triggers
```

Name	Null	Type
TRIGGER_NAME		VARCHAR2(30)
TRIGGER_TYPE		VARCHAR2(16)
TRIGGERING_EVENT		VARCHAR2(227)
TABLE_OWNER		VARCHAR2(30)
BASE_OBJECT_TYPE		VARCHAR2(16)
TABLE_NAME		VARCHAR2(30)
COLUMN_NAME		VARCHAR2(4000)
REFERENCING_NAMES		VARCHAR2(128)
WHEN_CLAUSE		VARCHAR2(4000)
STATUS		VARCHAR2(8)
DESCRIPTION		VARCHAR2(4000)
ACTION_TYPE		VARCHAR2(11)
TRIGGER_BODY		LONG()
CROSSEDITION		VARCHAR2(7)
14 rows selected		

```
SELECT trigger_type, trigger_body
FROM user_triggers
WHERE trigger_name = 'SECURE_EMP';
```

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Using USER_TRIGGERS

If the source file is unavailable, then you can use the SQL Worksheet in SQL Developer or SQL*Plus to regenerate it from USER_TRIGGERS. You can also examine the ALL_TRIGGERS and DBA_TRIGGERS views, each of which contains the additional column OWNER, for the owner of the object. The result for the second slide example is as follows:

TRIGGER_TYPE	TRIGGER_BODY
BEFORE STATEMENT	<pre>BEGIN IF (TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN')) OR (TO_CHAR(SYSDATE,'HH24') NOT BETWEEN '08' AND '18') THEN IF DELETING THEN RAISE_APPLICATION_ERROR(-20502, 'You may delete from EMPLOYEES table only during normal business hours.');</pre>

Quiz

A triggering event can be one or more of the following:

1. An INSERT, UPDATE, or DELETE statement on a specific table (or view, in some cases)
2. A CREATE, ALTER, or DROP statement on any schema object
3. A database startup or instance shutdown
4. A specific error message or any error message
5. A user logon or logoff

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Answers: 1, 2, 3, 4, 5

Summary

In this lesson, you should have learned how to:

- Create database triggers that are invoked by DML operations
- Create statement and row trigger types
- Use database trigger-firing rules
- Enable, disable, and manage database triggers
- Develop a strategy for testing triggers
- Remove database triggers

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Summary

This lesson covered creating database triggers that execute before, after, or instead of a specified DML operation. Triggers are associated with database tables or views. The `BEFORE` and `AFTER` timings apply to DML operations on tables. The `INSTEAD OF` trigger is used as a way to replace DML operations on a view with appropriate DML statements against other tables in the database.

Triggers are enabled by default but can be disabled to suppress their operation until enabled again. If business rules change, triggers can be removed or altered as required.

Practice 9 Overview: Creating Statement and Row Triggers

This practice covers the following topics:

- Creating row triggers
- Creating a statement trigger
- Calling procedures from a trigger

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Practice 9: Overview

In this practice, you create statement and row triggers. You also create procedures that are invoked from within the triggers.

Practice 9

1. The rows in the JOBS table store a minimum and maximum salary allowed for different JOB_ID values. You are asked to write code to ensure that employees' salaries fall in the range allowed for their job type, for insert and update operations.
 - a. Create a procedure called CHECK_SALARY as follows:
 - i. The procedure accepts two parameters, one for an employee's job ID string and the other for the salary.
 - ii. The procedure uses the job ID to determine the minimum and maximum salary for the specified job.
 - iii. If the salary parameter does not fall within the salary range of the job, inclusive of the minimum and maximum, then it should raise an application exception, with the message "Invalid salary <sal>. Salaries for job <jobid> must be between <min> and <max>". Replace the various items in the message with values supplied by parameters and variables populated by queries. Save the file.
 - b. Create a trigger called CHECK_SALARY_TRG on the EMPLOYEES table that fires before an INSERT or UPDATE operation on each row:
 - i. The trigger must call the CHECK_SALARY procedure to carry out the business logic.
 - ii. The trigger should pass the new job ID and salary to the procedure parameters.
2. Test the CHECK_SAL_TRG using the following cases:
 - a. Using your EMP_PKG.ADD_EMPLOYEE procedure, add employee Eleanor Beh to department 30. What happens and why?
 - b. Update the salary of employee 115 to \$2,000. In a separate update operation, change the employee job ID to HR_REP. What happens in each case?
 - c. Update the salary of employee 115 to \$2,800. What happens?
3. Update the CHECK_SALARY_TRG trigger to fire only when the job ID or salary values have actually changed.
 - a. Implement the business rule using a WHEN clause to check whether the JOB_ID or SALARY values have changed.

Note: Make sure that the condition handles the NULL in the OLD.column_name values if an INSERT operation is performed; otherwise, an INSERT operation will fail.

Practice 9 (continued)

- b. Test the trigger by executing the `EMP_PKG.ADD_EMPLOYEE` procedure with the following parameter values:
 - `p_first_name: 'Eleanor'`
 - `p_last name: 'Beh'`
 - `p_Email: 'EBEH'`
 - `p_Job: 'IT_PROG'`
 - `p_Sal: 5000`
 - c. Update employees with the `IT_PROG` job by incrementing their salary by \$2,000. What happens?
 - d. Update the salary to \$9,000 for Eleanor Beh.
Hint: Use an `UPDATE` statement with a subquery in the `WHERE` clause. What happens?
 - e. Change the job of Eleanor Beh to `ST_MAN` using another `UPDATE` statement with a subquery. What happens?
4. You are asked to prevent employees from being deleted during business hours.
- a. Write a statement trigger called `DELETE_EMP_TRG` on the `EMPLOYEES` table to prevent rows from being deleted during weekday business hours, which are from 9:00 AM through 6:00 PM.
 - b. Attempt to delete employees with `JOB_ID` of `SA_REP` who are not assigned to a department.
Hint: This is employee Grant with ID 178.

10

Creating Compound, DDL, and Event Database Triggers

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Objectives

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

- Describe compound triggers
- Describe mutating tables
- Create triggers on DDL statements
- Create triggers on system events
- Display information about triggers

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Lesson Aim

In this lesson, you learn how to create and use database triggers.

What Is a Compound Trigger?

A single trigger on a table that allows you to specify actions for each of the following four timing points:

- Before the firing statement
- Before each row that the firing statement affects
- After each row that the firing statement affects
- After the firing statement

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What Is a Compound Trigger?

Starting with Oracle Database 11g, you can use a compound trigger. A compound trigger is a single trigger on a table that allows you to specify actions for each of the four triggering timing points:

- Before the firing statement
- Before each row that the firing statement affects
- After each row that the firing statement affects
- After the firing statement

Note: For additional information about triggers, refer to the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)*.

Working with Compound Triggers

- The compound trigger body supports a common PL/SQL state that the code for each timing point can access.
- The compound trigger common state is:
 - Established when the triggering statement starts
 - Destroyed when the triggering statement completes
- A compound trigger has a declaration section and a section for each of its timing points.

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Working with Compound Triggers

The compound trigger body supports a common PL/SQL state that the code for each timing point can access. The common state is automatically destroyed when the firing statement completes, even when the firing statement causes an error. Your applications can avoid the mutating table error by allowing rows destined for a second table (such as a history table or an audit table) to accumulate and then bulk-inserting them.

Before Oracle Database 11g Release 1 (11.1), you needed to model the common state with an ancillary package. This approach was both cumbersome to program and subject to memory leak when the firing statement caused an error and the after-statement trigger did not fire. Compound triggers make PL/SQL easier for you to use and improve run-time performance and scalability.

The Benefits of Using a Compound Trigger

You can use compound triggers to:

- Program an approach where you want the actions you implement for the various timing points to share common data.
- Accumulate rows destined for a second table so that you can periodically bulk-insert them
- Avoid the mutating-table error (ORA-04091) by allowing rows destined for a second table to accumulate and then bulk-inserting them

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Timing-Point Sections of a Table Compound Trigger

A compound trigger defined on a table has one or more of the following timing-point sections. Timing-point sections must appear in the order shown in the table.

Timing Point	Compound Trigger Section
Before the triggering statement executes	BEFORE statement
After the triggering statement executes	AFTER statement
Before each row that the triggering statement affects	BEFORE EACH ROW
After each row that the triggering statement affects	AFTER EACH ROW

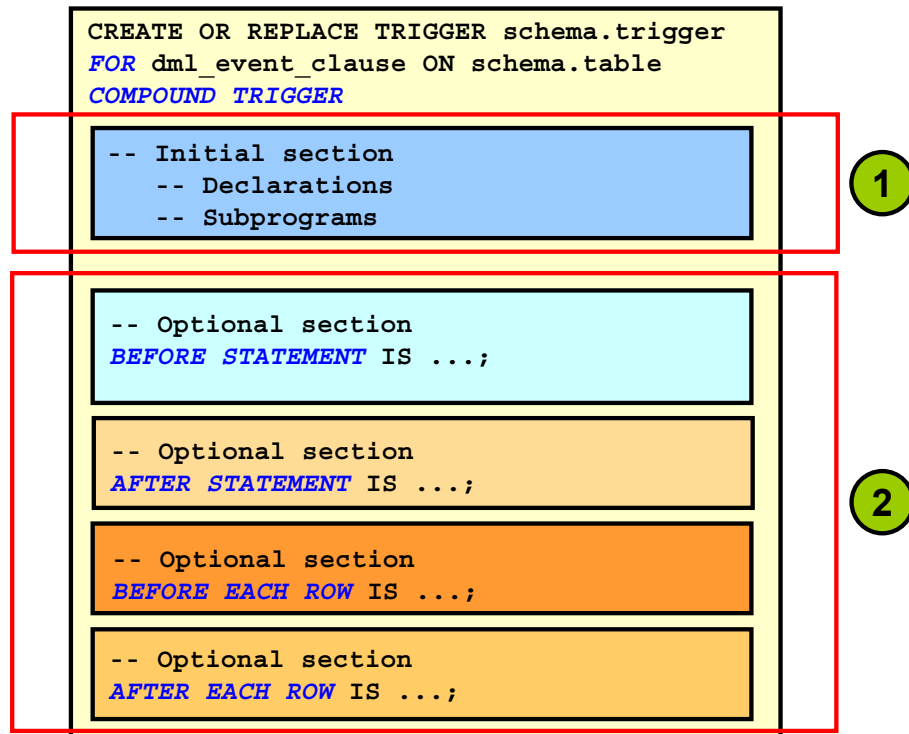
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Timing-Point Sections of a Table Compound Trigger

Note: Timing-point sections must appear in the order shown in the slide. If a timing-point section is absent, nothing happens at its timing point.

Compound Trigger Structure for Tables



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Compound Trigger Structure for Tables

A compound trigger has two main sections:

- An initial section where variables and subprograms are declared. The code in this section executes before any of the code in the optional section.
- An optional section that defines the code for each possible trigger point. Depending on whether you are defining a compound trigger for a table or for a view, these triggering points are different and are listed in the image shown above and on the following page. The code for the triggering points must follow the order shown above.

Note: For additional information about Compound Triggers, refer to the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)* guide.

Compound Trigger Structure for Views

```
CREATE OR REPLACE TRIGGER
schema.trigger

FOR dml_event_clause ON schema.view
COMPOUND TRIGGER

-- Initial section
-- Declarations
-- Subprograms

-- Optional section (exclusive)
INSTEAD OF EACH ROW IS
...;
```

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Compound Trigger Structure for Views

With views, the only allowed section is an INSTEAD OF EACH ROW clause.

Compound Trigger Restrictions

- A compound trigger must be a DML trigger and defined on either a table or a view.
- The body of a compound trigger must be compound trigger block, written in PL/SQL.
- A compound trigger body cannot have an initialization block; therefore, it cannot have an exception section.
- An exception that occurs in one section must be handled in that section. It cannot transfer control to another section.
- `:OLD` and `:NEW` cannot appear in the declaration, `BEFORE STATEMENT`, or the `AFTER STATEMENT` sections.
- Only the `BEFORE EACH ROW` section can change the value of `:NEW`.
- The firing order of compound triggers is not guaranteed unless you use the `FOLLOWS` clause.

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Compound Trigger Restrictions

The following are some of the restrictions when working with compound triggers:

- The body of a compound trigger must compound trigger block, written in PL/SQL.
- A compound trigger must be a DML trigger.
- A compound trigger must be defined on either a table or a view.
- A compound trigger body cannot have an initialization block; therefore, it cannot have an exception section. This is not a problem, because the `BEFORE STATEMENT` section always executes exactly once before any other timing-point section executes.
- An exception that occurs in one section must be handled in that section. It cannot transfer control to another section.
- `:OLD`, `:NEW`, and `:PARENT` cannot appear in the declaration section, the `BEFORE STATEMENT` section, or the `AFTER STATEMENT` section.
- The firing order of compound triggers is not guaranteed unless you use the `FOLLOWS` clause.

Trigger Restrictions on Mutating Tables

- A mutating table is:
 - A table that is being modified by an `UPDATE`, `DELETE`, or `INSERT` statement, or
 - A table that might be updated by the effects of a `DELETE CASCADE` constraint
- The session that issued the triggering statement cannot query or modify a mutating table.
- This restriction prevents a trigger from seeing an inconsistent set of data.
- This restriction applies to all triggers that use the `FOR EACH ROW` clause.
- Views being modified in the `INSTEAD OF` triggers are not considered mutating.

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Rules Governing Triggers

Reading and writing data using triggers is subject to certain rules. The restrictions apply only to row triggers, unless a statement trigger is fired as a result of `ON DELETE CASCADE`.

Mutating Table

A mutating table is a table that is currently being modified by an `UPDATE`, `DELETE`, or `INSERT` statement, or a table that might need to be updated by the effects of a declarative `DELETE CASCADE` referential integrity action. For `STATEMENT` triggers, a table is not considered a mutating table.

A mutating table error (`ORA-4091`) occurs when a row-level trigger attempts to change or examine a table that is already undergoing change via a DML statement.

The triggered table itself is a mutating table, as well as any table referencing it with the `FOREIGN KEY` constraint. This restriction prevents a row trigger from seeing an inconsistent set of data.

Mutating Table: Example

```
CREATE OR REPLACE TRIGGER check_salary
  BEFORE INSERT OR UPDATE OF salary, job_id
  ON employees
  FOR EACH ROW
  WHEN (NEW.job_id <> 'AD_PRES')
DECLARE
  v_minsalary employees.salary%TYPE;
  v_maxsalary employees.salary%TYPE;
BEGIN
  SELECT MIN(salary), MAX(salary)
    INTO  v_minsalary, v_maxsalary
    FROM  employees
    WHERE job_id = :NEW.job_id;
  IF :NEW.salary < v_minsalary OR :NEW.salary > v_maxsalary THEN
    RAISE_APPLICATION_ERROR(-20505,'Out of range');
  END IF;
END;
/
```

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Mutating Table: Example

The CHECK_SALARY trigger in the slide example attempts to guarantee that whenever a new employee is added to the EMPLOYEES table or whenever an existing employee's salary or job ID is changed, the employee's salary falls within the established salary range for the employee's job.

When an employee record is updated, the CHECK_SALARY trigger is fired for each row that is updated. The trigger code queries the same table that is being updated. Therefore, it is said that the EMPLOYEES table is a mutating table.

Mutating Table: Example

```
UPDATE employees
SET salary = 3400
WHERE last_name = 'Stiles';
```

```
TRIGGER check_salary Compiled.

Error starting at line 1 in command:
UPDATE employees
SET salary = 3400
WHERE last_name = 'Stiles'
Error report:
SQL Error: ORA-04091: table ORA42.EMPLOYEES is mutating, trigger/function may not see it
ORA-06512: at "ORA42.CHECK_SALARY", line 5
ORA-04088: error during execution of trigger 'ORA42.CHECK_SALARY'
04091. 00000 - "table %s.%s is mutating, trigger/function may not see it"
*Cause:      A trigger (or a user defined plsql function that is referenced in
              this statement) attempted to look at (or modify) a table that was
              in the middle of being modified by the statement which fired it.
*Action:      Rewrite the trigger (or function) so it does not read that table.
```

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Mutating Table: Example (continued)

In the slide example, the trigger code tries to read or select data from a mutating table.

If you restrict the salary within a range between the minimum existing value and the maximum existing value, then you get a run-time error. The EMPLOYEES table is mutating, or in a state of change; therefore, the trigger cannot read from it.

Remember that functions can also cause a mutating table error when they are invoked in a DML statement.

Possible Solutions

Possible solutions to this mutating table problem include the following:

- Use a compound trigger as described earlier in this lesson.
- Store the summary data (the minimum salaries and the maximum salaries) in another summary table, which is kept up-to-date with other DML triggers.
- Store the summary data in a PL/SQL package, and access the data from the package. This can be done in a BEFORE statement trigger.

Depending on the nature of the problem, a solution can become more convoluted and difficult to solve. In this case, consider implementing the rules in the application or middle tier and avoid using database triggers to perform overly complex business rules.

Using a Compound Trigger to Resolve the Mutating Table Error

```
CREATE OR REPLACE TRIGGER check_salary
FOR INSERT OR UPDATE OF salary, job_id
ON employees
WHEN (NEW.job_id <> 'AD_PRES')
COMPOUND TRIGGER

TYPE salaries_t          IS TABLE OF employees.salary%TYPE;
min_salaries              salaries_t;
max_salaries              salaries_t;

TYPE department_ids_t     IS TABLE OF employees.department_id%TYPE;
department_ids            department_ids_t;

TYPE department_salaries_t IS TABLE OF employees.salary%TYPE
INDEX BY VARCHAR2(80);
department_min_salaries   department_salaries_t;
department_max_salaries   department_salaries_t;

-- example continues on next slide
```

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Using a Compound Trigger to Resolve the Mutating Table Error

The CHECK_SALARY compound trigger resolves the mutating table error in the earlier example. This is achieved by storing the values in PL/SQL collections, and then performing a bulk insert/update in the “before statement” section of the compound trigger. In the slide example, PL/SQL collections are used. The element types used are based on the SALARY and DEPARTMENT_ID columns from the EMPLOYEES table. To create collections, you define a collection type, and then declare variables of that type. Collections are instantiated when you enter a block or subprogram, and cease to exist when you exit. min_salaries is used to hold the minimum salary for each department and max_salaries is used to hold the maximum salary for each department. department_ids is used to hold the department ids. If the employee who earns the minimum or maximum salary does not have an assigned department, you use the NVL function to store -1 for the department id instead of NULL. Next, you collect the minimum salary, maximum salary, and the department id using a bulk insert into the min_salaries, max_salaries, and department_ids respectively grouped by department ID. The select statement returns 13 rows. The values of the department_ids are used as an index for the department_min_salaries and department_max_salaries tables. Therefore, the index for those two tables (VARCHAR2) represents the actual department #s.

Using a Compound Trigger to Resolve the Mutating Table Error

```
. . .
BEFORE STATEMENT IS
BEGIN
    SELECT MIN(salary), MAX(salary), NVL(department_id, -1)
      BULK COLLECT INTO min_salaries, max_salaries, department_ids
    FROM     employees
    GROUP BY department_id;
    FOR j IN 1..department_ids.COUNT() LOOP
        department_min_salaries(department_ids(j)) := min_salaries(j);
        department_max_salaries(department_ids(j)) := max_salaries(j);
    END LOOP;
END BEFORE STATEMENT;

AFTER EACH ROW IS
BEGIN
    IF :NEW.salary < department_min_salaries(:NEW.department_id)
       OR :NEW.salary > department_max_salaries(:NEW.department_id) THEN
        RAISE_APPLICATION_ERROR(-20505, 'New Salary is out of acceptable
                                         range');
    END IF;
END AFTER EACH ROW;
END check_salary;
```

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Using a Compound Trigger to Resolve the Mutating Table Error (continued)

After each row is added, if the new salary is less than the minimum salary for that department or greater than the department's maximum salary, then an error message is displayed.

To test the newly created compound trigger, issue the following statement:

```
UPDATE employees
SET salary = 3400
WHERE last_name = 'Stiles';
```

CHECK_SALARY Compiled

To ensure that the salary for employee Stiles was updated, issue the following query:

```
SELECT employee_id, first_name, last_name, job_id, department_id,
       salary
FROM employees
WHERE last_name = 'Stiles';
```

	EMPLOYEE_ID	FIRST_NAME	LAST_NAME	JOB_ID	DEPARTMENT_ID	SALARY
1	138	Stephen	Stiles	ST_CLERK	50	3400

Comparing Database Triggers to Stored Procedures

Triggers	Procedures
Defined with <code>CREATE TRIGGER</code>	Defined with <code>CREATE PROCEDURE</code>
Data dictionary contains source code in <code>USER_TRIGGERS</code>	Data dictionary contains source code in <code>USER_SOURCE</code>
Implicitly invoked by DML	Explicitly invoked
<code>COMMIT</code> , <code>SAVEPOINT</code> , and <code>ROLLBACK</code> are not allowed	<code>COMMIT</code> , <code>SAVEPOINT</code> , and <code>ROLLBACK</code> are allowed

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Comparing Database Triggers and Stored Procedures

There are differences between database triggers and stored procedures:

Database Trigger

A database is invoked implicitly. `COMMIT`, `ROLLBACK`, and `SAVEPOINT` statements are not allowed within the trigger body; however, it is possible to commit or roll back indirectly by calling a procedure, but it is not recommended because of side effects to transactions.

Stored Procedure

A stored procedure is invoked explicitly. `COMMIT`, `ROLLBACK`, and `SAVEPOINT` statements are permitted within the procedure body.

Triggers are fully compiled when the `CREATE TRIGGER` command is issued and the executable code is stored in the data dictionary.

Note: If errors occur during the compilation of a trigger, the trigger is still created.

Comparing Database Triggers to Oracle Forms Triggers

Database Trigger	Forms Builder Trigger
Executed by actions from any database tool or application	Executed only within a particular Forms Builder application
Always triggered by a SQL DML, DDL, or a certain database event	Triggered by navigating from field to field, pressing a key, or many other actions
Can be a statement or row trigger	Can be a statement or row trigger
Upon failure, causes the triggering statement to roll back	Upon failure, causes the cursor to freeze and the entire transaction may roll back
Fires independently of, and in addition to, Forms Builder triggers	Fires independently of, and in addition to, database triggers
Executes under the security domain of the author of the trigger	Executes under the security domain of the Forms Builder user

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Creating Triggers on DDL Statements

```
CREATE [OR REPLACE] TRIGGER trigger_name
BEFORE | AFTER -- Timing
[ddl_event1 [OR ddl_event2 OR ...]]
ON {DATABASE | SCHEMA}
trigger_body
```

Sample DDL Events	Fires When
CREATE	Any database object is created using the CREATE command.
ALTER	Any database object is altered using the ALTER command.
DROP	Any database object is dropped using the DROP command.

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Creating Triggers on DDL Statements

You can specify one or more types of DDL statements that can cause the trigger to fire. You can create triggers for these events on DATABASE or SCHEMA unless otherwise noted. You can also specify BEFORE and AFTER for the timing of the trigger. The Oracle database fires the trigger in the existing user transaction.

You cannot specify as a triggering event any DDL operation performed through a PL/SQL procedure.

The trigger body in the syntax in the slide represents a complete PL/SQL block.

DDL triggers fire only if the object being created is a cluster, function, index, package, procedure, role, sequence, synonym, table, tablespace, trigger, type, view, or user.

Creating Database-Event Triggers

- Triggering user event:
 - CREATE, ALTER, or DROP
 - Logging on or off
- Triggering database or system event:
 - Shutting down or starting up the database
 - A specific error (or any error) being raised

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Creating Database Triggers

Before coding the trigger body, decide on the components of the trigger.

Triggers on system events can be defined at the database or schema level. For example, a database shutdown trigger is defined at the database level. Triggers on data definition language (DDL) statements, or a user logging on or off, can also be defined at either the database level or schema level. Triggers on data manipulation language (DML) statements are defined on a specific table or a view.

A trigger defined at the database level fires for all users whereas a trigger defined at the schema or table level fires only when the triggering event involves that schema or table.

Triggering events that can cause a trigger to fire:

- A data definition statement on an object in the database or schema
- A specific user (or any user) logging on or off
- A database shutdown or startup
- Any error that occurs

Creating Triggers on System Events

```
CREATE [OR REPLACE] TRIGGER trigger_name
BEFORE | AFTER -- timing
[database_event1 [OR database_event2 OR ...]]
ON {DATABASE | SCHEMA}
trigger_body
```

Database Event	Triggers Fires When
AFTER SERVERERROR	An Oracle error is raised
AFTER LOGON	A user logs on to the database
BEFORE LOGOFF	A user logs off the database
AFTER STARTUP	The database is opened
BEFORE SHUTDOWN	The database is shut down normally

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Creating Triggers on System Events

You can create triggers for the events listed in the table in the slide on DATABASE or SCHEMA, except SHUTDOWN and STARTUP, which apply only to DATABASE.

LOGON and LOGOFF Triggers: Example

```
-- Create the log_trig_table shown in the notes page
-- first
```

```
CREATE OR REPLACE TRIGGER logon_trig
AFTER LOGON ON SCHEMA
BEGIN
    INSERT INTO log_trig_table(user_id,log_date,action)
    VALUES (USER, SYSDATE, 'Logging on');
END;
/
```

```
CREATE OR REPLACE TRIGGER logoff_trig
BEFORE LOGOFF ON SCHEMA
BEGIN
    INSERT INTO log_trig_table(user_id,log_date,action)
    VALUES (USER, SYSDATE, 'Logging off');
END;
/
```

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LOGON and LOGOFF Triggers: Example

You can create these triggers to monitor how often you log on and off, or you may want to write a report that monitors the length of time for which you are logged on. When you specify ON SCHEMA, the trigger fires for the specific user. If you specify ON DATABASE, the trigger fires for all users.

The definition of the log_trig_table used in the slide examples is as follows:

```
CREATE TABLE log_trig_table(
    user_id VARCHAR2(30),
    log_date DATE,
    action VARCHAR2(40))
/
```

CALL Statements in Triggers

```
CREATE [OR REPLACE] TRIGGER trigger_name
  timing
  event1 [OR event2 OR event3]
  ON table_name
  [REFERENCING OLD AS old | NEW AS new]
  [FOR EACH ROW]
  [WHEN condition]
  CALL procedure_name
/
```

```
CREATE OR REPLACE PROCEDURE log_execution IS
BEGIN
  DBMS_OUTPUT.PUT_LINE('log_exection: Employee Inserted');
END;
/
CREATE OR REPLACE TRIGGER log_employee
  BEFORE INSERT ON EMPLOYEES
  CALL log_execution -- no semicolon needed
/
```

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CALL Statements in Triggers

A CALL statement enables you to call a stored procedure, rather than code the PL/SQL body in the trigger itself. The procedure can be implemented in PL/SQL, C, or Java.

The call can reference the trigger attributes :NEW and :OLD as parameters, as in the following example:

```
CREATE OR REPLACE TRIGGER salary_check
  BEFORE UPDATE OF salary, job_id ON employees
  FOR EACH ROW
  WHEN (NEW.job_id <> 'AD_PRES')
  CALL check_salary(:NEW.job_id, :NEW.salary)
```

Note: There is no semicolon at the end of the CALL statement.

In the preceding example, the trigger calls a `check_salary` procedure. The procedure compares the new salary with the salary range for the new job ID from the JOBS table.

Benefits of Database-Event Triggers

- Improved data security:
 - Provide enhanced and complex security checks
 - Provide enhanced and complex auditing
- Improved data integrity:
 - Enforce dynamic data integrity constraints
 - Enforce complex referential integrity constraints
 - Ensure that related operations are performed together implicitly

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Benefits of Database-Event Triggers

You can use database triggers:

- As alternatives to features provided by the Oracle server
- If your requirements are more complex or more simple than those provided by the Oracle server
- If your requirements are not provided by the Oracle server at all

System Privileges Required to Manage Triggers

The following system privileges are required to manage triggers:

- The `CREATE/ALTER/DROP (ANY) TRIGGER` privilege that enables you to create a trigger in any schema
- The `ADMINISTER DATABASE TRIGGER` privilege that enables you to create a trigger on `DATABASE`
- The `EXECUTE` privilege (if your trigger refers to any objects that are not in your schema)

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System Privileges Required to Manage Triggers

To create a trigger in your schema, you need the `CREATE TRIGGER` system privilege, and you must own the table specified in the triggering statement, have the `ALTER` privilege for the table in the triggering statement, or have the `ALTER ANY TABLE` system privilege. You can alter or drop your triggers without any further privileges being required.

If the `ANY` keyword is used, you can create, alter, or drop your own triggers and those in another schema and can be associated with any user's table.

You do not need any privileges to invoke a trigger in your schema. A trigger is invoked by DML statements that you issue. But if your trigger refers to any objects that are not in your schema, the user creating the trigger must have the `EXECUTE` privilege on the referenced procedures, functions, or packages, and not through roles.

To create a trigger on `DATABASE`, you must have the `ADMINISTER DATABASE TRIGGER` privilege. If this privilege is later revoked, you can drop the trigger but you cannot alter it.

Note: Similar to stored procedures, statements in the trigger body use the privileges of the trigger owner, not the privileges of the user executing the operation that fires the trigger.

Guidelines for Designing Triggers

- You can design triggers to:
 - Perform related actions
 - Centralize global operations
- You must not design triggers:
 - Where functionality is already built into the Oracle server
 - That duplicate other triggers
- You can create stored procedures and invoke them in a trigger, if the PL/SQL code is very lengthy.
- Excessive use of triggers can result in complex interdependencies, which may be difficult to maintain in large applications.

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Guidelines for Designing Triggers

- Use triggers to guarantee that related actions are performed for a specific operation and for centralized, global operations that should be fired for the triggering statement, independent of the user or application issuing the statement.
- Do not define triggers to duplicate or replace the functionality already built into the Oracle database. For example, implement integrity rules using declarative constraints instead of triggers. To remember the design order for a business rule:
 - Use built-in constraints in the Oracle server, such as primary key, and so on.
 - Develop a database trigger or an application, such as a servlet or Enterprise JavaBeans (EJB) on your middle tier.
 - Use a presentation interface, such as Oracle Forms, HTML, JavaServer Pages (JSP) and so on, for data presentation rules.
- Excessive use of triggers can result in complex interdependencies, which may be difficult to maintain. Use triggers when necessary, and be aware of recursive and cascading effects.
- Avoid lengthy trigger logic by creating stored procedures or packaged procedures that are invoked in the trigger body.
- Database triggers fire for every user each time the event occurs on the trigger that is created.

Quiz

A trigger:

1. Defined with a `CREATE TRIGGER` statement
2. Data dictionary contains source code in `USER_TRIGGERS`
3. Explicitly invoked
4. Implicitly invoked by DML
5. `COMMIT`, `SAVEPOINT`, and `ROLLBACK` are not allowed

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Answers: 1, 2, 4, 5

Summary

In this lesson, you should have learned how to:

- Describe compound triggers
- Describe mutating tables
- Create triggers on DDL statements
- Create triggers on system events
- Display information about triggers

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Practice 10: Overview

This practice covers the following topics:

- Creating advanced triggers to manage data integrity rules
- Creating triggers that cause a mutating table exception
- Creating triggers that use package state to solve the mutating table problem

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Practice 10: Overview

In this practice, you implement a simple business rule for ensuring data integrity of employees' salaries with respect to the valid salary range for their job. You create a trigger for this rule.

During this process, your new triggers cause a cascading effect with triggers created in the practice section of the previous lesson. The cascading effect results in a mutating table exception on the JOBS table. You then create a PL/SQL package and additional triggers to solve the mutating table issue.

Practice 10

1. Employees receive an automatic increase in salary if the minimum salary for a job is increased to a value larger than their current salary. Implement this requirement through a package procedure called by a trigger on the JOBS table. When you attempt to update the minimum salary in the JOBS table and try to update the employees' salary, the CHECK_SALARY trigger attempts to read the JOBS table, which is subject to change, and you get a mutating table exception that is resolved by creating a new package and additional triggers.
 - a. Update your EMP_PKG package (that you last updated in Practice 8) as follows:
 - i. Add a procedure called SET_SALARY that updates the employees' salaries.
 - ii. The SET_SALARY procedure accepts the following two parameters:
 - The job ID for those salaries that may have to be updated, and
 - The new minimum salary for the job ID
 - iii. The procedure sets all the employees' salaries to the minimum for their jobs if their current salaries are less than the new minimum value.
 - b. Create a row trigger named UPD_MINSALARY_TRG on the JOBS table that invokes the EMP_PKG.SET_SALARY procedure, when the minimum salary in the JOBS table is updated for a specified job ID.
 - c. Write a query to display the employee ID, last name, job ID, current salary, and minimum salary for employees who are programmers—that is, their JOB_ID is 'IT_PROG'. Then update the minimum salary in the JOBS table to increase it by \$1,000. What happens?
2. To resolve the mutating table issue, create a JOBS_PKG to maintain in memory a copy of the rows in the JOBS table. Next, modify the CHECK_SALARY procedure to use the package data rather than issue a query on a table that is mutating to avoid the exception. However, you must create a BEFORE INSERT OR UPDATE statement trigger on the EMPLOYEES table to initialize the JOBS_PKG package state before the CHECK_SALARY row trigger is fired.
 - a. Create a new package called JOBS_PKG with the following specification:


```
PROCEDURE initialize;
FUNCTION get_minsalary(jobid VARCHAR2) RETURN NUMBER;
FUNCTION get_maxsalary(jobid VARCHAR2) RETURN NUMBER;
PROCEDURE set_minsalary(jobid VARCHAR2,min_salary NUMBER);
PROCEDURE set_maxsalary(jobid VARCHAR2,max_salary NUMBER);
```

Practice 10 (continued)

- b. Implement the body of the JOBS_PKG, as follows:
 - i. Declare a private PL/SQL index-by table called jobs_tab_type that is indexed by a string type based on the JOBS.JOB_ID%TYPE.
 - ii. Declare a private variable called jobstab based on the jobs_tab_type.
 - iii. The INITIALIZE procedure reads the rows in the JOBS table by using a cursor loop, and uses the JOB_ID value for the jobstab index that is assigned its corresponding row.
 - iv. The GET_MINSALARY function uses a p_jobid parameter as an index to the jobstab and returns the min_salary for that element.
 - v. The GET_MAXSALARY function uses a p_jobid parameter as an index to the jobstab and returns the max_salary for that element.
 - vi. The SET_MINSALARY procedure uses its p_jobid as an index to the jobstab to set the min_salary field of its element to the value in the min_salary parameter.
 - vii. The SET_MAXSALARY procedure uses its p_jobid as an index to the jobstab to set the max_salary field of its element to the value in the max_salary parameter.
- c. Copy the CHECK_SALARY procedure from Practice 10, Exercise 1 a, and modify the code by replacing the query on the JOBS table with statements to set the local minsal and maxsal variables with values from the JOBS_PKG data by calling the appropriate GET_*SALARY functions. This step should eliminate the mutating trigger exception.
- d. Implement a BEFORE INSERT OR UPDATE statement trigger called INIT_JOBPKG_TRG that uses the CALL syntax to invoke the JOBS_PKG.INITIALIZE procedure to ensure that the package state is current before the DML operations are performed.
- e. Test the code changes by executing the query to display the employees who are programmers, and then issue an update statement to increase the minimum salary of the IT_PROG job type by 1000 in the JOBS table, followed by a query on the employees with the IT_PROG job type to check the resulting changes. Which employees' salaries have been set to the minimum for their jobs?

Practice 10 (continued)

3. Because the `CHECK_SALARY` procedure is fired by the `CHECK_SALARY_TRG` before inserting or updating an employee, you must check whether this still works as expected.
 - a. Test this by adding a new employee using `EMP_PKG.ADD_EMPLOYEE` with the following parameters: (`'Steve'`, `'Morse'`, `'SMORSE'`, and `sal => 6500`). What happens?
 - b. To correct the problem encountered when adding or updating an employee:
 - i. Create a `BEFORE INSERT OR UPDATE` statement trigger called `EMPLOYEE_INITJOBS_TRG` on the `EMPLOYEES` table that calls the `JOBS_PKG.INITIALIZE` procedure.
 - ii. Use the `CALL` syntax in the trigger body.
 - c. Test the trigger by adding employee `Steve Morse` again. Confirm the inserted record in the `EMPLOYEES` table by displaying the employee ID, first and last names, salary, job ID, and department ID.

11

Using the PL/SQL Compiler

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Objectives

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

- Describe the new PL/SQL compiler and features
- Use the new PL/SQL compiler initialization parameters
- Use the new PL/SQL compile time warnings

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Lesson Agenda

- Describing the new PL/SQL compiler and features
- Using the new PLSQL_CODE_TYPE, PLSQL_DEBUG, and PLSQL_OPTIMIZE_LEVEL PL/SQL compilation initialization parameters
- Using the new PL/SQL compile time warnings:
 - Using the PLSQL_WARNING initialization parameter
 - Using the DBMS_WARNING package routines

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Using the PL/SQL Compiler

- PL/SQL uses a new optimizing compiler that can rearrange code for better performance.
- PL/SQL performance is improved across the board.
- Most improvements are automatic.
- The default optimization level improves performance for a broad range of PL/SQL operations.



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Using the PL/SQL Compiler in Oracle Database 11g

Starting with Oracle Database 10g, the PL/SQL compiler back end was completely redesigned and re-implemented which featured code optimization. The new PL/SQL compiler replaced the old compiler and all modern and current industry compiler techniques have been incorporated. It has the following purposes:

- An immediate improvement in the quality of the code generated by the PL/SQL compiler and thus improvement in the execution performance of PL/SQL programs
- A foundation for global optimization to improve PL/SQL execution

What Is New for PL/SQL Performance Starting with Oracle Database 10g?

- PL/SQL performance is improved across the board.
- Most improvements are automatic.
- The new PL/SQL compiler ensures optimized code generation.
- Global optimization of PL/SQL code is controlled by the `PLSQL_OPTIMIZE_LEVEL` initialization parameter.
- The default optimization level improves performance for a broad range of PL/SQL operations.

Changes in the PL/SQL Compiler

- Elimination of compiler-generated temporary operands
- Computation of some operations during compilation
- Reuse of some expression values
- Simplification or elimination of some branches and dead code elimination
- Avoidance of library calls by direct execution in the PL/SQL virtual machine of some operations
- All cursors correctly finalized upon exit from a cursor loop or a declare block
- Elimination of computations whose only effect is, as a side effect, to raise an exception

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Changes in the PL/SQL Compiler

The new PL/SQL compiler provides the same execution for PL/SQL programs as the previous PL/SQL compiler. The behavior of a program is intended to remain the same. Some of the implicit changes that may happen to compiled code are the following:

- Elimination of temporary operands generated by the PL/SQL compiler. Such elimination causes less storage to be used and speeds up the process of initializing temporary values.
- Computation of some operations during compilation rather than during execution
- Reuse of some expression values. For example, if the expression $A + B$ occurs twice and the values of A and B are not changed, the second occurrence may be removed by the optimizer.
- Simplification or elimination of some branches
- Avoidance of library calls by direct execution in the PL/SQL virtual machine of some operations
- All cursors correctly finalized upon exit from a cursor loop or a declare block
- Elimination of computations whose only effect is, as a side effect, to raise an exception. If there are no other side effects of the conditional expression besides the possible exception, the PL/SQL compiler optimization eliminates the entire computation.

Lesson Agenda

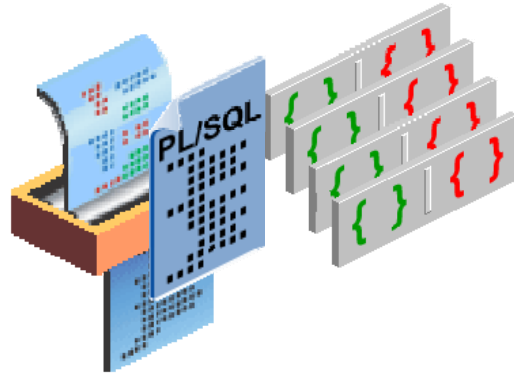
- Describing the new PL/SQL compiler and features
- **Using the new PLSQL_CODE_TYPE, PLSQL_DEBUG, and PLSQL_OPTIMIZE_LEVEL PL/SQL compilation initialization parameters**
- Using the new PL/SQL compile time warnings:
 - Using the PLSQL_WARNING initialization parameter
 - Using the DBMS_WARNING package routines

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Initialization Parameters for PL/SQL Compilation

- `PLSQL_CODE_TYPE`
- `PLSQL_OPTIMIZE_LEVEL`
- `PLSQL_CCFLAGS`
- `PLSQL_WARNINGS`



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Initialization Parameters for PL/SQL Compilation

In releases before Oracle Database 10g, the PL/SQL compiler translated your code to machine code without applying many changes for performance. Now, PL/SQL uses an optimizing compiler that can rearrange code for better performance. You do not need to do anything to get the benefits of this new optimizer; it is enabled by default.

Note

- The `PLSQL_CCFLAGS` initialization parameter is covered in the lesson titled “Managing PL/SQL Code.”
- The `PLSQL_WARNINGS` initialization parameter is covered later in this lesson.

Using the Initialization Parameters for PL/SQL Compilation

- `PLSQL_CODE_TYPE`: Specifies the compilation mode for PL/SQL library units

```
PLSQL_CODE_TYPE = { INTERPRETED | NATIVE }
```

- `PLSQL_OPTIMIZE_LEVEL`: Specifies the optimization level to be used to compile PL/SQL library units

```
PLSQL_OPTIMIZE_LEVEL = { 0 | 1 | 2 | 3 }
```

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Using the Initialization Parameters for PL/SQL Compilation

The `PLSQL_CODE_TYPE` Parameter

This parameter specifies the compilation mode for PL/SQL library units. If you choose `INTERPRETED`, PL/SQL library units will be compiled to PL/SQL bytecode format. Such 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) will be compiled to native (machine) code. Such modules will be executed natively without incurring any interpreter overhead. When the value of this parameter is changed, it has no effect on 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 will use native compilation. In Oracle Database 11g, native compilation is easier and more integrated, with fewer initialization parameters to set.

In rare cases, if the overhead of the optimizer makes compilation of very large applications take too long, you might lower the optimization level by setting the initialization parameter `PLSQL_OPTIMIZE_LEVEL` to 1 instead of its default value 2. In even rarer cases, you might see a change in exception behavior—either an exception that is not raised at all or one that is raised earlier than expected. Setting `PLSQL_OPTIMIZE_LEVEL` to 0 prevents the code from being rearranged at all.

Using the PL/SQL Initialization Parameters (continued)

The PLSQL_OPTIMIZE_LEVEL Parameter

This parameter specifies the optimization level that will be used to compile PL/SQL library units. The higher the setting of this parameter, the more effort the compiler makes to optimize PL/SQL library units. The available values are (0, 1, and 2 were available starting with Oracle 10g release 2):

0: Maintains the evaluation order and hence the pattern of side effects, exceptions, and package initializations of Oracle9i 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 code will run somewhat faster than it did in Oracle9i, use of level 0 will forfeit most of the performance gains of PL/SQL starting with Oracle Database 10g.

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 which may move source code relatively far from its original location

3: This value is new in Oracle Database 11g. 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.

Note: For additional information about inlining, refer to the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)* guide and the *Oracle Database 11g Advanced PL/SQL* instructor-led course.

Using the PL/SQL Initialization Parameters (continued)

The PLSQL_OPTIMIZE_LEVEL Parameter (continued)

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), then 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.

Note:

The PLSQL_CODE_TYPE parameter in Oracle Database 10g replaced the following obsolete parameters:

- PLSQL_NATIVE_C_COMPILER
- PLSQL_NATIVE_MAKE_FILE_NAME
- PLSQL_NATIVE_C_COMPILER
- PLSQL_NATIVE_MAKE_UTILITY
- PLSQL_NATIVE_LINKER

The PLSQL_DEBUG parameter is deprecated in Oracle Database 11g. The parameter PLSQL_DEBUG no longer controls the generation of debugging information by the PL/SQL compiler; debugging information is always generated and no special parameter is needed.

The New Compiler Settings Since Oracle 10g

Compiler Option	Description
PLSQL_CODE_TYPE	Specifies the compilation mode for PL/SQL library units.
PLSQL_OPTIMIZE_LEVEL	Specifies the optimization level to be used to compile PL/SQL library units.
PLSQL_WARNINGS	Enables or disables the reporting of warning messages by the PL/SQL compiler.
PLSQL_CCFLAGS	Controls conditional compilation of each PL/SQL library unit independently.

In general, for the fastest performance, use the following setting:

```
PLSQL_CODE_TYPE = NATIVE  
PLSQL_OPTIMIZE_LEVEL = 2
```

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The Compiler Settings

The new compiler increases the performance of PL/SQL code and allows it to execute approximately two times faster than an Oracle8i database and 1.5 times to 1.75 times as fast as Oracle9i Database Release 2.

To get the fastest performance, the compiler setting must be:

```
PLSQL_CODE_TYPE = NATIVE  
PLSQL_OPTIMIZE_LEVEL = 2
```

Displaying the PL/SQL Initialization Parameters

Use the USER | ALL | DBA_PLSQL_OBJECT_SETTINGS data dictionary views to display the settings for a PL/SQL object:

```
DESCRIBE USER_PLSQL_OBJECT_SETTINGS
```

Name	Null	Type
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)
9 rows selected		

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Displaying the PL/SQL Initialization Parameters

The columns of the USER_PLSQL_OBJECTS_SETTINGS data dictionary view are:

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 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 11g).

Displaying and Setting the PL/SQL Initialization Parameters

```
SELECT name, type, plsql_code_type AS CODE_TYPE,  
       plsql_optimize_level AS OPT_LVL  
FROM   user_plsql_object_settings;
```

...

AUDIT_EMP_VALUES	TRIGGER	INTERPRETED
ANNUAL_SAL	FUNCTION	INTERPRETED
ADD_ROW	PROCEDURE	INTERPRETED
ADD_JOB_HISTORY	PROCEDURE	INTERPRETED
ADD_DEPT	PROCEDURE	INTERPRETED
ADD_DEPARTMENT_NOEX	PROCEDURE	INTERPRETED
ADD_DEPARTMENT	PROCEDURE	INTERPRETED
ADD_COL	PROCEDURE	INTERPRETED

...

- Set the compiler initialization parameter's value using the ALTER SYSTEM or ALTER SESSION statements.
- The parameters' values are accessed when the CREATE OR REPLACE statement is executed.

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Note

- For additional information about the ALTER SYSTEM or ALTER SESSION statements, refer to the *Oracle Database SQL Reference 11g Release 1 (11.1) Guide*.
- The DBA_STORED_SETTINGS data dictionary view family is deprecated in Oracle Database 10g and is replaced with the DBA_PLSQL_OBJECT_SETTINGS data dictionary view family.

Changing PL/SQL Initialization Parameters: Example

```
ALTER SESSION SET PLSQL_OPTIMIZE_LEVEL = 1;
ALTER SESSION SET PLSQL_CODE_TYPE = 'NATIVE';
```

```
ALTER SESSION SET succeeded.
ALTER SESSION SET succeeded.
```

```
-- code displayed in the notes page
CREATE OR REPLACE PROCEDURE add_job_history
. . .
```

. . .

AUDIT_EMP_VALUES	TRIGGER	INTERPRETED
ANNUAL_SAL	FUNCTION	INTERPRETED
ADD_ROW	PROCEDURE	INTERPRETED
ADD_JOB_HISTORY	PROCEDURE	NATIVE
ADD_DEPT	PROCEDURE	INTERPRETED
ADD_DEPARTMENT_NOEX	PROCEDURE	INTERPRETED
ADD_DEPARTMENT	PROCEDURE	INTERPRETED
ADD_COL	PROCEDURE	INTERPRETED

. . .

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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 first set the PLSQL_CODE_TYPE parameter to NATIVE (optionally set the other parameters) and then, recompile the program. To enforce native compilation to all PL/SQL code, you must recompile each one. Scripts (in the rdbms/admin directory) are provided for you to achieve conversion to full native compilation (dbmsupgnv.sql) or full interpreted compilation (dbmsupgin.sql). The add_job_history procedure is created as follows:

```
CREATE OR REPLACE PROCEDURE add_job_history
( p_emp_id          job_history.employee_id%type
, p_start_date      job_history.start_date%type
, p_end_date        job_history.end_date%type
, p_job_id          job_history.job_id%type
, p_department_id   job_history.department_id%type )
IS
BEGIN
    INSERT INTO job_history (employee_id, start_date,
                           end_date, job_id, department_id)
    VALUES (p_emp_id, p_start_date, p_end_date,
            p_job_id, p_department_id);
END add_job_history;
```

Lesson Agenda

- Describing the new PL/SQL compiler and features
- Using the new `PLSQL_CODE_TYPE`, `PLSQL_DEBUG`, and `PLSQL_OPTIMIZE_LEVEL` PL/SQL compilation initialization parameters
- Using the new PL/SQL compile time warnings:
 - Using the `PLSQL_WARNING` initialization parameter
 - Using the `DBMS_WARNING` package routines

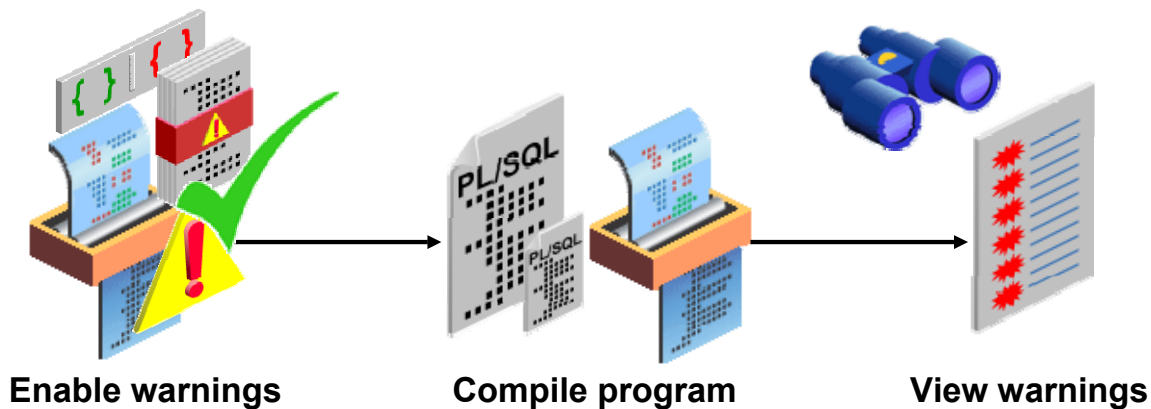
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Overview of PL/SQL Compile-Time Warnings for Subprograms

Starting with Oracle 10g, the PL/SQL compiler has been enhanced to produce warnings for subprograms.



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Overview of PL/SQL Compile-Time Warnings for Subprograms

To make your programs more robust and avoid problems at run time, you can turn on checking for certain warning conditions. These conditions are not serious enough to produce an error and keep you from compiling a subprogram. They may point out something in the subprogram that produces an undefined result or might create a performance problem.

In releases prior to Oracle Database 10g, compiling a PL/SQL program had two possible outcomes:

- Success, producing a valid compiled unit
- Failure, with compilation errors indicating that the program had either syntax or semantic errors

However, even when compilation of a program was successful, the program may have violated recommended best practices or could have been coded to be more efficient. Oracle Database 10g introduced a new ease-of-use feature that allows the PL/SQL compiler to communicate warning messages in these situations. Compiler warnings allow developers to avoid common coding pitfalls, thus improving productivity.

Overview of PL/SQL Compile-Time Warnings for Subprograms (continued)

PL/SQL supports passing of IN OUT and OUT parameters by value or by reference through the NOCOPY compiler hint. Passing parameters by value is inherently less efficient because it involves making multiple copies of the data. With Oracle Database 11g, the compiler automatically detects and recommends the use of the NOCOPY hint, where the parameter types are large object, record, or collection types.

With the PL/SQL compiler-warning feature, compiling a PL/SQL program could have additional possible outcomes:

- Success with compilation warnings
- Failure with compilation errors and compilation warnings

Note that the compiler may issue warning messages even on a successful compile. A compilation error must be corrected to be able to use the stored procedure whereas a warning is for informational purposes.

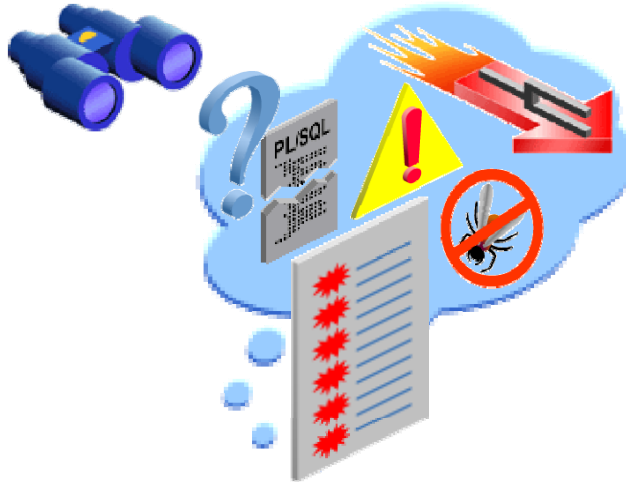
Examples of warning messages:

SP2-0804: Procedure created with compilation warnings

PLW-07203: Parameter ' IO_TBL ' may benefit from use of the NOCOPY compiler hint

Benefits of Compiler Warnings

- Make programs more robust and avoid problems at run time
- Identify potential performance problems
- Identify factors that produce undefined results



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Benefits of Compiler Warnings

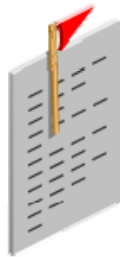
Using compiler warnings can help you to:

- Make your programs more robust and avoid problems at run time
- Identify potential performance problems
- Identify factors that produce undefined results

Note

- You can enable checking for certain warning conditions when these conditions are not serious enough to produce an error and keep you from compiling a subprogram.
- Warning messages can be issued during compilation of PL/SQL subprograms; anonymous blocks do not produce any warnings.
- All PL/SQL warning messages use the prefix PLW.

Categories of PL/SQL Compile-Time Warning Messages



SEVERE



PERFORMANCE



INFORMATIONAL



ALL

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Categories of PL/SQL Compile-Time Warning Messages

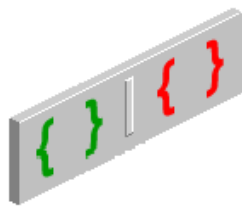
PL/SQL warning messages are divided into categories, so that you can suppress or display groups of similar warnings during compilation. The categories are:

- **SEVERE:** Messages for conditions that may cause unexpected behavior or wrong results, such as aliasing problems with parameters
- **PERFORMANCE:** Messages for conditions that may cause performance problems, such as passing a VARCHAR2 value to a NUMBER column in an INSERT statement
- **INFORMATIONAL:** Messages for conditions that do not have an effect on performance or correctness, but that you may want to change to make the code more maintainable, such as unreachable code that can never be executed

Setting the Warning Messages Levels

You can set warning levels using one of the following methods:

- Declaratively:
 - Using the `PLSQL_WARNINGS` initialization parameter
- Programmatically:
 - Using the `DBMS_WARNING` package



**PLSQL_WARNINGS
initialization parameter**



**DBMS_WARNING
package**

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Setting the Warning Messages Levels

You can set the compiler warning messages levels using one of the following methods:

Using the `PLSQL_WARNINGS` Initialization Parameter

The `PLSQL_WARNINGS` setting enables or disables the reporting of warning messages by the PL/SQL compiler, and specifies which warning messages to show as errors. The settings for the `PLSQL_WARNINGS` parameter are stored along with each compiled subprogram. You can use the `PLSQL_WARNINGS` initialization parameter to do the following:

- Enable or disable the reporting of all warnings, warnings of a selected category, or specific warning messages.
- Treat all warnings, a selected category of warning, or specific warning messages as errors.
- Any valid combination of the preceding

The keyword `ALL` is a shorthand way to refer to all warning messages: `SEVERE`, `PERFORMANCE`, and `INFORMATIONAL`.

Using the `DBMS_WARNING` Package

The `DBMS_WARNING` package provides a way to manipulate the behavior of PL/SQL warning messages, in particular by reading and changing the setting of the `PLSQL_WARNINGS` initialization parameter to control what kinds of warnings are suppressed, displayed, or treated as errors. This package provides the interface to query, modify, and delete current system or session settings. This package is covered later in this lesson.

Setting Compiler Warning Levels: Using PLSQL_WARNINGS

```
ALTER [SESSION|SYSTEM]
PLSQL_WARNINGS = 'value_clause1'[, 'value_clause2']...
```

```
value_clause = Qualifier Value : Modifier Value
```

```
Qualifier Value = { ENABLE | DISABLE | ERROR }
```

```
Modifier Value =
```

```
{ ALL | SEVERE | INFORMATIONAL | PERFORMANCE |  
  { integer | (integer [, integer ] ...) } }
```

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Modifying Compiler Warning Settings

The parameter value comprises a comma-separated list of quoted qualifier and modifier keywords, where the keywords are separated by colons. The qualifier values are: ENABLE, DISABLE, and ERROR. The modifier value ALL applies to all warning messages. SEVERE, INFORMATIONAL, and PERFORMANCE apply to messages in their own category, and an integer list for specific warning messages.

Possible values for ENABLE, DISABLE, and ERROR:

- ALL
- SEVERE
- INFORMATIONAL
- PERFORMANCE
- numeric_value

Values for numeric_value are in:

- Range 5000-5999 for severe
- Range 6000-6249 for informational
- Range 7000-7249 for performance

Setting Compiler Warning Levels: Using PLSQL_WARNINGS, Examples

```
ALTER SESSION  
SET plsql_warnings = 'enable:severe',  
                    'enable:performance',  
                    'disable:informational';
```

```
ALTER SESSION succeeded.
```

```
ALTER SESSION  
SET plsql_warnings = 'enable:severe';
```

```
ALTER SESSION succeeded.
```

```
ALTER SESSION SET PLSQL_WARNINGS='ENABLE:SEVERE',  
                    'DISABLE:PERFORMANCE' , 'ERROR:05003';
```

```
ALTER SESSION SET succeeded.
```

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Setting Compiler Warning Levels: Using PLSQL_WARNINGS, Examples

You can use the ALTER SESSION or ALTER SYSTEM command to change the PLSQL_WARNINGS initialization parameter. The graphic in the slide shows the various examples of enabling and disabling compiler warnings.

Example 1

In this example, you are enabling SEVERE and PERFORMANCE warnings and disabling INFORMATIONAL warnings.

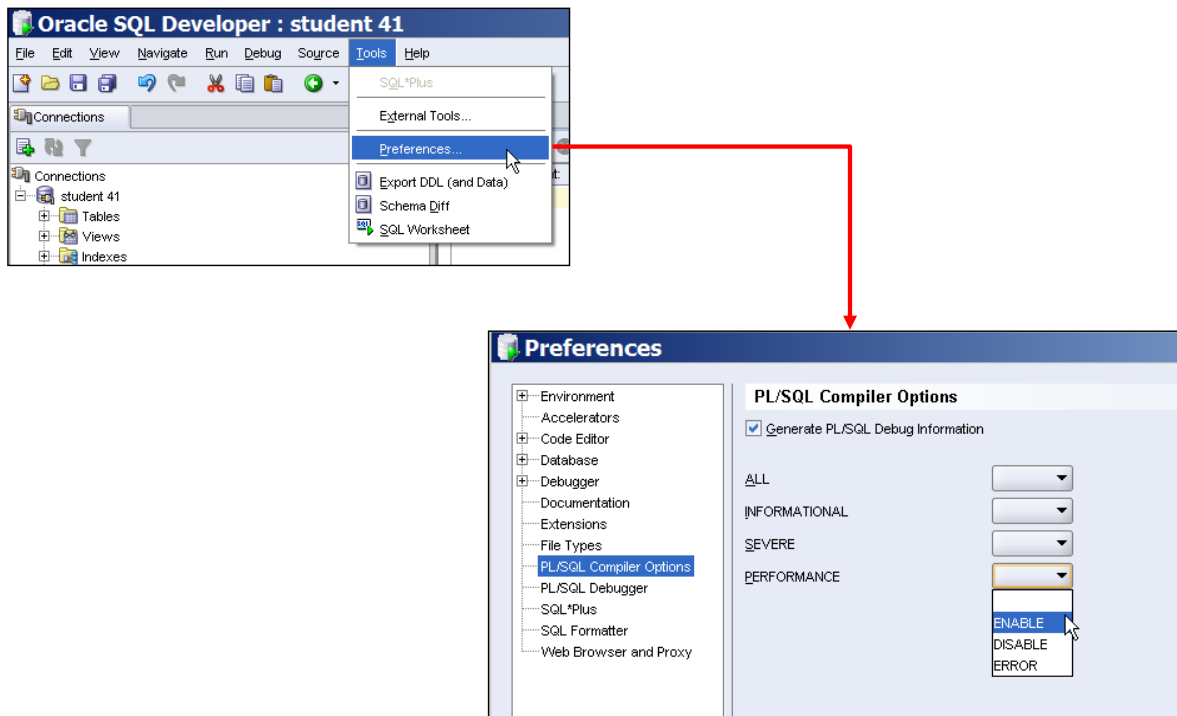
Example 2

In the second example, you are enabling only SEVERE warnings.

Example 3

You can also treat particular messages as errors instead of warnings. In this example, if you know that the warning message PLW-05003 represents a serious problem in your code, including 'ERROR:05003' in the PLSQL_WARNINGS setting makes that condition trigger an error message (PLS_05003) instead of a warning message. An error message causes the compilation to fail. In this example, you are also disabling PERFORMANCE warnings.

Setting Compiler Warning Levels: Using PLSQL_WARNINGS in SQL Developer



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Setting Compiler Warning Levels: Using PLSQL_WARNINGS in SQL Developer

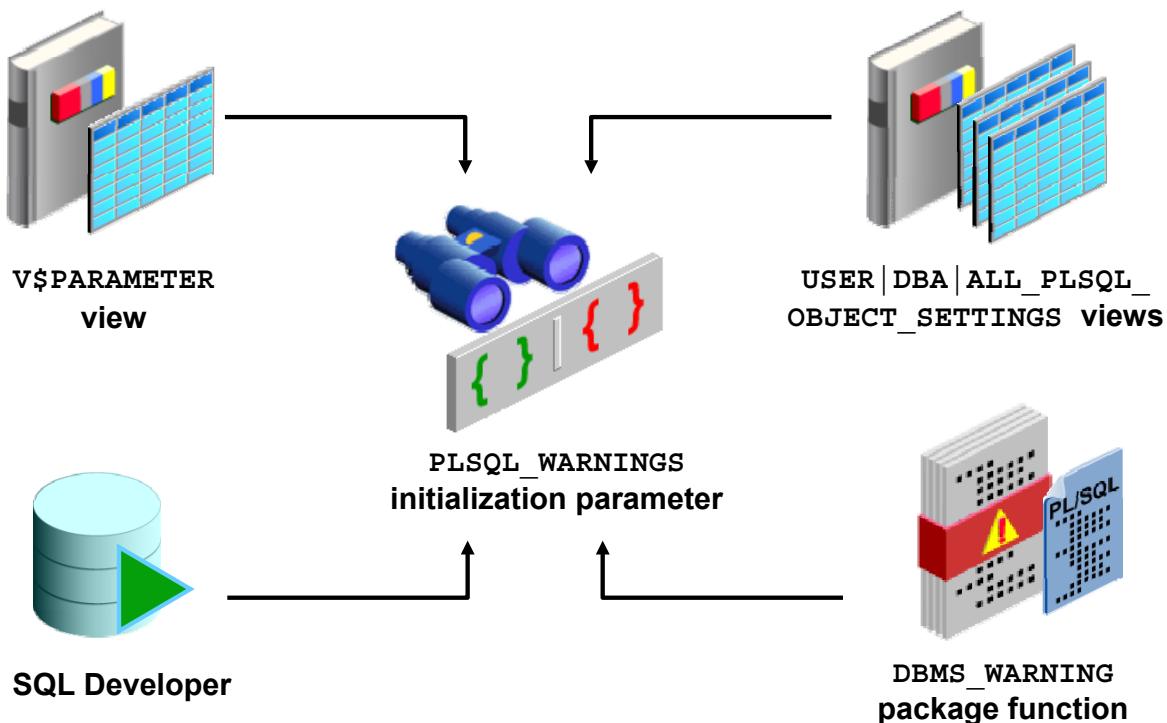
The PL/SQL Compiler pane specifies options for compilation of PL/SQL subprograms. If the **Generate PL/SQL Debug Information** check box is selected, PL/SQL debug information is included in the compiled code; if this option is not selected, this debug information is not included. The ability to stop on individual code lines and debugger access to variables are allowed only in code compiled with debug information generated.

Setting and Viewing the PL/SQL Compile-Time Warning Messages Categories in SQL Developer

You can control the display of informational, severe, and performance-related messages. The **ALL** type overrides any individual specifications for the other types of messages. For each type of message, you can specify any of the following:

- **No entry (blank):** Use any value specified for **ALL**; and if none is specified, use the Oracle default.
- **Enable:** Enable the display of all messages of this category.
- **Disable:** Disable the display of all messages of this category.
- **Error:** Enable the display of only error messages of this category.

Viewing the Current Setting of PLSQL_WARNINGS



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Viewing the Current Value of the PLSQL_WARNINGS Parameter

You can examine the current setting for the PLSQL_WARNINGS parameter by issuing a SELECT statement on the V\$PARAMETER view. For example:

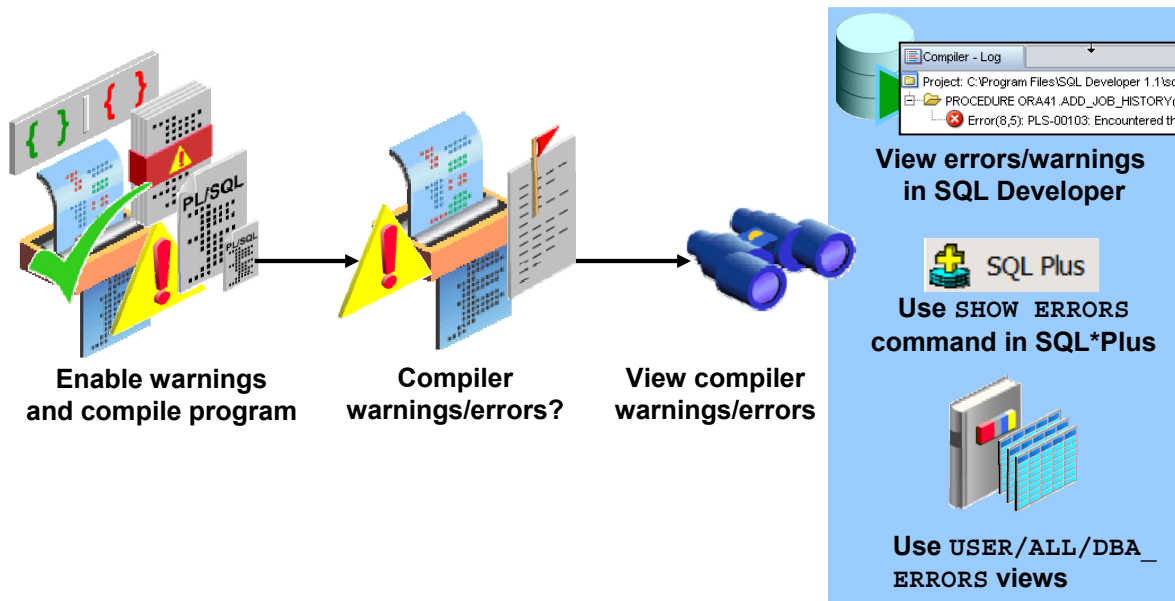
```
ALTER SESSION SET plsql_warnings = 'enable:severe',
    'enable:performance','enable:informational';
Session altered.
SELECT value FROM v$parameter WHERE name='plsql_warnings';
VALUE
-----
ENABLE:ALL
```

Alternatively, you can use the DBMS_WARNING.GET_WARNING_SETTING_STRING package and method to retrieve the current settings for the PLSQL_WARNINGS parameter:

```
DECLARE s VARCHAR2(1000);
BEGIN
    s := dbms_warning.get_warning_setting_string();
    dbms_output.put_line (s);
END;
/
```

```
anonymous block completed
ENABLE:ALL
```

Viewing the Compiler Warnings: Using SQL Developer, SQL*Plus, or Data Dictionary Views



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Viewing the Compiler Warnings

You can use SQL*Plus to see any warnings raised as a result of the compilation of a PL/SQL block. SQL*Plus indicates that a compilation warning has occurred. The ***"SP2-08xx: <object> created with compilation warnings."*** message is displayed for objects compiled with the PERFORMANCE, INFORMATIONAL, or SEVERE modifiers. There is no differentiation between the three. You must enable the compiler warnings before compiling the program. You can display the compiler warning messages using one of the following methods:

Using the SQL*Plus SHOW ERRORS Command

This command displays any compiler errors including the new compiler warnings and informational messages. This command is invoked immediately after a CREATE [PROGEDURE | FUNCTION | PACKAGE] command is used. The SHOW ERRORS command displays warnings and compiler errors. New compiler warnings and informational messages are "interleaved" with compiler errors when SHOW ERRORS is invoked.

Using the Data Dictionary Views

You can select from the USER_ | ALL_ | DBA_ERRORS data dictionary views to display PL/SQL compiler warnings. The ATTRIBUTES column of these views has a new attribute called WARNING and the warning message displays in the TEXT column.

SQL*Plus Warning Messages: Example

```
CREATE OR REPLACE PROCEDURE bad_proc(p_out ...) IS
BEGIN
    . . . ;
END;
/
```

SP2-0804: Procedure created with compilation warnings.

```
SHOW ERRORS;
Errors for PROCEDURE BAD_PROC:
```

LINE/COL	ERROR
6/24	PLW-07203: parameter 'p_out' may benefit from use of the NOCOPY compiler hint

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SQL*Plus Warning Messages: Example

Use the `SHOW ERRORS` command in SQL*Plus to display the compilation errors of a stored procedure. When you specify this option with no arguments, SQL*Plus displays the compilation errors for the most recently created or altered stored procedure. If SQL*Plus displays a compilation warnings message after you create or alter a stored procedure, you can use `SHOW ERRORS` commands to obtain more information.

With the introduction of the support for PL/SQL warnings, the range of feedback messages is expanded to include a third message as follows:

SP2-08xx: <object> created with compilation warnings.

This enables you to differentiate between the occurrence of a compilation warning and a compilation error. You must correct an error if you want to use the stored procedure, whereas a warning is for informational purposes only.

The SP2 prefix is included with the warning message, because this provides you with the ability to look up the corresponding message number in the *SQL*Plus User's Guide and Reference* to determine the cause and action for the particular message.

Note: The `SHOW SQL*Plus` command is not supported in the SQL Developer 1.2.0 (29.98) version that is used in this class. You can view the compiler errors and warnings using the `USER_` | `ALL_` | `DBA_ERRORS` data dictionary views.

Guidelines for Using PLSQL_WARNINGS

- The settings for the PLSQL_WARNINGS parameter are stored along with each compiled subprogram.
- If you recompile the subprogram using one of the following statements, the current settings for that session are used:
 - CREATE OR REPLACE
 - ALTER ... COMPILE
- If you recompile the subprogram using the ALTER ... COMPILE statement with the REUSE SETTINGS clause, the original setting stored with the program is used.

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Guidelines for Using PLSQL_WARNINGS

As already stated, the PLSQL_WARNINGS parameter can be set at the session level or the system level.

The settings for the PLSQL_WARNINGS parameter are stored along with each compiled subprogram. If you recompile the subprogram with a CREATE OR REPLACE statement, the current settings for that session are used. If you recompile the subprogram with an ALTER ... COMPILE statement, then the current session setting is used unless you specify the REUSE SETTINGS clause in the statement, which uses the original setting that is stored with the subprogram.

Lesson Agenda

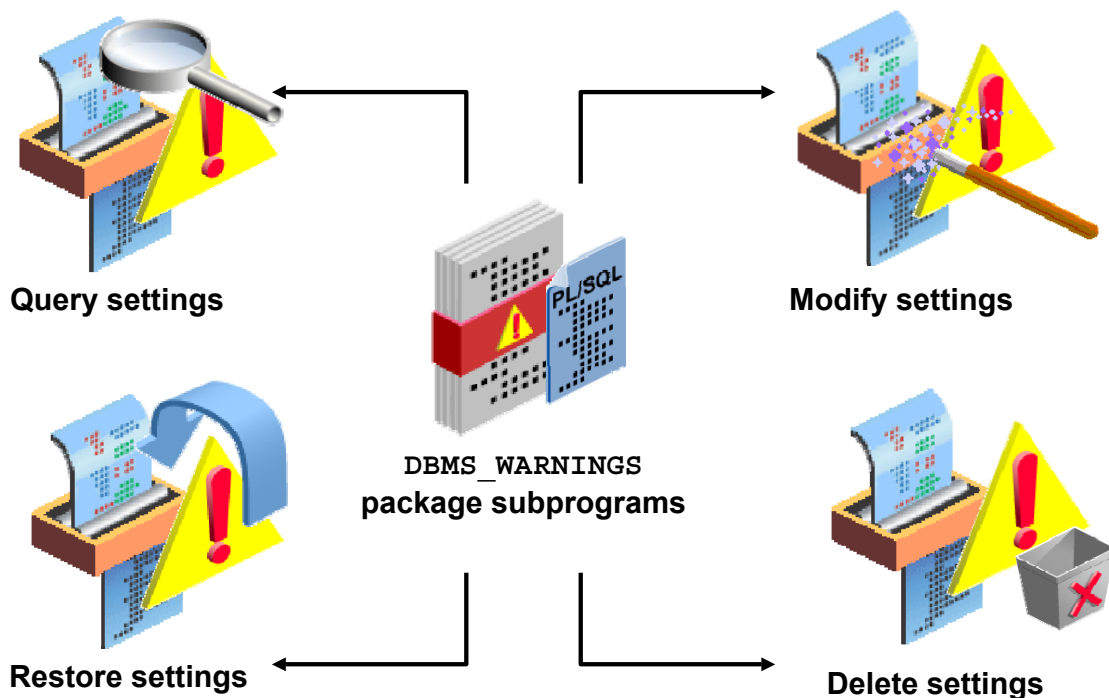
- Describing the new PL/SQL compiler and features
- Using the New `PLSQL_CODE_TYPE`, `PLSQL_DEBUG`, and `PLSQL_OPTIMIZE_LEVEL` PL/SQL Compilation Initialization Parameters
- Using the New PL/SQL Compile Time Warnings:
 - Using the `PLSQL_WARNING` Initialization Parameter
 - Using the `DBMS_WARNING` Package Routines

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Setting Compiler Warning Levels: Using the DBMS_WARNING Package



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Setting Compiler Warning Levels: Using the DBMS_WARNING Package

Use the DBMS_WARNING package to programmatically manipulate the behavior of current system or session PL/SQL warning settings. The DBMS_WARNING package provides a way to manipulate the behavior of PL/SQL warning messages, in particular by reading and changing the setting of the PLSQL_WARNINGS initialization parameter to control what kinds of warnings are suppressed, displayed, or treated as errors. This package provides the interface to query, modify, and delete current system or session settings.

The DBMS_WARNING package is valuable if you are writing a development environment that compiles PL/SQL subprograms. Using the package interface routines, you can control PL/SQL warning messages programmatically to suit your requirements.

Setting Compiler Warning Levels: Using the DBMS_WARNING Package (continued)

Overview of PL/SQL Compile-Time Warnings for Subprograms: Example

Assume that you write some code to compile PL/SQL code. You know that the compiler issues performance warnings when passing collection variables as OUT or IN OUT parameters without specifying the NOCOPY hint. The general environment that calls your compilation utility may or may not have appropriate warning-level settings. In any case, your business rules indicate that the calling environment set must be preserved and that your compilation process should suppress the warnings. By calling subprograms in the DBMS_WARNING package, you can detect the current warning settings, change the settings to suit your business requirements, and restore the original settings when your processing has completed.

When you use the ALTER SESSION or ALTER SYSTEM command to set the PLSQL_WARNINGS parameter, the new value specified completely replaces the previous value. A new package, DBMS_WARNING, is available in Oracle Database 10g, that has interfaces to query and incrementally change the setting for the PLSQL_WARNINGS parameter and make it more specific to your requirements.

The DBMS . WARNING package can be used to change the PLSQL_WARNINGS parameter incrementally, so that you can set the warnings that you want to set, without having to work out how to preserve the values of any warnings not of direct interest to you. For example, the DBA may only enable severe warnings for the entire database in the initialization parameter file, but a developer who is testing new code may want to view specific performance and informational messages. The developer can then use the DBMS_WARNING package to incrementally add the specific warnings that he or she wishes to see. This allows the developer to view the messages that he or she wants to see without replacing the DBA's settings.

Using the DBMS_WARNING Package Subprograms

Scenario	Subprograms to Use
Set warnings	ADD_WARNING_SETTING_CAT (procedure) ADD_WARNING_SETTING_NUM (procedure)
Query warnings	GET_WARNING_SETTING_CAT (function) GET_WARNING_SETTING_NUM (function) GET_WARNING_SETTING_STRING (function)
Replace warnings	SET_WARNING_SETTING_STRING (procedure)
Get the warnings' categories names	GET_CATEGORY (function)

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Using the DBMS_WARNING Subprograms

The following is a list of the DBMS_WARNING subprograms:

ADD_WARNING_SETTING_CAT: Modifies the current session or system warning settings of the warning_category previously supplied

ADD_WARNING_SETTING_NUM: Modifies the current session or system warning settings of the warning_number previously supplied

GET_CATEGORY: Returns the category name, given the message number

GET_WARNING_SETTING_CAT: Returns the specific warning category in the session

GET_WARNING_SETTING_NUM: Returns the specific warning number in the session

GET_WARNING_SETTING_STRING: Returns the entire warning string for the current session

SET_WARNING_SETTING_STRING: Replaces previous settings with the new value

Note: For additional information about the above subprograms, refer to *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)*.

The DBMS_WARNING Procedures: Syntax, Parameters, and Allowed Values

```
EXECUTE DBMS_WARNING.ADD_WARNING_SETTING_CAT (-  
  warning_category      IN      VARCHAR2,  
  warning_value         IN      VARCHAR2,  
  scope                 IN      VARCHAR2);
```

```
EXECUTE DBMS_WARNING.ADD_WARNING_SETTING_NUM (-  
  warning_number        IN      NUMBER,  
  warning_value         IN      VARCHAR2,  
  scope                 IN      VARCHAR2);
```

```
EXECUTE DBMS_WARNING.SET_WARNING_SETTING_STRING (-  
  warning_value         IN      VARCHAR2,  
  scope                 IN      VARCHAR2);
```

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The DBMS_WARNING Procedures: Syntax, Parameters, and Allowed Values

warning_category is the name of the category. The allowed values are: ALL, INFORMATIONAL, SEVERE, or PERFORMANCE.

warning_value is the value for the category. The allowed values are: ENABLE, DISABLE, or ERROR.

warning_number is the warning message number. The allowed values are all valid warning numbers.

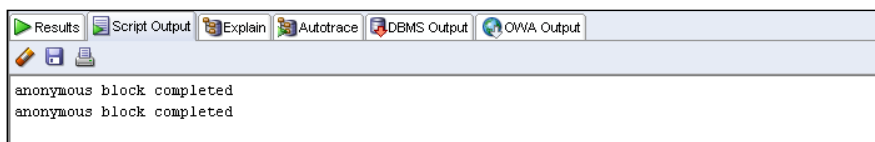
scope specifies whether the changes are being performed in the session context or the system context. The allowed values are SESSION or SYSTEM. Using SYSTEM requires the ALTER SYSTSEM privilege.

The DBMS_WARNING Procedures: Example

```
-- Establish the following warning setting string in the
-- current session:
-- ENABLE:INFORMATIONAL,
-- DISABLE:PERFORMANCE,
-- ENABLE:SEVERE
```

```
EXECUTE DBMS_WARNING.SET_WARNING_SETTING_STRING(-
    'ENABLE:ALL', 'SESSION');
```

```
EXECUTE DBMS_WARNING.ADD_WARNING_SETTING_CAT(-
    'PERFORMANCE','DISABLE', 'SESSION');
```



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Using DBMS_WARNING Procedures: Example

Using the SET_WARNING_SETTING_STRING procedure, you can set one warning setting. If you have multiple warning settings, you should perform the following steps:

1. Call SET_WARNING_SETTING_STRING to set the initial warning setting string.
2. Call ADD_WARNING_SETTING_CAT (or ADD_WARNING_SETTING_NUM) repeatedly to add more settings to the initial string.

The example in the slide establishes the following warning setting string in the current session:
ENABLE:INFORMATIONAL, DISABLE:PERFORMANCE, ENABLE:SEVERE

The DBMS_WARNING Functions: Syntax, Parameters, and Allowed Values

```
DBMS_WARNING.GET_WARNING_SETTING_CAT (-  
    warning_category IN VARCHAR2) RETURN warning_value;
```

```
DBMS_WARNING.GET_WARNING_SETTING_NUM (-  
    warning_number IN NUMBER) RETURN warning_value;
```

```
DBMS_WARNING.GET_WARNING_SETTING_STRING  
    RETURN pls_integer;
```

```
DBMS_WARNING.GET_CATEGORY (-  
    warning_number IN pls_integer) RETURN VARCHAR2;
```

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The DBMS_WARNING Functions: Syntax, Parameters, and Allowed Values

warning_category is the name of the category. The allowed values are: ALL, INFORMATIONAL, SEVERE, or PERFORMANCE.

warning_number is the warning message number. The allowed values are all valid warning numbers.

scope specifies whether the changes are being performed in the session context or the system context. The allowed values are SESSION or SYSTEM. Using SYSTEM requires the ALTER SYSTSEM privilege.

Note: Use the GET_WARNING_SETTING_STRING function when you do not have the SELECT privilege on the v\$parameter or v\$paramater2 fixed tables, or if you want to parse the warning string yourself and then modify and set the new value using SET_WARNING_SETTING_STRING.

The DBMS_WARNING Functions: Example

```
-- Determine the current session warning settings

EXECUTE DBMS_OUTPUT.PUT_LINE( -
DBMS_WARNING.GET_WARNING_SETTING_STRING);
```

```
anonymous block completed
ENABLE: INFORMATIONAL,DISABLE: PERFORMANCE,ENABLE: SEVERE
```

```
-- Determine the category for warning message number
-- PLW-07203

EXECUTE DBMS_OUTPUT.PUT_LINE( -
DBMS_WARNING.GET_CATEGORY(7203));
```

```
anonymous block completed
PERFORMANCE
```

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Note

The message numbers must be specified as positive integers, because the data type for the GET_CATEGORY parameter is PLS_INTEGER (allowing positive integer values).

Using DBMS_WARNING: Example

```
CREATE OR REPLACE PROCEDURE compile_code(p_pkg_name VARCHAR2) IS
  v_warn_value  VARCHAR2(200);
  v_compile_stmt VARCHAR2(200) :=
    'ALTER PACKAGE ' || p_pkg_name || ' COMPILE';

BEGIN
  v_warn_value := DBMS_WARNING.GET_WARNING_SETTING_STRING;
  DBMS_OUTPUT.PUT_LINE('Current warning settings: ' ||
    v_warn_value);
  DBMS_WARNING.ADD_WARNING_SETTING_CAT(
    'PERFORMANCE', 'DISABLE', 'SESSION');
  DBMS_OUTPUT.PUT_LINE('Modified warning settings: ' ||
    DBMS_WARNING.GET_WARNING_SETTING_STRING);
  EXECUTE IMMEDIATE v_compile_stmt;
  DBMS_WARNING.SET_WARNING_SETTING_STRING(v_warn_value,
    'SESSION');
  DBMS_OUTPUT.PUT_LINE('Restored warning settings: ' ||
    DBMS_WARNING.GET_WARNING_SETTING_STRING);
END;
/
```

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Using DBMS_WARNING: Example

Note: Before you run the code provided in the example in the slide, you must create the MY_PKG script found in demo_11_36.sql. This demo script creates the MY_PKG package. In the example in the slide, the compile_code procedure is designed to compile a named PL/SQL package. The code suppresses the PERFORMANCE category warnings. The calling environment's warning settings must be restored after the compilation is performed. The code does not know what the calling environment warning settings are; it uses the GET_WARNING_SETTING_STRING function to save the current setting. This value is used to restore the calling environment setting using the DBMS_WARNING.SET_WARNING_SETTING_STRING procedure in the last line of the example code. Before compiling the package using Native Dynamic SQL, the compile_code procedure alters the current session-warning level by disabling warnings for the PERFORMANCE category. The code also prints the original, modified, and the restored warning settings.

Using DBMS_WARNING: Example

```
EXECUTE DBMS_WARNING.SET_WARNING_SETTING_STRING(-  
  'ENABLE:ALL', 'SESSION');
```

```
anonymous block completed
```

```
@code_11_36_bs.sql
```

```
PROCEDURE compile_code(p_pkg_name Compiled.
```

```
@code_11_37_cs.sql -- compiles the DEPT_PKG package  
EXECUTE compile_code('DEPT_PKG');  
  
Current warning settings: ENABLE:ALL  
Modified warning settings:  
ENABLE:INFORMATIONAL,DISABLE:PERFORMANCE,ENABLE:SEVERE  
Restored warning settings: ENABLE:ALL
```

```
anonymous block completed  
Current warning settings: ENABLE:ALL  
Modified warning settings: ENABLE:INFORMATIONAL,DISABLE:PERFORMANCE,ENABLE:SEVERE  
Restored warning settings: ENABLE:ALL
```

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Using DBMS_WARNING: Example (continued)

In the example in the slide, the example provided in the previous slide is tested. First, enable all compiler warnings. Next, run the script on the previous page. Finally, call the `compile_code` procedure and pass it an existing package name, `DEPT_PKG`, as a parameter.

Using the New PLW 06009 Warning Message

- A new PLW warning is available in Oracle Database 11g.
- This warning indicates that the OTHERS handler of your PL/SQL subroutine can exit without executing:
 - Some form of RAISE, or
 - A call to the standard procedure RAISE_APPLICATION_ERROR
- A good programming practice suggests that OTHERS handlers must always pass an exception upward.



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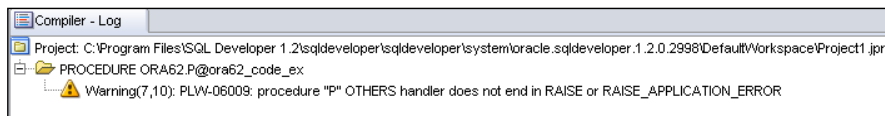
Using the New PLW 06009 Warning

As a good programming practice, you should have your OTHERS exception handler pass the exception upward to the calling subroutine. If you fail to add this functionality, you run the risk of having exceptions go unnoticed. To avoid this flaw in your code, you can turn on warnings for your session and recompile the code that you want to verify. If the OTHERS handler does not handle the exception, the PLW 06009 warning will inform you.

Note: PLW 06009 is not the only new warning message in Oracle Database 11g. For a complete list of all PLW warnings, see the *Oracle Database Error Messages 11g Release 1 (11.1)* guide.

The New PLW 06009 Warning: Example

```
-- You must create table t shown in the notes section first.
CREATE OR REPLACE PROCEDURE p(i IN VARCHAR2)
IS
BEGIN
    INSERT INTO t(col_a) VALUES (i);
EXCEPTION
    WHEN OTHERS THEN null;
END p;
/
ALTER PROCEDURE P COMPILE
    PLSQL_warnings = 'enable:all' REUSE SETTINGS;
```



```
SELECT *
FROM user_errors
WHERE name = 'P'
```

Results							
Script Output Explain Autotrace DBMS Output OWA Output							
Results:							
	NAME	TYPE	SEQUENCE	LINE	POSITION	TEXT	ATTRIBUTE MESSAGE_NUMBER
1	P	PROCEDURE		1	6	10 PLW-06009: procedure "P" OTHERS handler does not end in RAISE or RAISE_APPLICATION_ERROR WARNING	6009

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The New PLW 06009 Warning: Example

After running the first code example in the slide and after compiling the procedure using the Object Navigation tree, the Compiler – Log tab displays the PLW-06009 warning.

You can also use the user_error data dictionary view to display the error.

The definition of table t that is used in the slide example is as follows:

```
CREATE TABLE t (col_a NUMBER);
```

Quiz

The categories of PL/SQL compile-time warning messages are:

1. SEVERE
2. PERFORMANCE
3. INFORMATIONAL
4. All
5. CRITICAL

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Answers: 1, 2, 3, 4

PL/SQL warning messages are divided into categories, so that you can suppress or display groups of similar warnings during compilation. The categories are:

- **SEVERE:** Messages for conditions that may cause unexpected behavior or wrong results, such as aliasing problems with parameters.
- **PERFORMANCE:** Messages for conditions that may cause performance problems, such as passing a VARCHAR2 value to a NUMBER column in an INSERT statement.
- **INFORMATIONAL:** Messages for conditions that do not have an effect on performance or correctness, but that you may want to change to make the code more maintainable, such as unreachable code that can never be executed.
- **ALL:** Displays all categories.

Summary

In this lesson, you should have learned how to:

- Describe the new PL/SQL compiler and features
- Use the new PL/SQL compiler initialization parameters
- Use the new PL/SQL compile time warnings

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Practice 11: Overview

This practice covers the following topics:

- Displaying the compiler initialization parameters
- Enabling native compilation for your session and compiling a procedure
- Disabling the compiler warnings, and then restoring the original session-warning settings
- Identifying the categories for some compiler-warning message numbers

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Practice 11: Overview

In this practice, you display the compiler initialization parameters. You then enable native compilation for your session and compile a procedure. You then suppress all compiler warnings categories and then restore the original session-warning settings. Finally, you identify the categories for some compiler-warning message numbers.

Practice 11

1. Create and run a `lab_11_01` script to display the following information about compiler-initialization parameters by using the `USER_PLSQL_OBJECT_SETTINGS` data dictionary view. Note the settings for the `ADD_JOB_HISTORY` object.
Note: Use the Execute Statement (F9) icon to display the results in the Results tab.
 - a. Object name
 - b. Object type
 - c. Whether or not the object was compiled for debugging
 - d. The object's compilation mode
 - e. The compilation optimization level
2. Alter the `PLSQL_CODE_TYPE` parameter to enable native compilation for your session, and compile `ADD_JOB_HISTORY`.
 - a. Execute the `ALTER SESSION` command to enable native compilation for the session.
 - b. Compile the `ADD_JOB_HISTORY` procedure.
 - c. Rerun the `sol_11_01` script. Note the `PLSQL_CODE_TYPE` parameter.
 - d. Switch compilation to use interpreted compilation mode.
3. Use the Tools > Preferences > PL/SQL Compiler Options region to disable all compiler warnings categories.
4. Edit, examine, and execute the `lab_11_04.sql` script to create the `UNREACHABLE_CODE` procedure. Click the Run Script icon to create the procedure. Use the procedure name in the Navigation tree to compile the procedure.
5. What are the compiler warnings that are displayed in the **Compiler – Log** tab, if any?
6. Enable all compiler-warning messages for this session using the Preferences window.
7. Recompile the `UNREACHABLE_CODE` procedure using the Object Navigation tree. What compiler warnings are displayed, if any?
8. Use the **Compiler – Log** tab in SQL developer or the `USER_ERRORS` data dictionary view to display the compiler-warning messages details.
9. Create a script named `warning_msgs` that uses the `EXECUTE DBMS_OUTPUT` and the `DBMS_WARNING` packages to identify the categories for the following compiler-warning message numbers: 5050, 6075, and 7100.

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Managing PL/SQL Code

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Objectives

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

- Describe and use conditional compilation
- Hide PL/SQL source code using dynamic obfuscation and the Wrap utility

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Lesson Aim

This lesson introduces the conditional compilation and obfuscating or wrapping PL/SQL code.

Lesson Agenda

- Using conditional compilation
- Obfuscating PL/SQL code

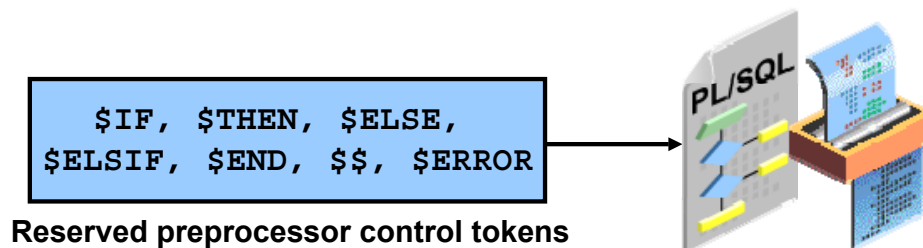
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What Is Conditional Compilation?

Enables you to customize the functionality in a PL/SQL application without removing any source code:

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



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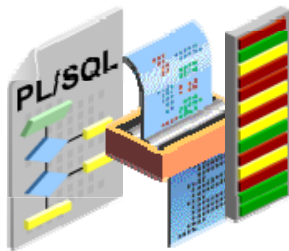
What Is Conditional Compilation?

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

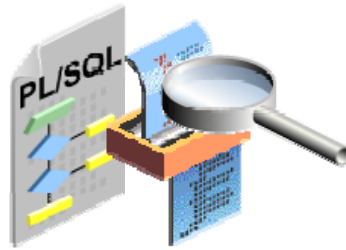
Benefits of Conditional Compilation

- Support for multiple versions of the same program in one source code
- Easy maintenance and debugging of code
- Easy migration of code to a different release of the database

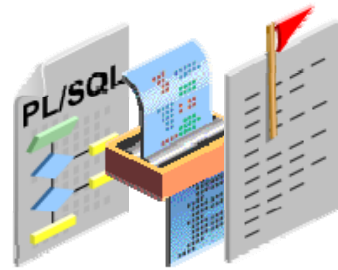
How Does Conditional Compilation Work?



Selection directives:
Use the `$IF` token.



Inquiry directives:
Use the `$$` token.



Error directives:
Use the `$ERROR` token.



**DBMS_PREPROCESSOR
package**



**DBMS_DB_VERSION
package**

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How Does Conditional Compilation Work?

You can use conditional compilation by embedding directives in your PL/SQL source programs. When the PL/SQL program is submitted for compilation, a preprocessor evaluates these directives and selects parts of the program to be compiled. The selected program source is then handed off to the compiler for compilation.

Inquiry directives use the `$$` token to make inquiries about the compilation environment such as the value of a PL/SQL compiler initialization parameters `PLSQL_CCFLAGS` or `PLSQL_OPTIMIZE_LEVEL` for the unit being compiled. This directive can be used in conjunction with the conditional selection directive to select the parts of the program to compile.

Selection directives can test inquiry directives or static package constants by using the `$IF` construct to branch sections of code for possible compilation if a condition is satisfied.

Error directives issue a compilation error if an unexpected condition is encountered during conditional compilation using the `$ERROR` token.

The `DBMS_DB_VERSION` package provides database version and release constants that can be used for conditional compilation.

The `DBMS_PREPROCESSOR` package provides subprograms for accessing the post-processed source text that is selected by conditional compilation directives in a PL/SQL unit.

Using Selection Directives

```
$IF <Boolean-expression> $THEN Text
$ELSEIF <Boolean-expression> $THEN Text
. . .
$ELSE Text
$END
```

```
DECLARE
CURSOR cur IS SELECT employee_id FROM
employees WHERE
$IF myapp_tax_package.new_tax_code $THEN
    salary > 20000;
$ELSE
    salary > 50000;
$END
BEGIN
    OPEN cur;
. . .
END;
```

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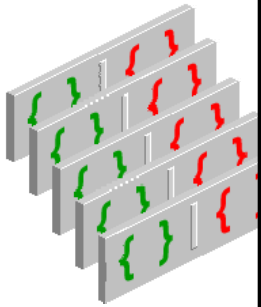
Using Selection Directives

The conditional selection directive looks like and operates like the IF-THEN-ELSE mechanism in PL/SQL proper. When the preprocessor encounters \$THEN, it verifies that the text between \$IF and \$THEN is a static expression. If the check succeeds and the result of the evaluation is TRUE, then the PL/SQL program text between \$THEN and \$ELSE (or \$ELSEIF) is selected for compilation.

The selection condition (the expression between \$IF and \$THEN) can be constructed by referring to constants defined in another package or an inquiry directive or some combination of the two.

In the example in the slide, conditional selection directive chooses between two versions of the cursor, cur, on the basis of the value of MYAPP_TAX_PACKAGE.NEW_TAX_CODE. If the value is TRUE, then employees with salary > 20000 are selected, else employees with salary > 50000 are selected.

Using Predefined and User-Defined Inquiry Directives



```
PLSQL_CCFLAGS  
PLSQL_CODE_TYPE  
PLSQL_DEBUG  
PLSQL_OPTIMIZE_LEVEL  
PLSQL_WARNINGS  
NLS_LENGTH_SEMANTICS  
PLSQL_LINE  
PLSQL_UNIT
```

Predefined inquiry directives

```
PLSQL_CCFLAGS = 'plsql_ccflags:true,debug:true,debug:0';
```

User-defined inquiry directives

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Using Predefined and User-Defined Inquiry Directives

An inquiry directive can be predefined or user-defined. The following describes the order of the processing flow when conditional compilation attempts to resolve an inquiry directive:

1. The ID is used as an inquiry directive in the form \$\$id for the search key.
2. The two-pass algorithm proceeds as follows:
 - a. The string in the PLSQL_CCFLAGS initialization parameter is scanned from right to left, searching with ID for a matching name (not case sensitive); done if found.
 - b. The predefined inquiry directives are searched; done if found.
3. If the \$\$ID cannot be resolved to a value, then the PLW-6003 warning message is reported if the source text is not wrapped. The literal NULL is substituted as the value for undefined inquiry directives. Note that if the PL/SQL code is wrapped, then the warning message is disabled so that the undefined inquiry directive is not revealed.

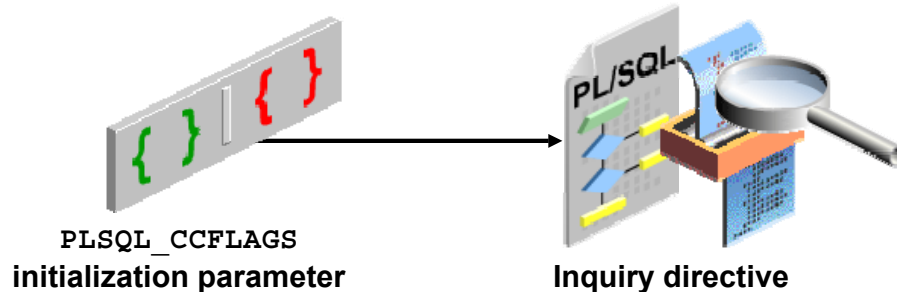
In the example in the slide, the value of \$\$debug is 0 and the value of \$\$plsql_ccflags is TRUE. Note that the value of \$\$plsql_ccflags resolves to the user-defined plsql_ccflags inside the value of the PLSQL_CCFLAGS compiler parameter. This occurs because a user-defined directive overrides the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

The PLSQL_CCFLAGS Parameter and the Inquiry Directive

Use the PLSQL_CCFLAGS parameter to control conditional compilation of each PL/SQL library unit independently.

```
PLSQL_CCFLAGS = '<v1>:<c1>,<v2>:<c2>,...,<vn>:<cn>'
```

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



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The PLSQL_CCFLAGS Parameter and the Inquiry Directive

Oracle Database 10g Release 2 introduced a new Oracle initialization parameter PLSQL_CCFLAGS for use with conditional compilation. This dynamic parameter enables you to set up name-value pairs. The names (called flag names) can then be referenced in inquiry directives. PLSQL_CCFLAGS provides a mechanism that allows PL/SQL programmers to control conditional compilation of each PL/SQL library unit independently.

Values

- **vi:** Has the form of an unquoted PL/SQL identifier. It is unrestricted and can be a reserved word or a keyword. The text is not case sensitive. Each one is known as a flag or flag name. Each vi can occur more than once in the string, each occurrence can have a different flag value, and the flag values can be of different kinds.
- **ci:** Can be any of the following:
 - A PL/SQL Boolean literal
 - A PLS_INTEGER literal
 - The literal NULL (default). The text is not case sensitive. Each one is known as a flag value and corresponds to a flag name.

Displaying the PLSQL_CCFLAGS Initialization Parameter Setting

```
SELECT name, type, plsql_ccflags
FROM   user_plsql_object_settings
```

Results:			
	NAME	TYPE	PLSQL_CCFLAGS
1	DEPT_PKG	PACKAGE	(null)
2	DEPT_PKG	PACKAGE BODY	(null)
3	TAXES_PKG	PACKAGE	(null)
4	TAXES_PKG	PACKAGE BODY	(null)
5	EMP_PKG	PACKAGE	(null)
6	EMP_PKG	PACKAGE BODY	(null)
7	SECURE_DML	PROCEDURE	(null)
8	SECURE_EMPLOYEES	TRIGGER	(null)
9	ADD_JOB_HISTORY	PROCEDURE	plsql_ccflags:true, debug:true, debug:0
10	UPDATE_JOB_HISTORY	TRIGGER	(null)

...

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Displaying the PLSQL_CCFLAGS Initialization Parameter Setting

Use the USER | ALL | DBA_PLSQL_OBJECT_SETTINGS data dictionary views to display the settings of a PL/SQL object.

You can define any allowable value for PLSQL_CCFLAGS. However, Oracle recommends that this parameter be used for controlling the conditional compilation of debugging or tracing code.

The flag names can be set to any identifier, including reserved words and keywords. The values must be the literals TRUE, FALSE, or NULL, or a PLS_INTEGER literal. The flag names and values are not case sensitive. The PLSQL_CCFLAGS parameter is a PL/SQL compiler parameter (like other compiler parameters) and is stored with the PL/SQL program unit.

Consequently, if the PL/SQL program gets recompiled later with the REUSE SETTINGS clause (example, ALTER PACKAGE ...REUSE SETTINGS), then the same value of PLSQL_CCFLAGS is used for the recompilation. Because the PLSQL_CCFLAGS parameter can be set to a different value for each PL/SQL unit, it provides a convenient method for controlling conditional compilation on a per unit basis.

The PLSQL_CCFLAGS Parameter and the Inquiry Directive: Example

```
ALTER SESSION SET PLSQL_CCFLAGS = 'Tracing:true';
CREATE OR REPLACE PROCEDURE P IS
BEGIN
  $IF $$tracing $THEN
    DBMS_OUTPUT.PUT_LINE ('TRACING');
  $END
END P;
```

ALTER SESSION SET succeeded.
PROCEDURE P Compiled.

```
SELECT name, plsql_ccflags
FROM USER_PLSQL_OBJECT_SETTINGS
WHERE name = 'P';
```

Results:

	NAME	PLSQL_CCFLAGS
1	P	Tracing:true

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The PLSQL_CCFLAGS Parameter and the Inquiry Directive: Example

In the example in the slide, the parameter is set and then the procedure is created. The setting is stored with each PL/SQL unit.

Using Conditional Compilation Error Directives to Raise User-Defined Errors

```
$ERROR varchar2_static_expression $END
```

```
ALTER SESSION SET Plsql_CCFlags = ' Trace_Level:3 '  
/  
CREATE PROCEDURE P IS  
BEGIN  
    $IF      $$Trace_Level = 0 $THEN ...;  
    $ELSIF   $$Trace_Level = 1 $THEN ...;  
    $ELSIF   $$Trace_Level = 2 $THEN ...;  
    $else $error 'Bad: ' || $$Trace_Level $END  
    $END  
END P; /
```

```
SHOW ERRORS  
Errors for PROCEDURE P:  
LINE/COL ERROR  
-----  
6/9          PLS-00179: $ERROR: Bad: 3
```

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Using Conditional Compilation Error Directives to Raise User-Defined Errors

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

```
$ERROR varchar2_static_expression $END
```

Note: varchar2_static_expression must be a VARCHAR2 static expression.

Using Static Expressions with Conditional Compilation

- Boolean static expressions:
 - TRUE, FALSE, NULL, IS NULL, IS NOT NULL
 - > , < , >= , <= , = , <>, NOT, AND, OR
- PLS_INTEGER static expressions:
 - -2147483648 to 2147483647, NULL
- VARCHAR2 static expressions include:
 - ||, NULL, TO_CHAR
- Static constants:

```
static_constant CONSTANT datatype := static_expression;
```

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Using Static Expressions with Conditional Compilation

As described earlier, a preprocessor processes conditional directives before proper compilation begins. Consequently, only expressions that can be fully evaluated at compile time are permitted in conditional compilation directives. Any expression that contains references to variables or functions that require the execution of the PL/SQL are not available during compilation and cannot be evaluated.

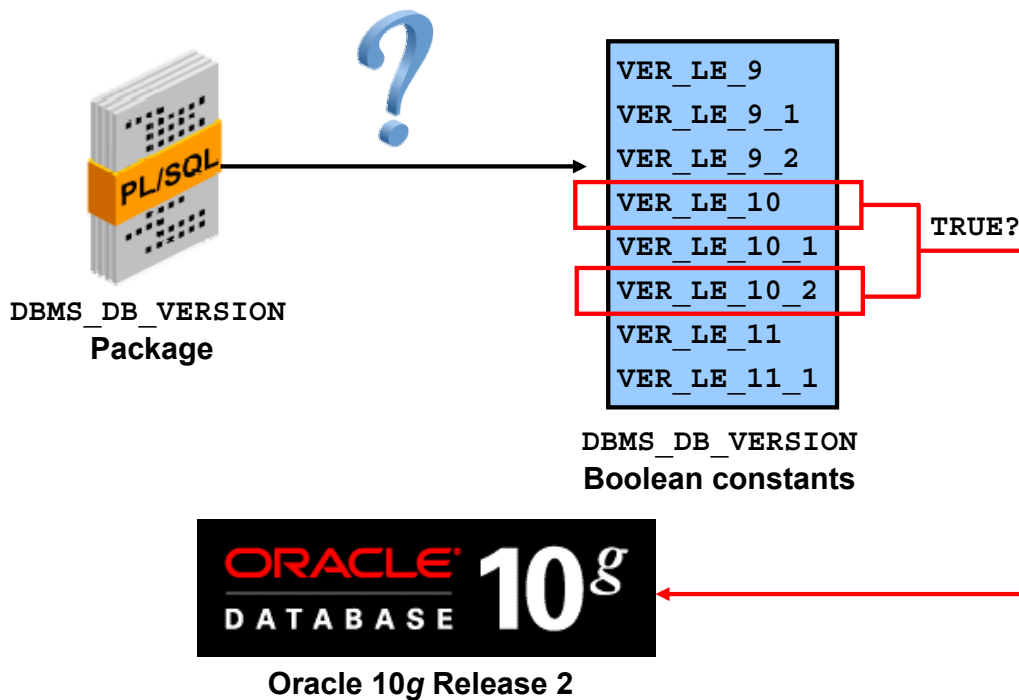
This subset of PL/SQL expressions allowed in conditional compilation directives is referred to as static expressions. Static expressions are carefully defined to guarantee that if a unit is automatically recompiled without any changes to the values it depends on, the expressions evaluate in the same way and the same source is compiled.

Generally, static expressions are composed of three sources:

- Inquiry directives marked with \$\$
- Constants defined in PL/SQL packages such as DBMS_DB_VERSION. These values can be combined and compared using the ordinary operations of PL/SQL.
- Literals such as TRUE, FALSE, 'CA', 123, NULL

Static expressions can also contain operations that include comparisons, logical Boolean operations (such as OR and AND), or concatenations of static character expression.

The DBMS_DB_VERSION Package: Boolean Constants



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The DBMS_DB_VERSION Package

Oracle Database 10g Release 2 introduced the DBMS_DB_VERSION package. This package specifies the Oracle database version and release numbers that are useful when making simple selections for conditional compilation.

The constants represent a Boolean condition that evaluates to less than or equal to the version and the release, if present.

Example

VER_LE_10 indicates that the database version \leq 10. The values of the constants are either TRUE or FALSE. For example, in an Oracle Database 10g Release 2 database, VER_LE_10 and VER_LE_10_2 are TRUE and all other constants are FALSE.

The DBMS_DB_VERSION Package Constants

Name	Value	Description
VERSION	10	Current version.
RELEASE	2	Current release.
VER_LE_9	FALSE	Version <= 9.
VER_LE_9_1	FALSE	Version <= 9 and release <= 1.
VER_LE_9_2	FALSE	Version <= 9 and release <= 2.
VER_LE_10	TRUE	Version <= 10.
VER_LE_10_1	FALSE	Version <= 10 and release <= 1.
VER_LE_10_2	TRUE	Version <=10 and release <= 2.
VER_LE_11	FALSE	Version <= 11.
VER_LE_11_1	TRUE	Version <=11 and release <= 1.

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The DBMS_DB_VERSION Package

The package for the Oracle Database 11g Release 1 version is shown below:

```

PACKAGE DBMS_DB_VERSION IS
    VERSION CONSTANT PLS_INTEGER := 11; -- RDBMS version
                                         -- number
    RELEASE CONSTANT PLS_INTEGER := 1;  -- RDBMS release
                                         -- number

    ver_le_9_1      CONSTANT BOOLEAN := FALSE;
    ver_le_9_2      CONSTANT BOOLEAN := FALSE;
    ver_le_9        CONSTANT BOOLEAN := FALSE;
    ver_le_10_1     CONSTANT BOOLEAN := FALSE;
    ver_le_10_2     CONSTANT BOOLEAN := FALSE;
    ver_le_10       CONSTANT BOOLEAN := FALSE;
    ver_le_11_1     CONSTANT BOOLEAN := TRUE;
    ver_le_11       CONSTANT BOOLEAN := TRUE;
END DBMS_DB_VERSION;
```

The DBMS_DB_VERSION package contains different constants for different Oracle Database releases. The Oracle Database 11g Release 1 version of the DBMS_DB_VERSION package uses the constants shown in the slide.

Using Conditional Compilation with Database Versions: Example

```
ALTER SESSION SET PLSQL_CCFLAGS = 'my_debug:FALSE, my_tracing:FALSE';
CREATE PACKAGE my_pkg AS
  SUBTYPE my_real IS
    -- Check the database version, if >= 10g, use BINARY_DOUBLE data type,
    -- else use NUMBER data type
    $IF DBMS_DB_VERSION.VERSION < 10 $THEN      NUMBER;
    $ELSE    BINARY_DOUBLE;
    $END
  my_pi my_real; my_e my_real;
END my_pkg;
/
CREATE PACKAGE BODY my_pkg AS
BEGIN
  $IF DBMS_DB_VERSION.VERSION < 10 $THEN
    my_pi := 3.14016408289008292431940027343666863227;
    my_e  := 2.71828182845904523536028747135266249775;
  $ELSE
    my_pi := 3.14016408289008292431940027343666863227d;
    my_e  := 2.71828182845904523536028747135266249775d;
  $END
END my_pkg;
/
```

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Using Conditional Compilation with Database Versions: Example

This example also shows the use of the PLSQL_CCFLAGS parameter. First, you set the PLSQL_CCFLAGS parameter flag for displaying debugging code and tracing information.

In the example in the slide on this page and the next page, conditional compilation is used to specify code for database versions. Conditional compilation is used to determine whether the BINARY_DOUBLE data type can be utilized in the calculations for PL/SQL units in the database. The BINARY_DOUBLE data type can only be used in Oracle Database 10g or later. If you are using Oracle Database 10g, then the data type for my_real is BINARY_DOUBLE; otherwise, the data type for my_real is NUMBER.

In the specification of the new package, my_pkg, conditional compilation is used to check for the database version. In the body definition of the package, conditional compilation is used again to set the values of my_pi and my_e for future calculations based on the database version.

The result of the slide example code is as follows:

```
ALTER SESSION SET succeeded.
PACKAGE my_pkg Compiled.
PACKAGE BODY my_pkg Compiled.
```

Using Conditional Compilation with Database Versions: Example

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

```
PROCEDURE circle_area(p_radius Compiled.
```

```
CALL circle_area(50); -- Using Oracle Database 11g Release 1
```

```
CALL circle_area(50) succeeded.
Radius: 5.0E+001 Area: 1.5700820414450413E+002
```

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Using Conditional Compilation with Database Versions: Example (continued)

In the example in the slide, a new procedure called `circle_area` is defined. This procedure calculates the area of a circle based on the values of the variables in the `my_pkg` package defined on the previous page. The procedure has one IN formal parameter, `radius`.

The procedure declares a couple of variables: `my_area`, which is the same data type as `my_real` in `my_pkg`, and `my_datatype`, which is a `VARCHAR2(30)`.

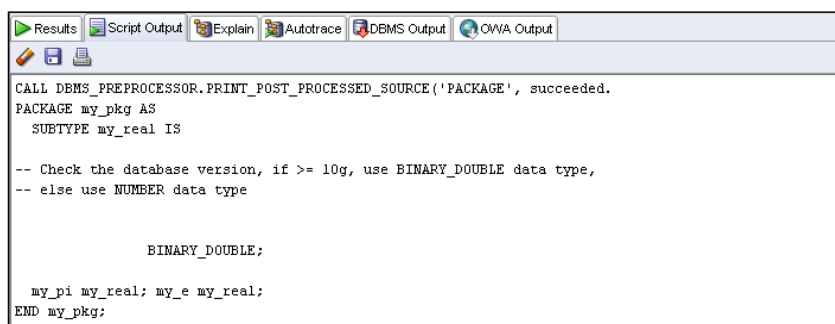
In the procedure's body, `my_area` becomes equal to the value of `my_pi` set in `my_pkg` multiplied by the value that is passed to the procedure as a radius. A message is printed displaying the radius and the area of the circle as shown in the second code example in the slide.

Note: If you want to set `my_debug` to `TRUE`, you can make this change only for the `circle_area` procedure with the `REUSE SETTINGS` clause as follows:

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


Using DBMS_PREPROCESSOR Procedures to Print or Retrieve Source Text

```
-- Substitute ORA62 with your user account as needed
CALL
  DBMS_PREPROCESSOR.PRINT_POST_PROCESSED_SOURCE('PACKAGE'
    , 'ORA62', 'MY_PKG');
```

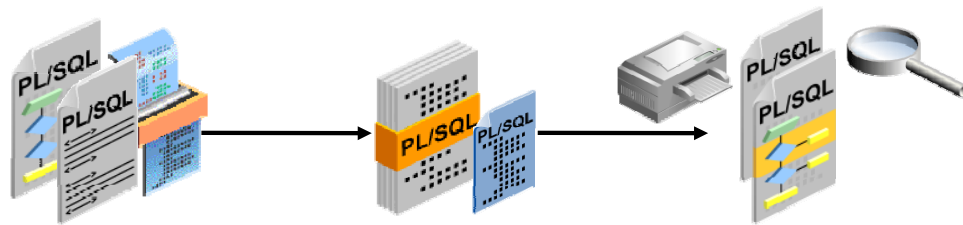


```
CALL DBMS_PREPROCESSOR.PRINT_POST_PROCESSED_SOURCE('PACKAGE', succeeded.
PACKAGE my_pkg AS
  SUBTYPE my_real IS

-- Check the database version, if >= 10g, use BINARY_DOUBLE data type,
-- else use NUMBER data type

      BINARY_DOUBLE;

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



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Using DBMS_PREPROCESSOR Procedures to Print or Retrieve Source Text

DBMS_PREPROCESSOR subprograms print or retrieve the postprocessed source text of a PL/SQL unit after processing the conditional compilation directives. This postprocessed text is the actual source used to compile a valid PL/SQL unit. The example in the slide shows how to print the postprocessed form of my_pkg using the PRINT_POST_PROCESSED_SOURCE procedure.

When my_pkg is compiled on an Oracle Database 10g release or later database using the HR account, the resulting output is shown in the slide above.

The PRINT_POST_PROCESSED_SOURCE removes unselected text. The lines of code that are not included in the postprocessed text are removed. The arguments for the PRINT_POST_PROCESSED_SOURCE procedure are: object type, schema name (using student account ORA62), and object name.

Note: For additional information about the DBMS_PREPROCESSOR package, refer to the *Oracle Database PL/SQL Packages and Types Reference 11g Release 1 (11.1)* guide.

Lesson Agenda

- Using conditional compilation
- Obfuscating PL/SQL code

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What Is Obfuscation?

- Obfuscation (or wrapping) of a PL/SQL unit is the process of hiding the PL/SQL source code.
- Wrapping can be done with the wrap utility and DBMS_DDL subprograms.
- The wrap utility is run from the command line and it processes an input SQL file, such as a SQL*Plus installation script.
- The DBMS_DDL subprograms wrap a single PL/SQL unit, such as a single CREATE PROCEDURE command, that has been generated dynamically.

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Note

For additional information about obfuscation, refer to the *Oracle Database PL/SQL Language Reference 11g Release 1 (11.1)* guide.

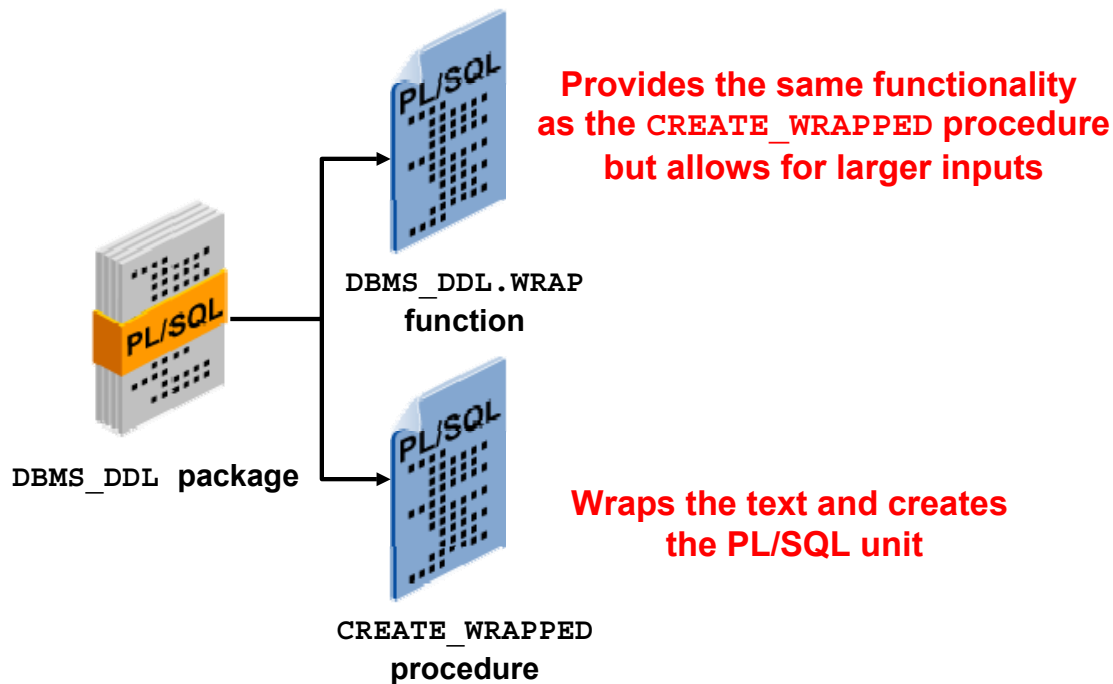
Benefits of Obfuscating

- It prevents others from seeing your source code.
- Your source code is not visible through the `USER_SOURCE`, `ALL_SOURCE`, or `DBA_SOURCE` data dictionary views.
- SQL*Plus can process the obfuscated source files.
- The `Import` and `Export` utilities accept wrapped files.

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What's New in Dynamic Obfuscating Since Oracle 10g?



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What's New in Dynamic Obfuscating Since Oracle 10g?

The `CREATE_WRAPPED` Procedure

It takes as input a single `CREATE` OR `REPLACE` statement that specifies creation of a PL/SQL package specification, package body, function, procedure, type specification, or type body, generates a `CREATE` OR `REPLACE` statement with the PL/SQL source text obfuscated, and executes the generated statement.

The `WRAP` Function

It takes as input a `CREATE` OR `REPLACE` statement that specifies the creation of a PL/SQL package specification, package body, function, procedure, type specification, or type body and returns a `CREATE` OR `REPLACE` statement, where the text of the PL/SQL unit has been obfuscated.

Nonobfuscated PL/SQL Code: Example

```
BEGIN -- The ALL_SOURCE view family shows source code
EXECUTE IMMEDIATE '
CREATE OR REPLACE PROCEDURE P1 IS
BEGIN
    DBMS_OUTPUT.PUT_LINE (''I am not wrapped'');
END P1;
';
END;
/
CALL p1();
```

```
anonymous block completed
CALL p1() succeeded.
I'm not wrapped
```

```
SELECT text FROM user_source
WHERE name = 'P1' ORDER BY line;
```

	TEXT
1	PROCEDURE P1 IS
2	BEGIN
3	DBMS_OUTPUT.PUT_LINE ('I am not wrapped');
4	END P1;
5	

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Nonobfuscated PL/SQL Code: Example

In the first example in the slide, the `EXECUTE IMMEDIATE` statement is used to create the procedure `P1`. The code in the created procedure is not wrapped. The code is not hidden when you use any of the views from the `ALL_SOURCE` view family to display the procedure's code as shown in the slide.

Obfuscated PL/SQL Code: Example

```
BEGIN -- ALL_SOURCE view family obfuscates source code
  DBMS_DDL.CREATE_WRAPPED ( '
    CREATE OR REPLACE PROCEDURE P1 IS
    BEGIN
      DBMS_OUTPUT.PUT_LINE ('I am wrapped now');
    END P1;
  ' );
END;
/
CALL p1();
```

```
anonymous block completed
call p1() succeeded.
I am wrapped now
```

```
SELECT text FROM user_source
WHERE name = 'P1' ORDER BY line;
```

```
TEXT
-----
PROCEDURE P1 wrapped
a000000
b2
abcd
. . .
```

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Obfuscated PL/SQL Code: Example

In the example in the slide, the `DBMS_DDL.CREATE_WRAPPED` package procedure is used to create the procedure `P1`.

The code is obfuscated when you use any of the views from the `ALL_SOURCE` view family to display the procedure's code as shown on the next page. When you check the `*_SOURCE` views, the source is wrapped, or hidden, so that others cannot view the code details as shown in the output of the command in the slide.

Dynamic Obfuscation: Example

```
SET SERVEROUTPUT ON

DECLARE
c_code CONSTANT VARCHAR2(32767) :=
' CREATE OR REPLACE PROCEDURE new_proc AS
  v_VDATE  DATE;
  BEGIN
    v_VDATE := SYSDATE;
    DBMS_OUTPUT.PUT_LINE(v_VDATE) ;
  END; ' ;
BEGIN
  DBMS_DDL.CREATE_WRAPPED (c_CODE);
END;
/
```

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Dynamic Obfuscation: Example

The example in the slide displays the creation of a dynamically obfuscated procedure called NEW_PROC. To verify that the code for NEW_PROC is obfuscated, you can query from the DBA|ALL|USER_SOURCE dictionary views as shown below:

```
SELECT text FROM user_source
WHERE name = 'NEW_PROC';
```

TEXT

```
-----
PROCEDURE new_proc wrapped
a0000000
```

...

```
7
71 9e
hBWMPGeSsd58b4jCP3/0d04rof0wg5nnm7+fMr2ywFyFDGLQlhaXriu4dCuPCWnnx1J0U1xp
pvc8nsr7Seq/riQvHRsXAQovdohOK6ZvM1Kbskr+KLK957KzHQYwLK4k6rJLCS5EyJ7qJB/2
RDmm3j79Uw==
```

1 rows selected

The PL/SQL Wrapper Utility

- The PL/SQL wrapper is a stand-alone utility that hides application internals by converting PL/SQL source code into portable object code.
- Wrapping has the following features:
 - Platform independence
 - Dynamic loading
 - Dynamic binding
 - Dependency checking
 - Normal importing and exporting when invoked

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PL/SQL Wrapper

The PL/SQL wrapper is a stand-alone utility that converts PL/SQL source code into portable object code. Using it, you can deliver PL/SQL applications without exposing your source code, which may contain proprietary algorithms and data structures. The wrapper converts the readable source code into unreadable code. By hiding application internals, it prevents misuse of your application.

Wrapped code, such as PL/SQL stored programs, has several features:

- It is platform independent, so you do not need to deliver multiple versions of the same compilation unit.
- It permits dynamic loading, so users need not shut down and restart to add a new feature.
- It permits dynamic binding, so external references are resolved at load time.
- It offers strict dependency checking, so that invalidated program units are recompiled automatically when they are invoked.
- It supports normal importing and exporting, so the import/export utility can process wrapped files.

Running the Wrapper Utility

```
WRAP INAME=input_file_name [ONAME=output_file_name]
```

- Do not use spaces around the equal signs.
- The INAME argument is required.
- The default extension for the input file is .sql, unless it is specified with the name.
- The ONAME argument is optional.
- The default extension for output file is .plb, unless specified with the ONAME argument.

Examples

```
WRAP INAME=demo_04_hello.sql  
WRAP INAME=demo_04_hello  
WRAP INAME=demo_04_hello.sql ONAME=demo_04_hello.plb
```

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Running the Wrapper

The wrapper is an operating system executable called WRAP. To run the wrapper, enter the following command at your operating system prompt:

```
WRAP INAME=input_file_name [ONAME=output_file_name]
```

Each of the examples shown in the slide takes a file called demo_04_hello.sql as input and creates an output file called demo_04_hello.plb.

After the wrapped file is created, execute the .plb file from iSQL*Plus to compile and store the wrapped version of the source code, as you would execute SQL script files.

Note

- Only the INAME argument is required. If the ONAME argument is not specified, then the output file acquires the same name as the input file with an extension of .plb.
- The input file can have any extension, but the default is .sql.
- Case sensitivity of the INAME and ONAME values depends on the operating system.
- Generally, the output file is much larger than the input file.
- Do not put spaces around the equal signs in the INAME and ONAME arguments and values.

Results of Wrapping

```
-- Original PL/SQL source code in input file:
```

```
CREATE PACKAGE banking IS
  min_bal := 100;
  no_funds EXCEPTION;
  ...
END banking;
/
```

```
-- Wrapped code in output file:
```

```
CREATE PACKAGE banking
  wrapped
012abc463e ...
/
```

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Results of Wrapping

When it is wrapped, an object type, package, or subprogram has the following form: header, followed by the word `wrapped`, followed by the encrypted body.

The input file can contain any combination of SQL statements. However, the PL/SQL wrapper wraps only the following CREATE statements:

- CREATE [OR REPLACE] TYPE
- CREATE [OR REPLACE] TYPE BODY
- CREATE [OR REPLACE] PACKAGE
- CREATE [OR REPLACE] PACKAGE BODY
- CREATE [OR REPLACE] FUNCTION
- CREATE [OR REPLACE] PROCEDURE

All other SQL CREATE statements are passed intact to the output file.

Guidelines for Wrapping

- You must wrap only the package body, not the package specification.
- The wrapper can detect syntactic errors but cannot detect semantic errors.
- The output file should not be edited. You maintain the original source code and wrap again as required.
- To ensure that all the important parts of your source code are obfuscated, view the wrapped file in a text editor before distributing it.

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Guidelines for Wrapping

Guidelines include the following:

- When wrapping a package or object type, wrap only the body, not the specification. Thus, you give other developers the information that they need to use the package without exposing its implementation.
- If your input file contains syntactic errors, the PL/SQL wrapper detects and reports them. However, the wrapper cannot detect semantic errors because it does not resolve external references. For example, the wrapper does not report an error if the table or view emp does not exist:

```
CREATE PROCEDURE raise_salary (emp_id INTEGER, amount NUMBER)
AS
BEGIN
    UPDATE emp -- should be emp
        SET sal = sal + amount WHERE empno = emp_id;
END;
```

However, the PL/SQL compiler resolves external references. Therefore, semantic errors are reported when the wrapper output file (.plb file) is compiled.

- Because its contents are not readable, the output file should not be edited. To change a wrapped object, you need to modify the original source code and wrap the code again.

DBMS_DDL Package Versus the Wrap Utility

Functionality	DBMS_DDL	Wrap Utility
Code obfuscation	Yes	Yes
Dynamic Obfuscation	Yes	No
Obfuscate multiple programs at a time	No	Yes

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DBMS_DDL Versus the Wrap Utility

Both the Wrap utility and the DBMS_DDL package have distinct uses:

The Wrap utility is useful for obfuscating multiple programs with one execution of the utility. In essence, a complete application may be wrapped. However, the Wrap utility cannot be used to obfuscate dynamically generated code at run time. The Wrap utility processes an input SQL file and obfuscates only the PL/SQL units in the file, such as:

- Package specification and body
- Function and procedure
- Type specification and body

The Wrap utility does not obfuscate PL/SQL content in:

- Anonymous blocks
- Triggers
- Non-PL/SQL code

The DBMS_DDL package is intended to obfuscate a dynamically generated program unit from within another program unit. The DBMS_DDL package methods cannot obfuscate multiple program units at one execution. Each execution of these methods accepts only one CREATE OR REPLACE statement at a time as argument.

Quiz

Conditional compilation enables you to customize the functionality in a PL/SQL application without removing any source code.

1. True
2. False

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Answer: 1

Conditional Compilation

Conditional compilation enables you to customize the functionality in a PL/SQL application without removing any source code:

Utilize the latest functionality with the latest database release or disable the new features to run the application against an older release of the database.

Activate debugging or tracing functionality in the development environment and hide that functionality in the application while it runs at a production site.

Summary

In this lesson, you should have learned how to:

- Describe and use conditional compilation
- Hide PL/SQL source code using dynamic obfuscation and the Wrap utility

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Summary

This lesson introduced the conditional compilation and obfuscating (or wrapping) of PL/SQL code.

Practice 12: Overview

This practice covers the following topics:

- Creating a package and a procedure that uses conditional compilation
- Using the appropriate package to retrieve the postprocessed source text of the PL/SQL unit
- Obfuscating some PL/SQL code

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Practice 12: Overview

In this practice, you create a package and a procedure that use conditional compilation. In addition, you use the appropriate package to retrieve the postprocessed source text of the PL/SQL unit. You also obfuscate some PL/SQL code.

Practice 12

1. Examine and then execute the `lab_12_01.sql` script. This script sets flags for displaying debugging code and tracing information. The script also creates the `my_pkg` package and the `circle_area` procedure.
2. Use the `DBMS_PREPROCESSOR` subprogram to retrieve the postprocessed source text of the PL/SQL unit after processing the conditional compilation directives from `lab_12_01`.
3. Create a PL/SQL script that uses the `DBMS_DB_VERSION` constant with conditional compilation. The code should test for the Oracle database version:
 - a. If the database version is less than or equal to 10.1, it should display the following error message:
Unsupported database release.
 - b. If the database version is 11.1 or higher, it should display the following message:
Release 11.1 is supported.
4. Consider the following code in the `lab_12_04.sql` script that uses `CREATE_WRAPPED` to dynamically create and wrap a package specification and a package body in a database. Edit the `lab_12_04.sql` script to add the needed code to obfuscate the PL/SQL code. Save and then execute the script.

```
DECLARE
-- the package_text variable contains the text to create
-- the package spec and body
package_text VARCHAR2(32767);
FUNCTION generate_spec (pkgname VARCHAR2) RETURN VARCHAR2
AS
BEGIN
    RETURN 'CREATE PACKAGE ' || pkgname || ' AS
        PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER);
        PROCEDURE fire_employee (emp_id NUMBER);
        END ' || pkgname || ';' ;
END generate_spec;
```

Practice 12 (continued)

4. (continued)

```
FUNCTION generate_body (pkgname VARCHAR2) RETURN VARCHAR2
AS
BEGIN
    RETURN 'CREATE PACKAGE BODY ' || pkgname || ' AS
        PROCEDURE raise_salary (emp_id NUMBER, amount NUMBER)
IS
    BEGIN
        UPDATE employees SET salary = salary + amount WHERE
employee_id = emp_id;
    END raise_salary;
    PROCEDURE fire_employee (emp_id NUMBER) IS
    BEGIN
        DELETE FROM employees WHERE employee_id = emp_id;
    END fire_employee;
    END ' || pkgname || ';' ;
END generate_body;
```

- Generate the package specification while passing the emp_actions parameter.
- Create and wrap the package specification.
- Generate the package body.
- Create and wrap the package body.
- Call a procedure from the wrapped package as follows:
CALL emp_actions.raise_salary(120, 100);
- Use the USER_SOURCE data dictionary view to verify that the code is hidden as follows:

```
SELECT text FROM USER_SOURCE WHERE name = 'EMP_ACTIONS';
```

13

Managing Dependencies

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Objectives

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

- Track procedural dependencies
- Predict the effect of changing a database object on procedures and functions
- Manage procedural dependencies

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Lesson Aim

This lesson introduces you to object dependencies and implicit and explicit recompilation of invalid objects.

Overview of Schema Object Dependencies

Object Type	Can Be Dependent or Referenced
Package body	Dependent only
Package specification	Both
Sequence	Referenced only
Subprogram	Both
Synonym	Both
Table	Both
Trigger	Both
User-defined object	Both
User-defined collection	Both
View	Both

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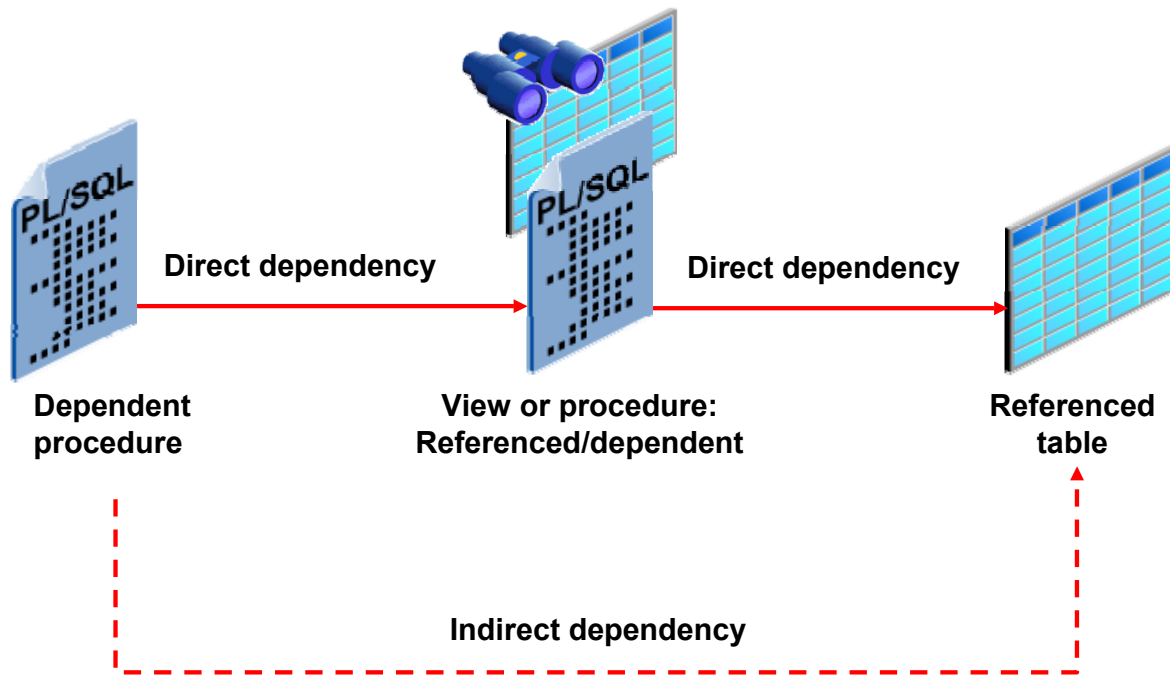
Dependent and Referenced Objects

Some types of schema objects can reference other objects in their definitions. For example, a view is defined by a query that references tables or other views, and the body of a subprogram can include SQL statements that reference other objects. If the definition of object A references object B, then A is a dependent object (with respect to B) and B is a referenced object (with respect to A).

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, the procedure may or may not continue to work without 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.
- If the status of a schema object is VALID, then the object has been compiled and can be immediately used when referenced.
- If the status of a schema object is INVALID, then the schema object must be compiled before it can be used.

Dependencies



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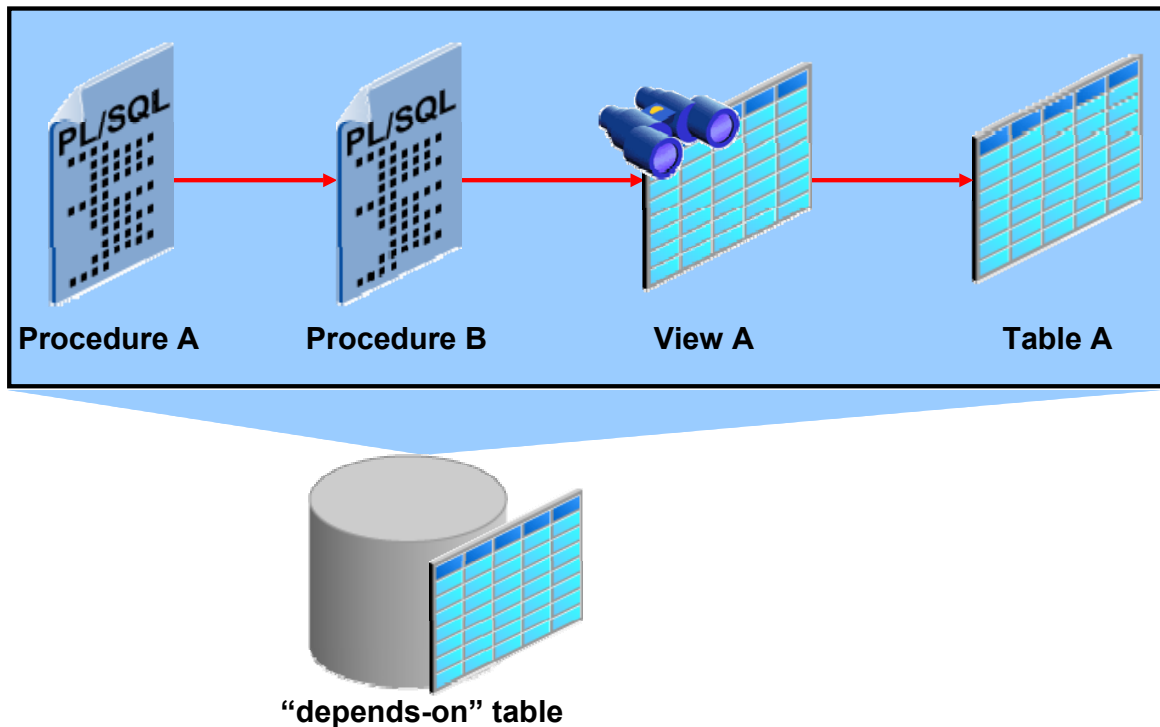
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Dependent and Referenced Objects (continued)

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

Direct Local Dependencies



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Managing Local Dependencies

In the case of local dependencies, the objects are on the same node in the same database. The Oracle server automatically manages all local dependencies, using the database's internal "depends-on" table. When a referenced object is modified, the dependent objects are sometimes invalidated. The next time an invalidated object is called, the Oracle server automatically recompiles it.

If you alter the definition of a referenced object, dependent objects might or might not continue to function without error, depending on the type of alteration. For example, if you drop a table, no view based on the dropped table is usable.

Starting with Oracle Database 10g, the `CREATE OR REPLACE SYNONYM` command has been enhanced to minimize the invalidations to dependent PL/SQL program units and views that reference it. This is covered later in this lesson.

Starting with Oracle Database 11g, dependencies are tracked at the level of element within unit. This is referred to as fine-grained dependency. Fine-grained dependencies are covered later in this lesson.

Querying Direct Object Dependencies: Using the USER_DEPENDENCIES View

DESC User_dependencies		
Name	Null	Type

NAME	NOT NULL	VARCHAR2(30)
TYPE		VARCHAR2(17)
REFERENCED_OWNER		VARCHAR2(30)
REFERENCED_NAME		VARCHAR2(64)
REFERENCED_TYPE		VARCHAR2(17)
REFERENCED_LINK_NAME		VARCHAR2(128)
SCHEMAID		NUMBER
DEPENDENCY_TYPE		VARCHAR2(4)
8 rows selected		

```
SELECT name, type, referenced_name, referenced_type
FROM   user_dependencies
WHERE  referenced_name IN ('EMPLOYEES', 'EMP_VW' );
```

Results:				
	NAME	TYPE	REFERENCED_NAME	REFERENCED_TYPE
1	QUERY_EMP	PROCEDURE	EMPLOYEES	TABLE
2	DML_CALL_SQL	FUNCTION	EMPLOYEES	TABLE
3	QUERY_CALL_SQL	FUNCTION	EMPLOYEES	TABLE
4	COMM_PKG	PACKAGE BODY	EMPLOYEES	TABLE
5	CURS_PKG	PACKAGE BODY	EMPLOYEES	TABLE
6	EMP_PKG	PACKAGE	EMPLOYEES	TABLE
7	EMP_PKG	PACKAGE BODY	EMPLOYEES	TABLE

...

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Querying Direct Object Dependencies: Using the USER_DEPENDENCIES View

You can determine which database objects to recompile manually by displaying direct dependencies from the USER_DEPENDENCIES data dictionary view.

The ALL_DEPENDENCIES and DBA_DEPENDENCIES views contain the additional OWNER column, which references the owner of the object.

The USER_DEPENDENCIES Data Dictionary View Columns

The columns of the USER_DEPENDENCIES data dictionary view are as follows:

- NAME: The name of the dependent object
- TYPE: The type of the dependent object (PROCEDURE, FUNCTION, PACKAGE, PACKAGE BODY, TRIGGER, or VIEW)
- REFERENCED_OWNER: The schema of the referenced object
- REFERENCED_NAME: The name of the referenced object
- REFERENCED_TYPE: The type of the referenced object
- REFERENCED_LINK_NAME: The database link used to access the referenced object

Querying an Object's Status

Every database object has one of the following status values:

Status	Description
VALID	The object was successfully compiled, using the current definition in the data dictionary.
COMPILED WITH ERRORS	The most recent attempt to compile the object produced errors.
INVALID	The object is marked invalid because an object that it references has changed. (Only a dependent object can be invalid.)
UNAUTHORIZED	An access privilege on a referenced object was revoked. (Only a dependent object can be unauthorized.)

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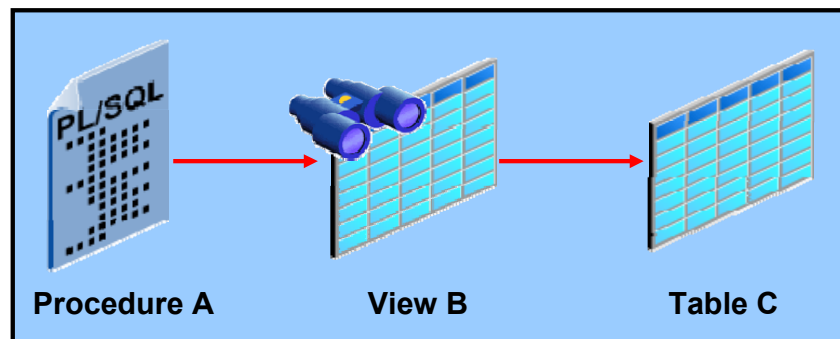
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Querying an Object's Status

Every database object has one of the status values shown in the table in the slide.

Note: The static data dictionary views—USER_OBJECTS, ALL_OBJECTS, and DBA_OBJECTS—do not distinguish between Compiled with errors, Invalid, and Unauthorized; instead, they describe all these as INVALID.

Invalidation of Dependent Objects



- Procedure A is a direct dependent of View B. View B is a direct dependent of Table C. Procedure A is an indirect dependent of Table C.
- Direct dependents are invalidated only by changes to the referenced object that affect them.
- Indirect dependents can be invalidated by changes to the reference object that do not affect them.

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Invalidation of Dependent Objects

If object A depends on object B, which depends on object C, then A is a direct dependent of B, B is a direct dependent of C, and A is an indirect dependent of C.

In Oracle Database 11g, direct dependents are invalidated only by changes to the referenced object that affect them (changes to the signature of the referenced object).

Indirect dependents can be invalidated by changes to the reference object that do not affect them: If a change to Table C invalidates View B, it invalidates Procedure A (and all other direct and indirect dependents of View B). This is called cascading invalidation.

Assume that the structure of the table on which a view is based is modified. When you describe the view by using the SQL*Plus DESCRIBE command, you get an error message that states that the object is invalid to describe. This is because the command is not a SQL command; at this stage, the view is invalid because the structure of its base table is changed. If you query the view now, then the view is recompiled automatically and you can see the result if it is successfully recompiled.

Schema Object Change That Invalidates Some Dependents: Example

```
CREATE VIEW commissioned AS  
SELECT first_name, last_name, commission_pct FROM employees  
WHERE commission_pct > 0.00;
```

```
CREATE VIEW six_figure_salary AS  
SELECT * FROM employees  
WHERE salary >= 100000;
```

```
SELECT object_name, status  
FROM user_objects  
WHERE object_type = 'VIEW';
```

Results:

	OBJECT_NAME	STATUS
1	EMP_DETAILS	VALID
2	COMMISSIONED	VALID
3	SIX_FIGURE_SALARY	VALID
4	EMP_DETAILS_VIEW	VALID

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Schema Object Change That Invalidates Some Dependents: Example

The example in the slide demonstrates an example of a schema object change that invalidates some dependents but not others. The two newly created views are based on the EMPLOYEES table in the HR schema. The status of the newly created views is VALID.

Schema Object Change That Invalidates Some Dependents: Example

```
ALTER TABLE employees MODIFY email VARCHAR2(50);

SELECT object_name, status
FROM user_objects
WHERE object_type = 'VIEW';
```

Results:

	OBJECT_NAME	STATUS
1	EMP_DETAILS	VALID
2	COMMISSIONED	VALID
3	SIX_FIGURE_SALARY	INVALID
4	EMP_DETAILS_VIEW	VALID

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Schema Object Change That Invalidates Some Dependents: Example (continued)

Suppose you determine that the EMAIL column in the EMPLOYEES table needs to be lengthened from 25 to 50, you alter the table as shown in the slide above.

Because the COMMISSIONED view does not include the EMAIL column in its select list, it is not invalidated. However, the SIXFIGURES view is invalidated because all columns in the table are selected.

Displaying Direct and Indirect Dependencies

1. Run the `utldtree.sql` script that creates the objects that enable you to display the direct and indirect dependencies.

```
@D:/Labs/plpu/labs/utldtree.sql
```

2. Execute the `DEPTREE_FILL` procedure.

```
EXECUTE deptree_fill('TABLE', 'ORA61', 'EMPLOYEES')
```

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Displaying Direct and Indirect Dependencies by Using Views Provided by Oracle

Display direct and indirect dependencies from additional user views called `DEPTREE` and `IDETREE`; these views are provided by Oracle.

Example

1. Make sure that the `utldtree.sql` script has been executed. This script is located in the `$ORACLE_HOME/rdbms/admin` folder. You can run the script as follows:

```
@?/rdbms/admin/utldtree.sql
```

Note: In this class, this script is supplied in the `lab` folder of your class files. The code example above uses the student account `ORA61`.

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:

<i>object_type</i>	Type of the referenced object
<i>object_owner</i>	Schema of the referenced object
<i>object_name</i>	Name of the referenced object

Displaying Dependencies Using the DEPTREE View

```
SELECT  nested_level, type, name
FROM    deptree
ORDER BY seq#;
```

NESTED_LEVEL	TYPE	NAME
0	TABLE	EMPLOYEES
1	VIEW	EMP_DETAILS_VIEW
1	TRIGGER	SECURE_EMPLOYEES
1	TRIGGER	UPDATE_JOB_HISTORY
1	PROCEDURE	RAISE_SALARY
2	PROCEDURE	PROCESS_EMPLOYEES
1	PROCEDURE	QUERY_EMP
1	PROCEDURE	PROCESS_EMPLOYEES
1	FUNCTION	DML_CALL_SQL
1	FUNCTION	QUERY_CALL_SQL
1	PACKAGE BODY	COMM_PKG
1	PACKAGE BODY	CURS_PKG
1	PACKAGE	EMP_PKG
2	PACKAGE BODY	EMP_PKG
1	PACKAGE BODY	EMP_PKG
1	PROCEDURE	SAL_STATUS

...

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Displaying Dependencies Using the DEPTREE View

You can display a tabular representation of all dependent objects by querying the DEPTREE view. You can display an indented representation of the same information by querying the IDEPTREE view, which consists of a single column named DEPENDENCIES as follows:

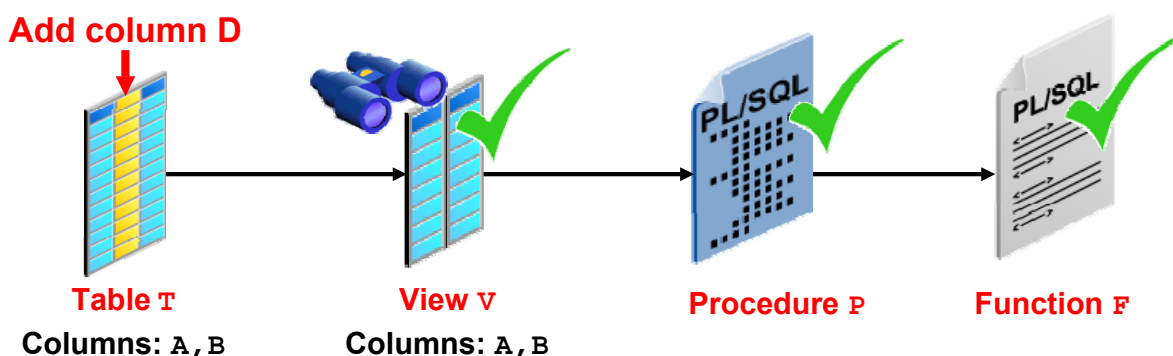
```
SELECT *
FROM   ideptree;
```

DEPENDENCIES

```
VIEW ORA61.EMP_DETAILS_VIEW
PROCEDURE ORA61.UPDATE_SALARY
TRIGGER ORA61.AUDIT_EMP_VALUES
TRIGGER ORA61.CHECK_SALARY
VIEW ORA61.SIX_FIGURE_SALARY
PROCEDURE ORA61.QUERY_EMP
PACKAGE BODY ORA61.COMM_PKG
PACKAGE ORA61.EMP_PKG
VIEW ORA61.EMP_DETAILS
  TRIGGER ORA61.NEW_EMP_DEPT
TRIGGER ORA61.SECURE_EMPLOYEES
  PACKAGE BODY ORA61.EMP_PKG
PROCEDURE ORA61.EMPLOYEE_SAL
FUNCTION ORA61.EMP_HIRE_DATE
```

More Precise Dependency Metadata in Oracle Database 11g

- Before 11g, adding column D to table T invalidated the dependent objects.
- Oracle Database 11g records additional, finer-grained dependency management:
 - Adding column D to table T does not impact view V and does not invalidate the dependent objects



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Fine-Grained Dependencies

Starting with Oracle Database 11g, you have access to records that describe more precise dependency metadata. This is called fine-grained dependency and it enables you to see when the dependent objects are not invalidated without logical requirement.

Earlier Oracle Database releases record dependency metadata—for example, PL/SQL unit P depends on PL/SQL unit F, or that view V depends on table T—with the precision of the whole object. This means that dependent objects are sometimes invalidated without logical requirement. For example, if view V depends only on columns A and B in table T, and column D is added to table T, the validity of view V is not logically affected. Nevertheless, before Oracle Database Release 11.1, view V is invalidated by the addition of column D to table T. With Oracle Database Release 11.1, adding column D to table T does not invalidate view V. Similarly, if procedure P depends only on elements E1 and E2 within a package, adding element E99 to the package does not invalidate procedure P.

Reducing the invalidation of dependent objects in response to changes to the objects on which they depend increases application availability, both in the development environment and during online application upgrade.

For more information about this topic, refer to the *11g: Infrastructure Grid – High Availability PL eStudy*.

Fine-Grained Dependency Management

- In Oracle Database 11g, dependencies are now tracked at the level of *element within unit*.
- Element-based dependency tracking covers the following:
 - Dependency of a single-table view on its base table
 - Dependency of a PL/SQL program unit (package specification, package body, or subprogram) on the following:
 - Other PL/SQL program units
 - Tables
 - Views



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Fine-Grained Dependency Management: Example 1

```
CREATE TABLE t2 (col_a NUMBER, col_b NUMBER, col_c NUMBER);
CREATE VIEW v AS SELECT col_a, col_b FROM t2;
```

```
SELECT ud.name, ud.type, ud.referenced_name,
       ud.referenced_type, uo.status
FROM user_dependencies ud, user_objects uo
WHERE ud.name = uo.object_name AND ud.name = 'V';
```

Results:					
	NAME	TYPE	REFERENCED_NAME	REFERENCED_TYPE	STATUS
1	V	VIEW	T2	TABLE	VALID

```
ALTER TABLE t2 ADD (col_d VARCHAR2(20));
```

```
SELECT ud.name, ud.type, ud.referenced_name,
       ud.referenced_type, uo.status
FROM user_dependencies ud, user_objects uo
WHERE ud.name = uo.object_name AND ud.name = 'V';
```

Results:					
	NAME	TYPE	REFERENCED_NAME	REFERENCED_TYPE	STATUS
1	V	VIEW	T2	TABLE	VALID

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Fine-Grained Dependency Management: Example 1

Example of Dependency of a Single-Table View on Its Base Table

In the first slide example, table T2 is created with three columns: COL_A, COL_B, and COL_C. A view named V is created based on columns COL_A and COL_B of table T2. The dictionary views are queried and the view V is dependent on table T and its status is valid.

In the third slide example, table T2 is altered. A new column named COL_D is added. The dictionary views still report that the view V is dependent because element-based dependency tracking realizes that the columns COL_A and COL_B are not modified and, therefore, the view does not need to be invalidated.

Fine-Grained Dependency Management: Example 1

```
ALTER TABLE t2 MODIFY (col_a VARCHAR2(20));  
SELECT ud.name, ud.referenced_name, ud.referenced_type,  
       uo.status  
FROM user_dependencies ud, user_objects uo  
WHERE ud.name = uo.object_name AND ud.name = 'V';
```

Results:				
	NAME	REFERENCED_NAME	REFERENCED_TYPE	STATUS
1	V	T2	TABLE	INVALID

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Fine-Grained Dependency Management: Example 1 (continued)

In the slide example, the view is invalidated because its element (COL_A) is modified in the table on which the view is dependent.

Fine-Grained Dependency Management: Example 2

```
CREATE PACKAGE pkg IS
  PROCEDURE proc_1;
END pkg;
/
CREATE OR REPLACE PROCEDURE p IS
BEGIN
  pkg.proc_1();
END p;
/
CREATE OR REPLACE PACKAGE pkg
IS
  PROCEDURE proc_1;
  PROCEDURE unheard_of;
END pkg;
/
```

```
PACKAGE pkg Compiled.
PROCEDURE p Compiled.
PACKAGE pkg Compiled.
```

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Fine-Grained Dependency Management: Example 2

In the slide example, you create a package named PKG that has procedure PROC_1 declared. A procedure named P invokes PKG.PROC_1.

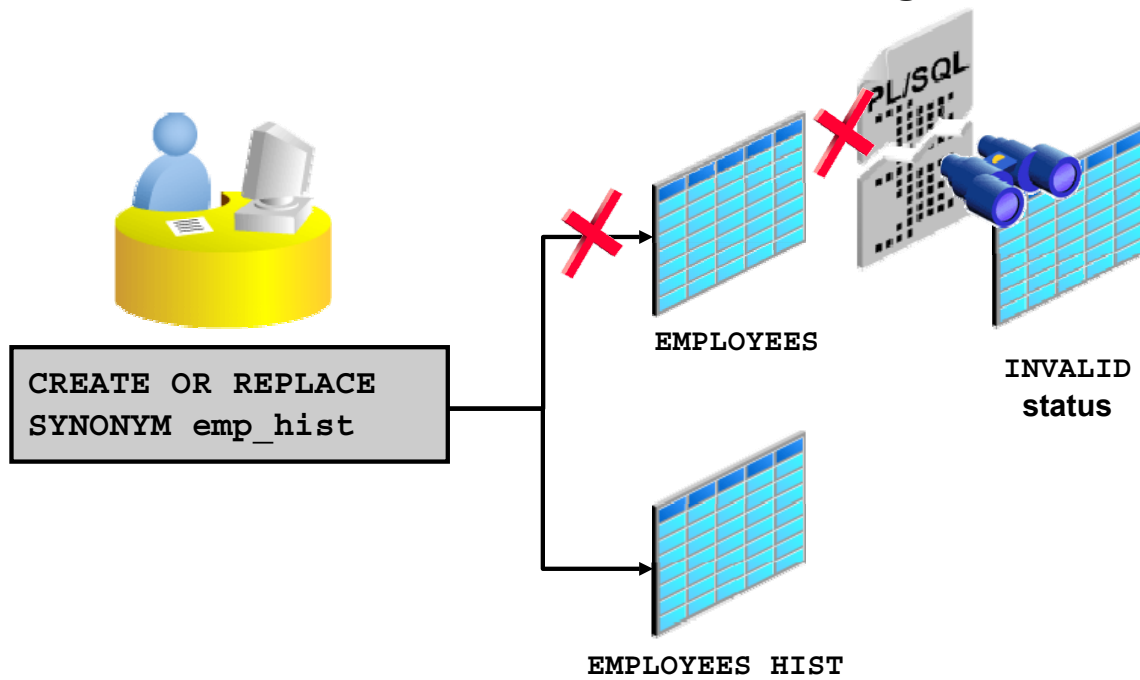
The definition of the PKG package is modified and another subroutine is added to the package declaration.

When you query the USER_OBJECTS dictionary view for the status of the P procedure, it is still valid as shown as follows because the element you added to the definition of PKG is not referenced through procedure P.

```
SELECT status FROM user_objects
WHERE object_name = 'P';
```

Results:	
STATUS	
1 VALID	

Impact of Redefining Synonyms Before Oracle Database 10g



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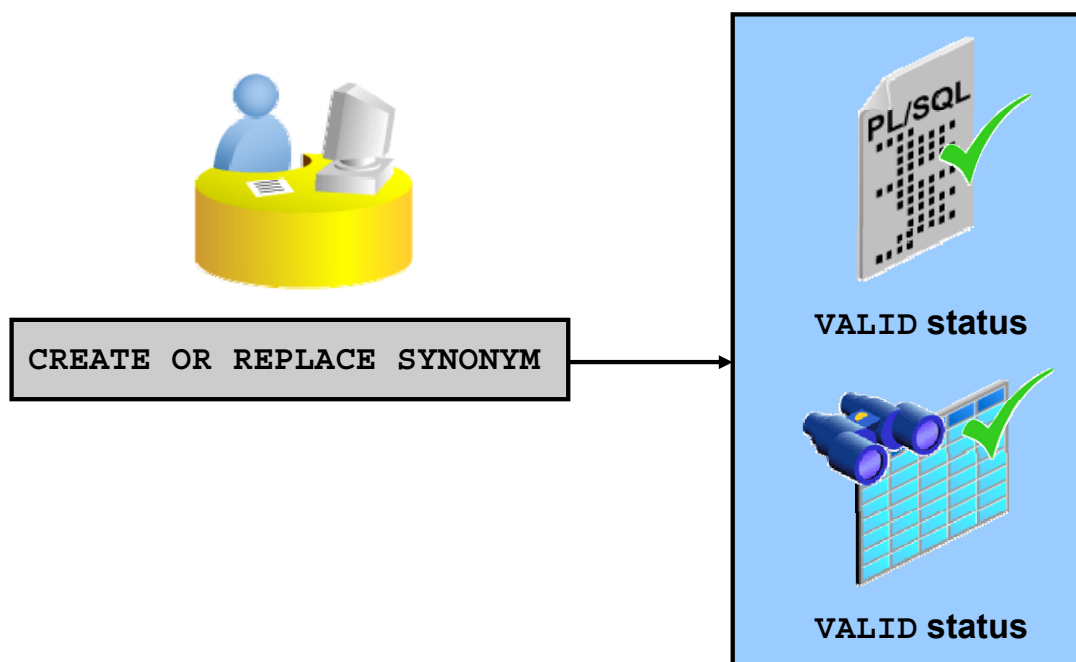
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Impact of Redefining Synonyms

You can use synonyms to achieve data independence and location transparency. However, you must be careful when you reassign a synonym from one table to another. In many cases, this invalidates dependent objects such as PL/SQL program units, views, or object types.

Before the introduction of this feature, when you redefined a synonym, the status of any dependent PL/SQL program unit was set to **INVALID**. If you did not recompile the PL/SQL program units manually, they would recompile automatically the next time they were invoked, causing run-time performance overhead.

Changes to Synonym Dependencies Starting with Oracle Database 10g



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Changes to Synonym Dependencies

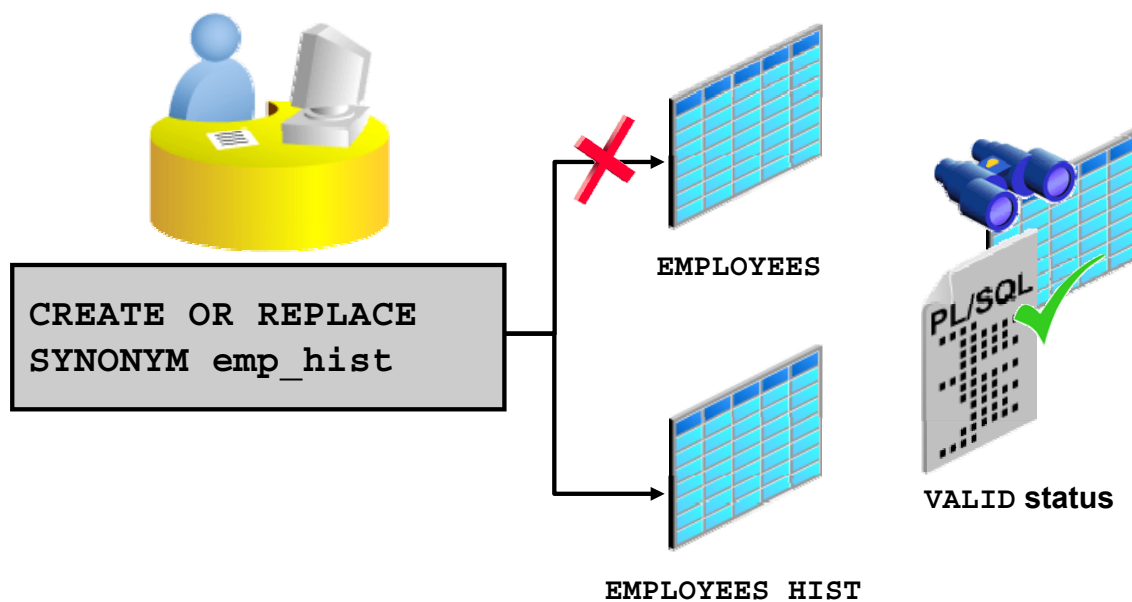
Starting with version 10g, Oracle Database minimizes down time during code upgrades or schema merges.

When certain conditions on columns, privileges, partitions, and so on are met, a table or object type is considered equivalent and dependent objects are no longer invalidated. For detailed information, refer to the *Oracle Database 10g: Maximize Availability - General Enhancements* eStudy.

In Oracle Database 10g, the `CREATE OR REPLACE SYNONYM` command has been enhanced to minimize the invalidations to dependent PL/SQL program units and views that reference it. This eliminates the need for time-consuming recompilation of the program units after redefinition of the synonyms or during execution. You do not have to set any parameters or issue any special commands to enable this functionality; invalidations are minimized automatically.

Note: This enhancement applies only to synonyms pointing to tables.

Maintaining Valid PL/SQL Program Units and Views



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Maintaining Valid PL/SQL Program Units

Starting with Oracle Database 10g Release 2, you can change the definition of a synonym, and the dependent PL/SQL program units are not invalidated under the following conditions:

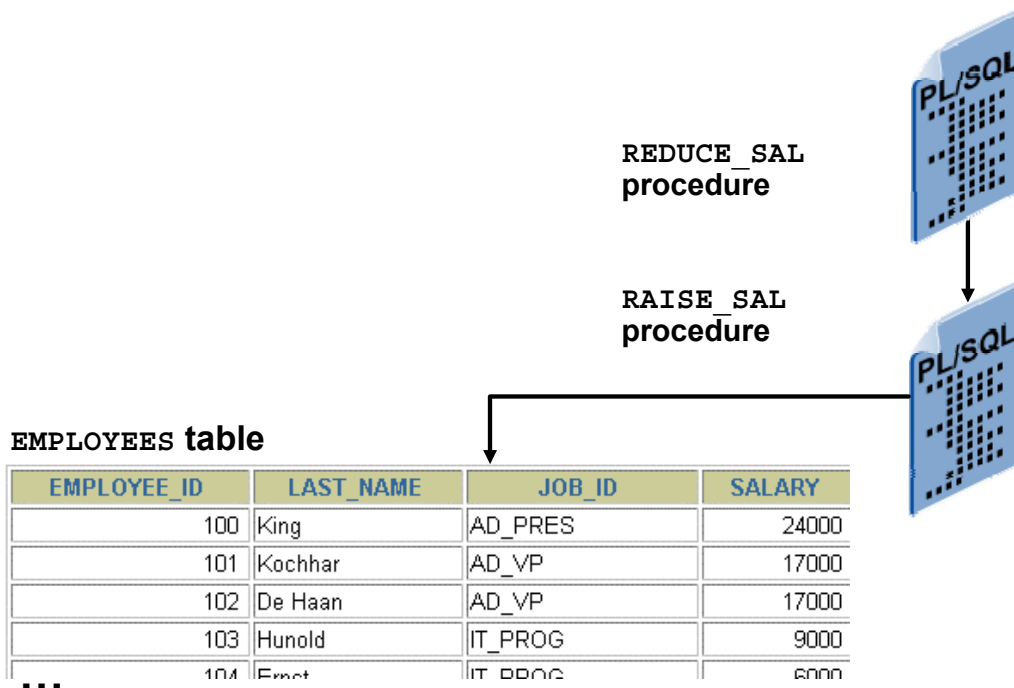
- The column order, column names, and column data types of the tables are identical.
- The privileges on the newly referenced table and its columns are a superset of the set of privileges on the original table. These privileges must not be derived through roles alone.
- The names and types of partitions and subpartitions are identical.
- The tables are of the same organization type.
- Object type columns are of the same type.

Maintaining Valid Views

As with dependent PL/SQL program units, you can change the definition of a synonym, and the dependent views are not invalidated under the conditions listed in the preceding paragraph. In addition, the following must be true to preserve the VALID status of dependent views, but not of dependent PL/SQL program units, when you redefine a synonym:

- Columns and order of columns defined for primary key and unique indexes, NOT NULL constraints, and primary key and unique constraints must be identical.
- The dependent view cannot have any referential constraints.

Another Scenario of Local Dependencies



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Another Scenario of Local Dependencies

Example 1

Predict the effect that a change in the definition of a procedure has on the recompilation of a dependent procedure.

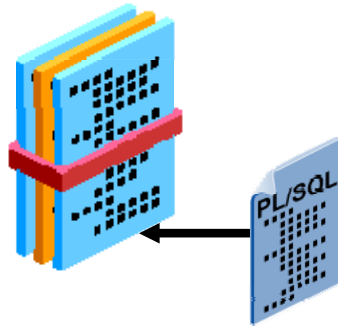
Assume that the RAISE_SAL procedure updates the EMPLOYEES table directly, and that the REDUCE_SAL procedure updates the EMPLOYEES table indirectly by way of RAISE_SAL.

In each of the following cases, does the REDUCE_SAL procedure successfully recompile?

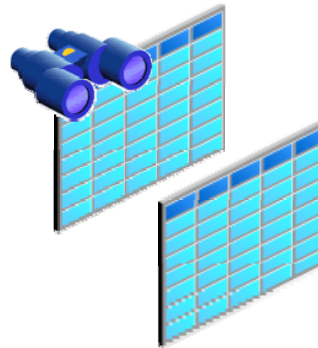
1. The internal logic of the RAISE_SAL procedure is modified.
2. One of the formal parameters to the RAISE_SAL procedure is eliminated.

Guidelines for Reducing Invalidation

To reduce invalidation of dependent objects:



Add new items to the end of the package



Reference each table through a view

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Guidelines for Reducing Invalidation

Add New Items to End of Package

When adding new items to a package, add them to the end of the package. This preserves the slot numbers and entry-point numbers of existing top-level package items, preventing their invalidation. For example, consider the following package:

```
CREATE OR REPLACE PACKAGE pkg1 IS  
  FUNCTION get_var RETURN VARCHAR2;  
  PROCEDURE set_var (v VARCHAR2);  
END;
```

Adding an item to the end of `pkg1` does not invalidate dependents that reference `get_var`. Inserting an item between the `get_var` function and the `set_var` procedure invalidates dependents that reference the `set_var` function.

Reference Each Table Through a View

Reference tables indirectly, using views. This allows you to do the following:

- Add columns to the table without invalidating dependent views or dependent PL/SQL objects
- Modify or delete columns not referenced by the view without invalidating dependent objects

Object Revalidation

- An object that is not valid when it is referenced must be validated before it can be used.
- Validation occurs automatically when an object is referenced; it does not require explicit user action.
- If an object is not valid, its status is either `COMPILED WITH ERRORS`, `UNAUTHORIZED`, or `INVALID`.

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Object Revalidation

The compiler cannot automatically revalidate an object that compiled with errors. The compiler recompiles the object, and if it recompiles without errors, it is revalidated; otherwise, it remains invalid.

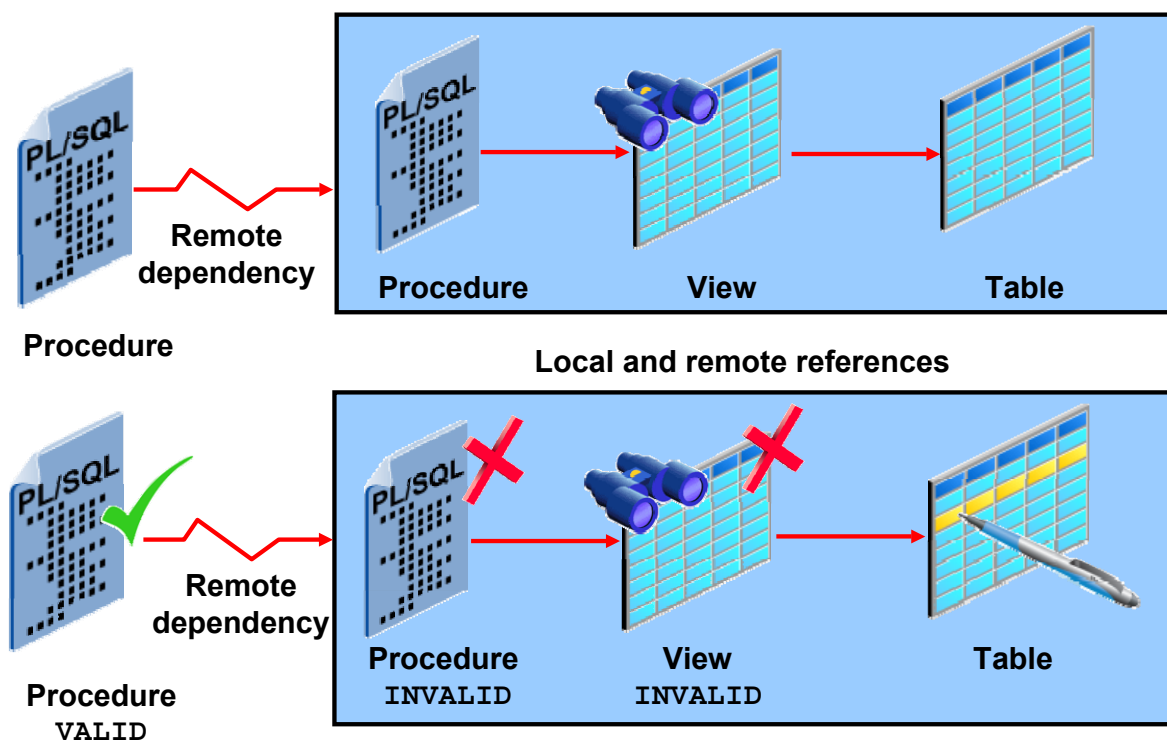
The compiler checks whether the unauthorized object has access privileges to all of its referenced objects. If so, the compiler revalidates the unauthorized object without recompiling it. If not, the compiler issues appropriate error messages.

The SQL compiler recompiles the invalid object. If the object recompiles without errors, it is revalidated; otherwise, it remains invalid.

For an invalid PL/SQL program unit (procedure, function, or package), the PL/SQL compiler checks whether any referenced object changed in a way that affects the invalid object.

- If so, the compiler recompiles the invalid object. If the object recompiles without errors, it is revalidated; otherwise, it remains invalid. If not, the compiler revalidates the invalid object without recompiling it.
- If not, the compiler revalidates the invalid object without recompiling it. Fast revalidation is usually performed on objects that were invalidated due to cascading invalidation.

Remote Dependencies



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Remote Dependencies

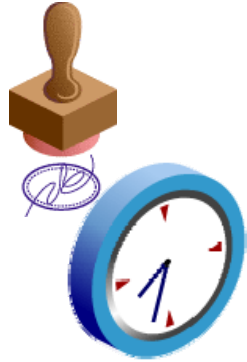
In the case of remote dependencies, the objects are on separate nodes. The Oracle server does not manage dependencies among remote schema objects other than local-procedure-to-remote-procedure dependencies (including functions, packages, and triggers). The local stored procedure and all its dependent objects are invalidated but do not automatically recompile when called for the first time.

Recompilation of Dependent Objects: Local and Remote

- Verify successful explicit recompilation of the dependent remote procedures and implicit recompilation of the dependent local procedures by checking the status of these procedures within the `USER_OBJECTS` view.
- If an automatic implicit recompilation of the dependent local procedures fails, the status remains invalid and the Oracle server issues a run-time error. Therefore, to avoid disrupting production, it is strongly recommended that you recompile local dependent objects manually, rather than relying on an automatic mechanism.

Concepts of Remote Dependencies

Remote dependencies are governed by the mode that is chosen by the user:



TIMESTAMP checking



SIGNATURE checking

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Concepts of Remote Dependencies

TIMESTAMP Checking

Each PL/SQL program unit carries a time stamp that is set when it is created or recompiled. Whenever you alter a PL/SQL program unit or a relevant schema object, all its dependent program units are marked as invalid and must be recompiled before they can execute. The actual time stamp comparison occurs when a statement in the body of a local procedure calls a remote procedure.

SIGNATURE Checking

For each PL/SQL program unit, both the time stamp and the signature are recorded. The signature of a PL/SQL construct contains information about the following:

- The name of the construct (procedure, function, or package)
- The base types of the parameters of the construct
- The modes of the parameters (IN, OUT, or IN OUT)
- The number of the parameters

The recorded time stamp in the calling program unit is compared with the current time stamp in the called remote program unit. If the time stamps match, the call proceeds. If they do not match, the remote procedure call (RPC) layer performs a simple comparison of the signature to determine whether the call is safe or not. If the signature has not been changed in an incompatible manner, execution continues; otherwise, an error is returned.

Setting the REMOTE_DEPENDENCIES_MODE Parameter

- As an `init.ora` parameter:
`REMOTE_DEPENDENCIES_MODE = value`
- At the system level:
`ALTER SYSTEM SET REMOTE_DEPENDENCIES_MODE = value`
- At the session level:
`ALTER SESSION SET REMOTE_DEPENDENCIES_MODE = value`

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REMOTE_DEPENDENCIES_MODE Parameter

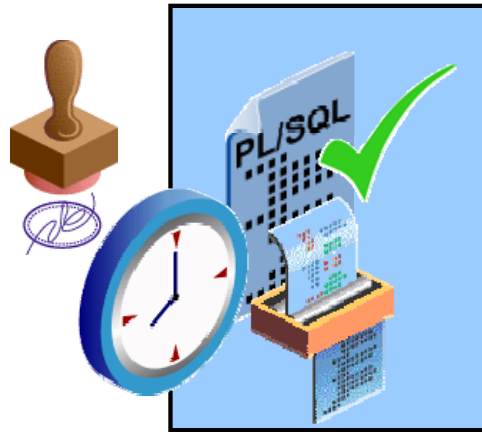
Setting the REMOTE_DEPENDENCIES_MODE

value `TIMESTAMP`
 `SIGNATURE`

Specify the value of the `REMOTE_DEPENDENCIES_MODE` parameter using one of the three methods described in the slide.

Note: The calling site determines the dependency model.

Remote Procedure B Compiles at 8:00 AM



**Remote procedure B:
Compiles and is VALID
at 8:00 AM**

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Local Procedures Referencing Remote Procedures

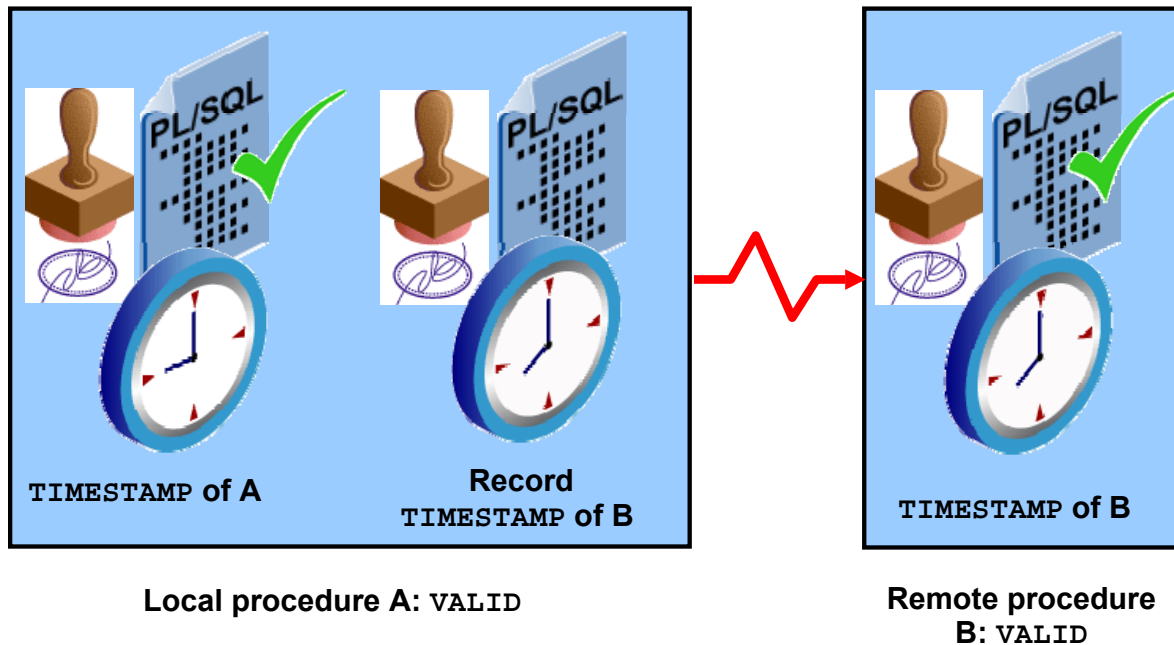
A local procedure that references a remote procedure is invalidated by the Oracle server if the remote procedure is recompiled after the local procedure is compiled.

Automatic Remote Dependency Mechanism

When a procedure compiles, the Oracle server records the time stamp of that compilation within the P code of the procedure.

In the slide, when the remote procedure B is successfully compiled at 8:00 AM, this time is recorded as its time stamp.

Local Procedure A Compiles at 9:00 AM



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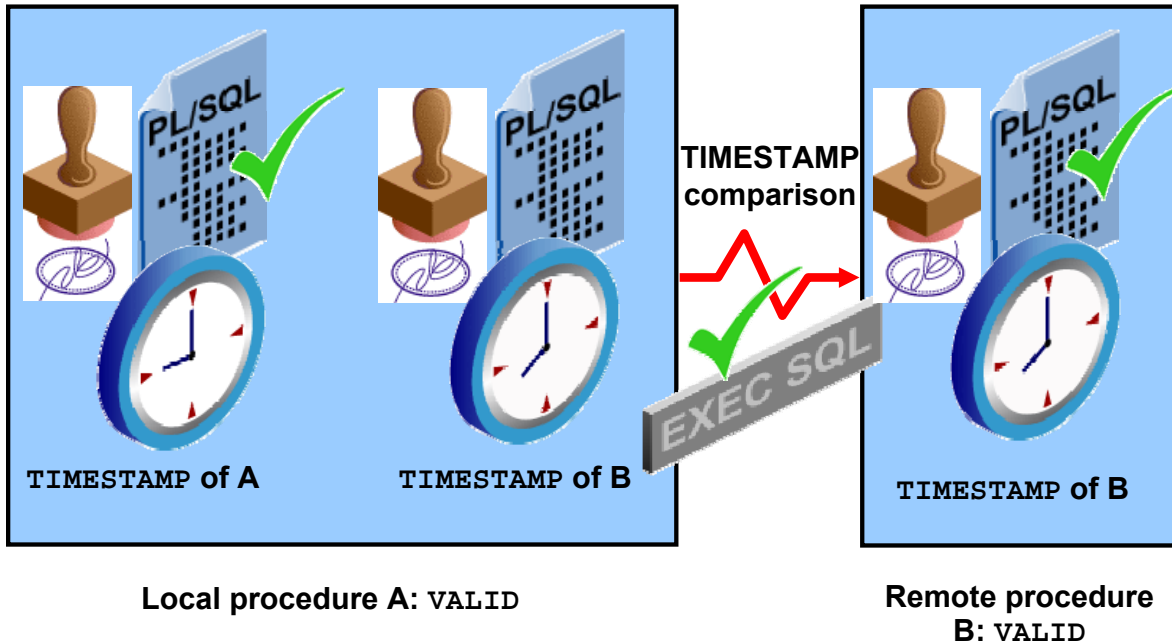
Local Procedures Referencing Remote Procedures (continued)

Automatic Remote Dependency Mechanism (continued)

When a local procedure referencing a remote procedure compiles, the Oracle server also records the time stamp of the remote procedure in the P code of the local procedure.

In the slide, local procedure A (which is dependent on remote procedure B) is compiled at 9:00 AM. The time stamps of both procedure A and remote procedure B are recorded in the P code of procedure A.

Execute Procedure A



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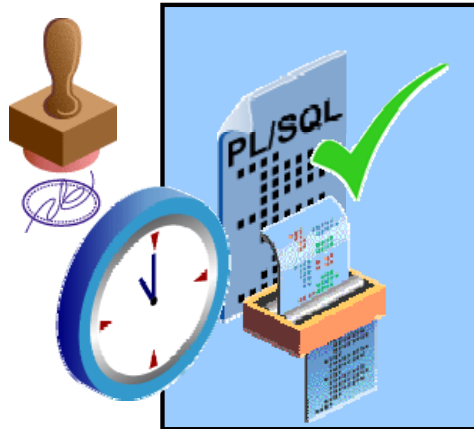
Automatic Remote Dependency

When the local procedure is invoked at run time, the Oracle server compares the two time stamps of the referenced remote procedure.

If the time stamps are equal (indicating that the remote procedure has not recompiled), then the Oracle server executes the local procedure.

In the example in the slide, the time stamp recorded with the P code of remote procedure B is the same as that recorded with local procedure A. Therefore, local procedure A is valid.

Remote Procedure B Recompiled at 11:00 AM



**Remote procedure B:
Recompiles and is VALID
at 11:00 AM**

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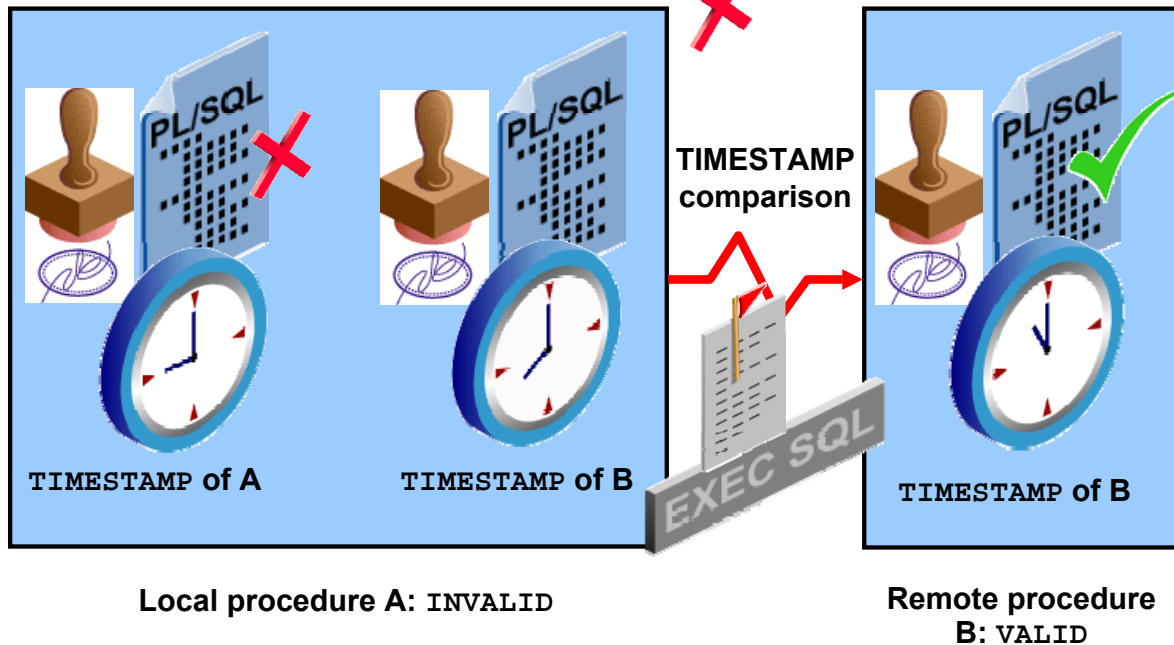
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Local Procedures Referencing Remote Procedures

Assume that remote procedure B is successfully recompiled at 11:00 AM. The new time stamp is recorded along with its P code.

Execute Procedure A

Saved TIMESTAMP of B \neq COMPILE TIME of B



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Automatic Remote Dependency

If the time stamps are not equal (indicating that the remote procedure has recompiled), then the Oracle server invalidates the local procedure and returns a run-time error. If the local procedure (which is now tagged as invalid) is invoked a second time, then the Oracle server recompiles it before executing, in accordance with the automatic local dependency mechanism.

Note: If a local procedure returns a run-time error the first time it is invoked (indicating that the remote procedure's time stamp has changed), then you should develop a strategy to reinvoke the local procedure.

In the example in the slide, the remote procedure is recompiled at 11:00 AM and this time is recorded as its time stamp in the P code. The P code of local procedure A still has 8:00 AM as the time stamp for remote procedure B. Because the time stamp recorded with the P code of local procedure A is different from that recorded with the remote procedure B, the local procedure is marked invalid. When the local procedure is invoked for the second time, it can be successfully compiled and marked valid.

A disadvantage of time stamp mode is that it is unnecessarily restrictive. Recompilation of dependent objects across the network is often performed when not strictly necessary, leading to performance degradation.

Signature Mode

- The signature of a procedure is:
 - The name of the procedure
 - The data types of the parameters
 - The modes of the parameters
- The signature of the remote procedure is saved in the local procedure.
- When executing a dependent procedure, the signature of the referenced remote procedure is compared.

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Signatures

To alleviate some of the problems with the time stamp-only dependency model, you can use the signature model. This allows the remote procedure to be recompiled without affecting the local procedures. This is important if the database is distributed.

The signature of a subprogram contains the following information:

- The name of the subprogram
- The data types of the parameters
- The modes of the parameters
- The number of parameters
- The data type of the return value for a function

If a remote program is changed and recompiled but the signature does not change, then the local procedure can execute the remote procedure. With the time stamp method, an error would have been raised because the time stamps would not have matched.

Recompiling a PL/SQL Program Unit

Recompilation:

- Is handled automatically through implicit run-time recompilation
- Is handled through explicit recompilation with the ALTER statement

```
ALTER PROCEDURE [SCHEMA.]procedure_name COMPILE;
```

```
ALTER FUNCTION [SCHEMA.]function_name COMPILE;
```

```
ALTER PACKAGE [SCHEMA.]package_name  
COMPILE [PACKAGE | SPECIFICATION | BODY];
```

```
ALTER TRIGGER trigger_name [COMPILE[DEBUG]];
```

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Recompiling PL/SQL Objects

If the recompilation is successful, the object becomes valid. If not, the Oracle server returns an error and the object remains invalid. When you recompile a PL/SQL object, the Oracle server first recompiles any invalid object on which it depends.

Procedure: Any local objects that depend on a procedure (such as procedures that call the recompiled procedure or package bodies that define the procedures that call the recompiled procedure) are also invalidated.

Packages: The COMPILE PACKAGE option recompiles both the package specification and the body, regardless of whether it is invalid. The COMPILE SPECIFICATION option recompiles the package specification. Recompiling a package specification invalidates any local objects that depend on the specification, such as subprograms that use the package. Note that the body of a package also depends on its specification. The COMPILE BODY option recompiles only the package body.

Triggers: Explicit recompilation eliminates the need for implicit run-time recompilation and prevents associated run-time compilation errors and performance overhead.

The DEBUG option instructs the PL/SQL compiler to generate and store the code for use by the PL/SQL debugger.

Unsuccessful Recompilation

Recompiling dependent procedures and functions is unsuccessful when:

- The referenced object is dropped or renamed
- The data type of the referenced column is changed
- The referenced column is dropped
- A referenced view is replaced by a view with different columns
- The parameter list of a referenced procedure is modified

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Unsuccessful Recompilation

Sometimes a recompilation of dependent procedures is unsuccessful (for example, when a referenced table is dropped or renamed).

The success of any recompilation is based on the exact dependency. If a referenced view is re-created, any object that is dependent on the view needs to be recompiled. The success of the recompilation depends on the columns that the view now contains, as well as the columns that the dependent objects require for their execution. If the required columns are not part of the new view, then the object remains invalid.

Successful Recompilation

Recompiling dependent procedures and functions is successful if:

- The referenced table has new columns
- The data type of referenced columns has not changed
- A private table is dropped, but a public table that has the same name and structure exists
- The PL/SQL body of a referenced procedure has been modified and recompiled successfully

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Successful Recompilation

The recompilation of dependent objects is successful if:

- New columns are added to a referenced table
- All INSERT statements include a column list
- No new column is defined as NOT NULL

When a private table is referenced by a dependent procedure and the private table is dropped, the status of the dependent procedure becomes invalid. When the procedure is recompiled (either explicitly or implicitly) and a public table exists, the procedure can recompile successfully but is now dependent on the public table. The recompilation is successful only if the public table contains the columns that the procedure requires; otherwise, the status of the procedure remains invalid.

Recompiling Procedures

Minimize dependency failures by:

- Declaring records with the `%ROWTYPE` attribute
- Declaring variables with the `%TYPE` attribute
- Querying with the `SELECT *` notation
- Including a column list with `INSERT` statements

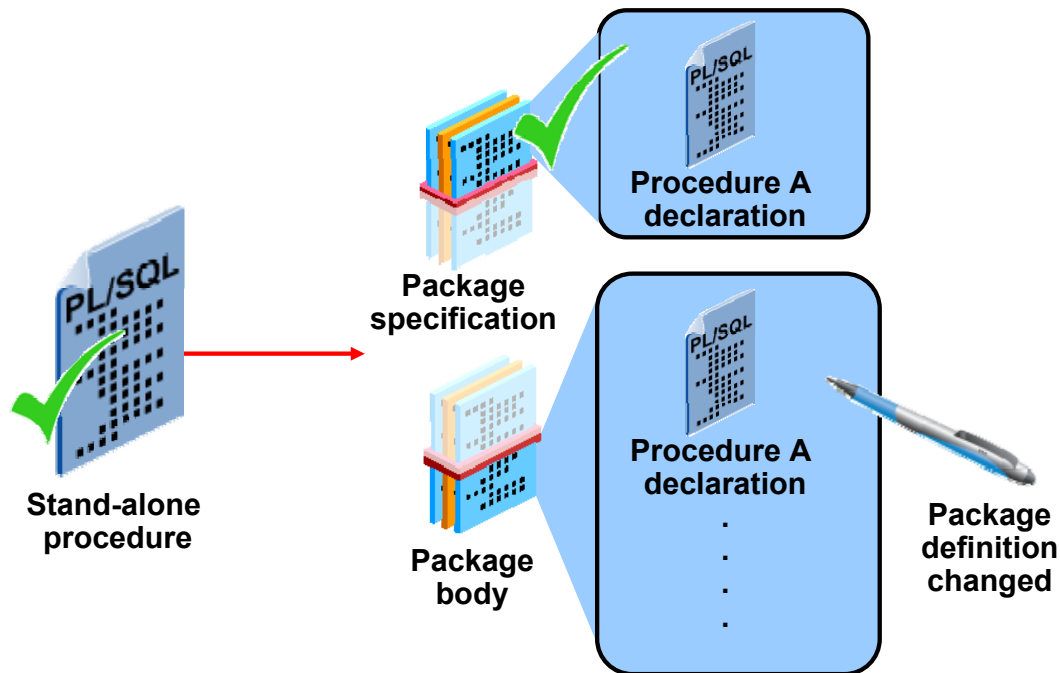
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Recompilation of Procedures

You can minimize recompilation failure by following the guidelines that are shown in the slide.

Packages and Dependencies: Subprogram References the Package



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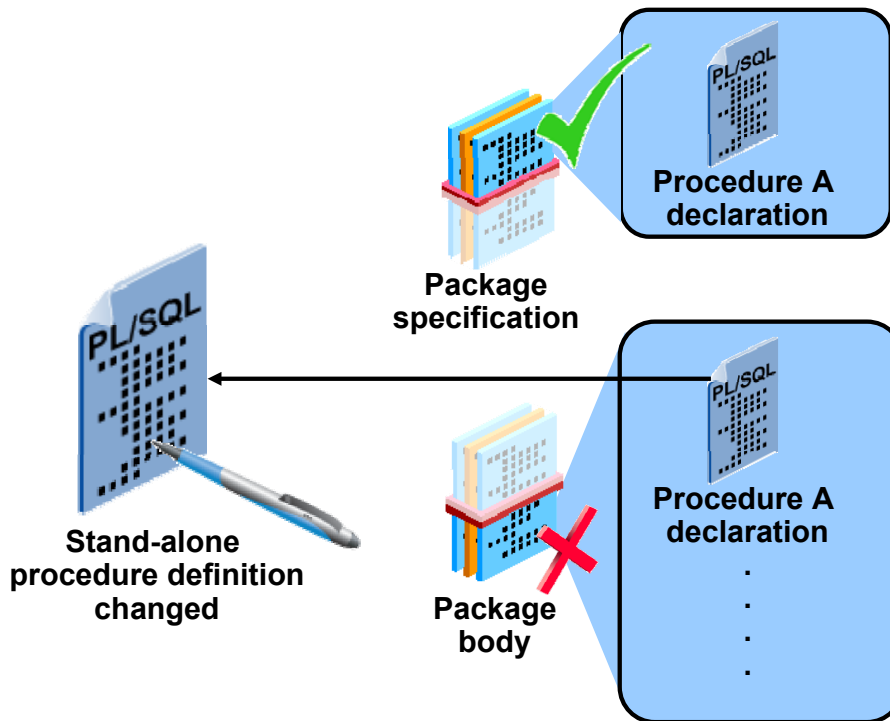
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Packages and Dependencies: Subprogram References the Package

You can simplify dependency management with packages when referencing a package procedure or function from a stand-alone procedure or function.

- If the package body changes and the package specification does not change, then the stand-alone procedure that references a package construct remains valid.
- If the package specification changes, then the outside procedure referencing a package construct is invalidated, as is the package body.

Packages and Dependencies: Package Subprogram References Procedure



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Packages and Dependencies: Package Subprogram References Procedure

If a stand-alone procedure that is referenced within the package changes, then the entire package body is invalidated, but the package specification remains valid. Therefore, it is recommended that you bring the procedure into the package.

Quiz

You can display direct and indirect dependencies by running the `utldtree.sql` script, populating the `DEPTREE_TEMPTAB` table with information for a particular referenced object, and querying the `DEPTREE` or `IDEPTREE` views.

1. True
2. False

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Answer: 1

Displaying Direct and Indirect Dependencies

You can display direct and indirect dependencies as follows:

1. Run the `utldtree.sql` script which creates the objects that enable you to display the direct and indirect dependencies.
2. Populate the `DEPTREE_TEMPTAB` table with information for a particular referenced object by executing the `DEPTREE_FILL` procedure.
3. Query the `DEPTREE` or `IDEPTREE` views.

Summary

In this lesson, you should have learned how to:

- Track procedural dependencies
- Predict the effect of changing a database object on procedures and functions
- Manage procedural dependencies

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Summary

Avoid disrupting production by keeping track of dependent procedures and recompiling them manually as soon as possible after the definition of a database object changes.

Practice 13 Overview: Managing Dependencies in Your Schema

This practice covers the following topics:

- Using `DEPTREE_FILL` and `IDEPTREE` to view dependencies
- Recompiling procedures, functions, and packages

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Practice 13: Overview

In this practice, you use the `DEPTREE_FILL` procedure and the `IDEPTREE` view to investigate dependencies in your schema. In addition, you recompile invalid procedures, functions, packages, and views.

Practice 13

1. Create a tree structure showing all dependencies involving your `add_employee` procedure and your `valid_deptid` function.

Note: `add_employee` and `valid_deptid` were created in the lesson 3 titled “Creating Functions”. You can run the solution scripts for Practice 3 if you need to create the procedure and function.

- a. Load and execute the `utldtree.sql` script, which is located in the `D:\lab\labs` folder.
- b. Execute the `deptree_fill` procedure for the `add_employee` procedure.
- c. Query the `IDeptree` view to see your results.
- d. Execute the `deptree_fill` procedure for the `valid_deptid` function.
- e. Query the `IDeptree` view to see your results.

If you have time, complete the following exercise:

2. Dynamically validate invalid objects.
 - a. Make a copy of your `EMPLOYEES` table, called `EMPS`.
 - b. Alter your `EMPLOYEES` table and add the column `TOTSAL` with data type `NUMBER(9,2)`.
 - c. Create and save a query to display the name, type, and status of all invalid objects.
 - d. In the `compile_pkg` (created in Practice 7 in the lesson titled “Using Dynamic SQL”), add a procedure called `recompile` that recompiles all invalid procedures, functions, and packages in your schema. Use Native Dynamic SQL to alter the invalid object type and compile it.
 - e. Execute the `compile_pkg.recompile` procedure.
 - f. Run the script file that you created in step 3 c to check the status column value. Do you still have objects with an `INVALID` status?