Oracle Database: Program with PL/SQL Accelerated - IBM Graduate Program

Student Guide – Vol 2 (PL/SQL Programming)

D59010GC10
Edition 1.0
June 2010

Contents

I

Introduction

Lesson Objectives

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

- Discuss the goals of the course
- Identify the modular components of PL/SQL:
  – Anonymous blocks
  – Procedures and functions
  – Packages
- Discuss the PL/SQL execution environment
- Describe the database schema and tables that are used in the course
- List the PL/SQL development environments that are available in the course

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.

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, file, and Web output
  - Schedule PL/SQL jobs to run independently
- Build and execute dynamic SQL statements
- Manipulate large objects (LOBs)

ORACLE

Course Objectives

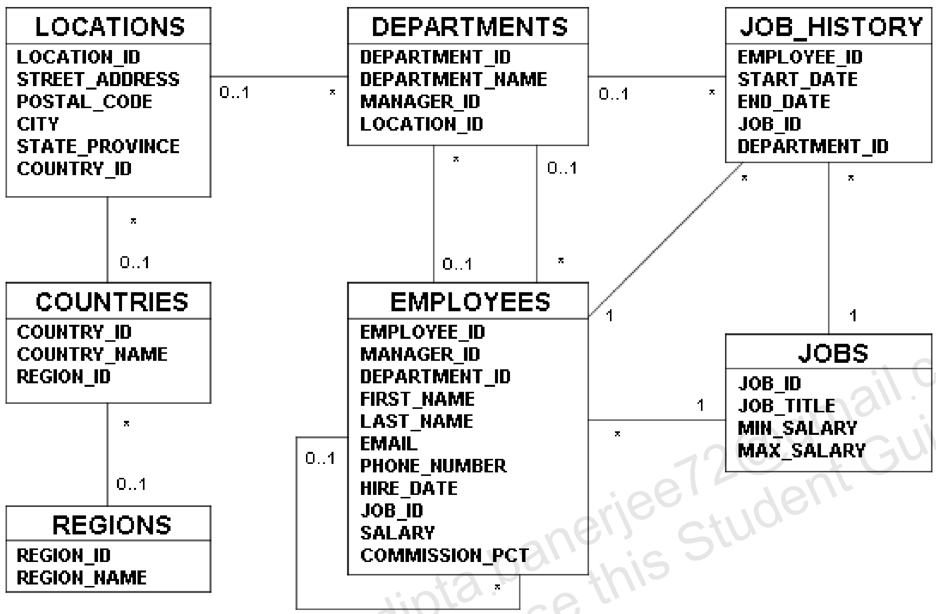
You can develop modularized applications with database procedures by using database objects such as the following:

- Procedures and functions
- Packages
- Database triggers

Modular applications improve:

- Functionality
- Security
- Overall performance

Human Resources (HR) Schema



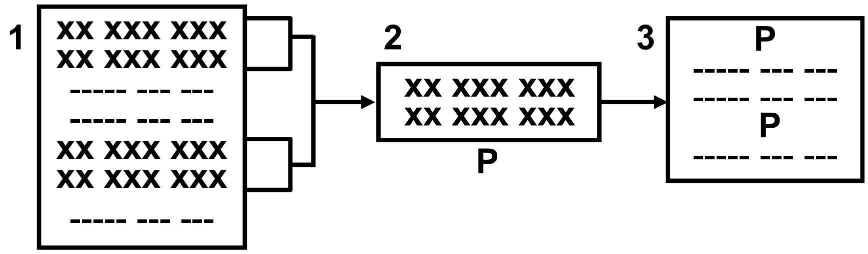
Human Resources (HR) Schema

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, then a new row is inserted into this table with the old job information of the employee.

Creating a Modularized and Layered 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.
- Create subprogram layers for your application.
  – Data access subprogram layer with SQL logic
  – Business logic subprogram layer, which may or may not use data access layer

ORACLE

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.

Subprogram Layers

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 the work of Oracle Database Optimizer, which 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

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 10g: PL/SQL Fundamentals*.

Review of Anonymous Blocks

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)
```


Review of Anonymous Blocks

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.

Introduction to PL/SQL Procedures

Procedures are named PL/SQL blocks that perform a sequence of actions.

```
CREATE PROCEDURE getemp IS  -- header
  emp_id  employees.employee_id%type;
  lname   employees.last_name%type;
BEGIN
  emp_id := 100;
  SELECT last_name INTO lname
  FROM EMPLOYEES
  WHERE employee_id = emp_id;
  DBMS_OUTPUT.PUT_LINE('Last name: '||lname);
END;
/
```


Introduction to PL/SQL Procedures

A procedure is a named PL/SQL block that is created by using a `CREATE PROCEDURE` statement. When called or invoked, a procedure performs a sequence of actions. The anatomy of the procedure includes:

- **The header:** "`PROCEDURE getemp IS`"
- **The declaration section:** With variable declarations `emp_id` and `lname`
- **The executable section:** Contains the PL/SQL and SQL statements used to obtain the last name of employee 100. The executable section makes use of the `DBMS_OUTPUT` package to print the last name of the employee.
- **The exception section:** Optional and not used in the example

Note: Hard-coding the value of `100` for `emp_id` is inflexible. The procedure would be more reusable if used as a parameter to obtain the employee ID value. Using parameters is covered in the lesson titled "Creating Stored Procedures."

To call a procedure by using an anonymous block, use the following:

```
BEGIN
  getemp;
END;
```

Introduction to PL/SQL Functions

Functions are named PL/SQL blocks that perform a sequence of actions and return a value. A function can be invoked from:

- Any PL/SQL block
- A SQL statement (subject to some restrictions)

```
CREATE FUNCTION avg_salary RETURN NUMBER IS
  avg_sal employees.salary%type;
BEGIN
  SELECT AVG(salary) INTO avg_sal
  FROM EMPLOYEES;
  RETURN avg_sal;
END;
/
```


Introduction to PL/SQL Functions

A function is a named PL/SQL block that is created with a CREATE FUNCTION statement. Functions are used to compute a value that must be returned to the caller.

PL/SQL functions follow the same block structure as procedures. However, the header starts with the keyword FUNCTION followed by the function name. The header includes the return data type after the function name (using the keyword RETURN followed by the data type). The example declares a variable called avg_sal in the declaration section, and uses the RETURN statement to return the value retrieved from the SELECT statement. The value returned represents the average salary for all employees.

A function can be called from:

- Another PL/SQL block where its return value can be stored in a variable or supplied as a parameter to a procedure
- A SQL statement, subject to restrictions (This topic is covered in the lesson titled "Creating Stored Functions.")

To call a function from an anonymous block, use the following:

```
BEGIN
  dbms_output.put_line('Average Salary: ' ||
     avg_salary);
END;
```

Introduction to PL/SQL Packages

PL/SQL packages have a specification and an optional body. Packages group related subprograms together.

```
CREATE PACKAGE emp_pkg IS
  PROCEDURE getemp;
  FUNCTION avg_salary RETURN NUMBER;
END emp_pkg;
/
CREATE PACKAGE BODY emp_pkg IS
  PROCEDURE getemp IS ...
  BEGIN ... END;

  FUNCTION avg_salary RETURN NUMBER IS ...
  BEGIN ... RETURN avg_sal; END;
END emp_pkg;
/
```


Introduction to PL/SQL Packages

A PL/SQL package is typically made up of two parts:

- A package specification declaring the public (accessible) components of the package
- A package body that implements public and private components of the package

A package is used to group related PL/SQL code and constructs together. This helps developers manage and maintain related code in one place. Packages are powerful constructs and provide a way to logically modularize code into application-specific or functional groups.

The example declares a package called `emp_package` that comprises a procedure `getemp` and a function `avg_salary`. The specification defines the procedure and function heading. The package body provides the full implementation of the procedure and function declared in the package specification. The example is incomplete but provides an introduction to the concept of a PL/SQL package. The details about PL/SQL packages are covered in the lesson titled “Creating Packages.”

To call the package procedure from an anonymous block, use the following:

```
BEGIN
 emp_pkg.getemp;
END;
```

Introduction to PL/SQL Triggers

PL/SQL triggers are code blocks that execute when a specified application, database, or table event occurs.

- Oracle Forms application triggers are standard anonymous blocks.
- Oracle database triggers have a specific structure.

```
CREATE TRIGGER check_salary
BEFORE INSERT OR UPDATE ON employees
FOR EACH ROW
DECLARE
  c_min constant number(8,2) := 1000.0;
  c_max constant number(8,2) := 500000.0;
BEGIN
  IF :new.salary > c_max OR
     :new.salary < c_min THEN
    RAISE_APPLICATION_ERROR(-20000,
      'New salary is too small or large');
  END IF;
END;
/
```

ORACLE

Introduction to PL/SQL Triggers

A trigger is a PL/SQL block that executes when a particular event occurs.

A PL/SQL trigger has two forms:

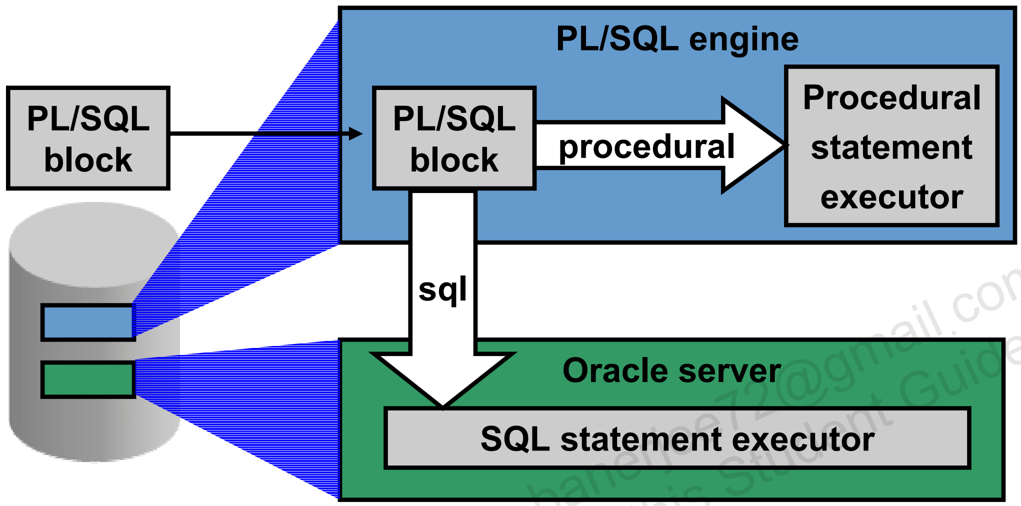
- **Application trigger:** Block of code that executes when a nominated application event occurs in an Oracle Forms execution environment
- **Database trigger:** Named block of code that is associated and executes when a nominated database or table event occurs

The `check_salary` trigger example shows a database trigger that executes before either an `INSERT` or an `UPDATE` operation occurs on the `EMPLOYEES` table. The trigger code checks whether the `salary` column value is within an acceptable range. If the value is outside the specified range, the code uses the `RAISE_APPLICATION_ERROR` built-in procedure to fail the operation. The `:new` syntax, which is used in the example, is a special bind/host variable that can be used in row-level triggers.

Triggers are covered in detail in the lesson titled “Creating Triggers.”

PL/SQL Execution Environment

The PL/SQL run-time architecture:



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.

PL/SQL Development Environments

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

- Oracle SQL*Plus (GUI or command-line versions)
- Oracle *i*SQL*Plus (used from a browser)
- Oracle JDeveloper IDE

ORACLE

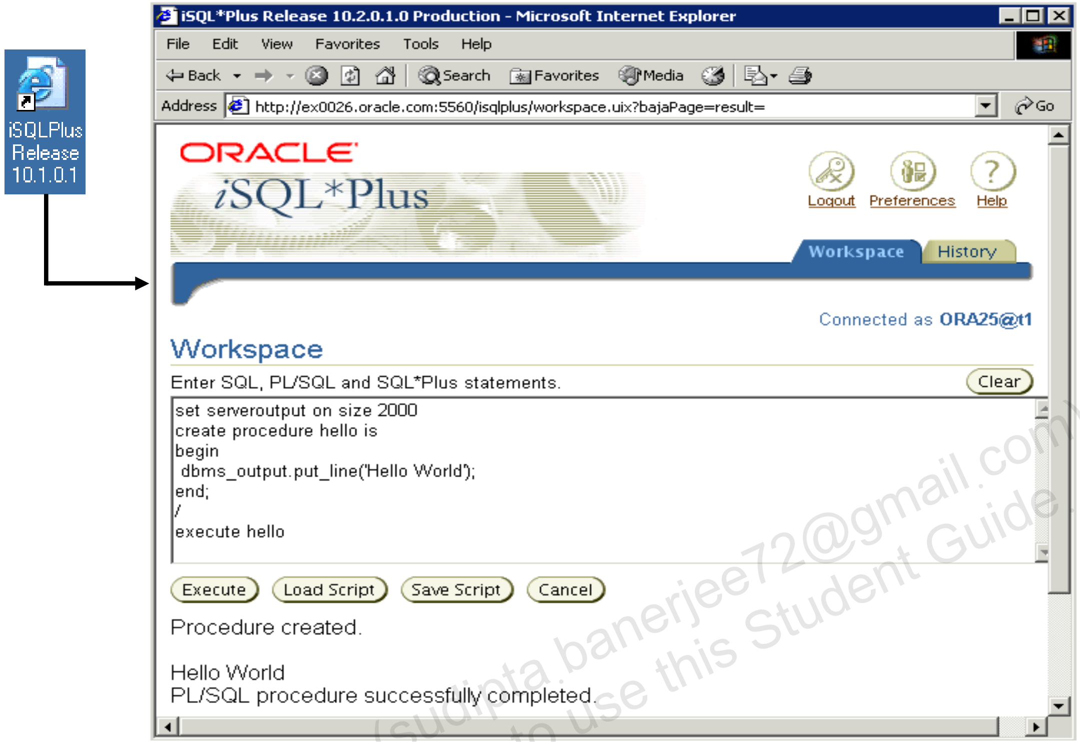
PL/SQL Development Environments

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 *i*SQL*Plus: A browser-based application
- 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 *i*SQL*Plus environment.

Coding PL/SQL in *i*SQL*Plus



ORACLE

Coding PL/SQL in *i*SQL*Plus

Oracle *i*SQL*Plus is a Web application that allows you to submit SQL statements and PL/SQL blocks for execution and receive the results in a standard Web browser.

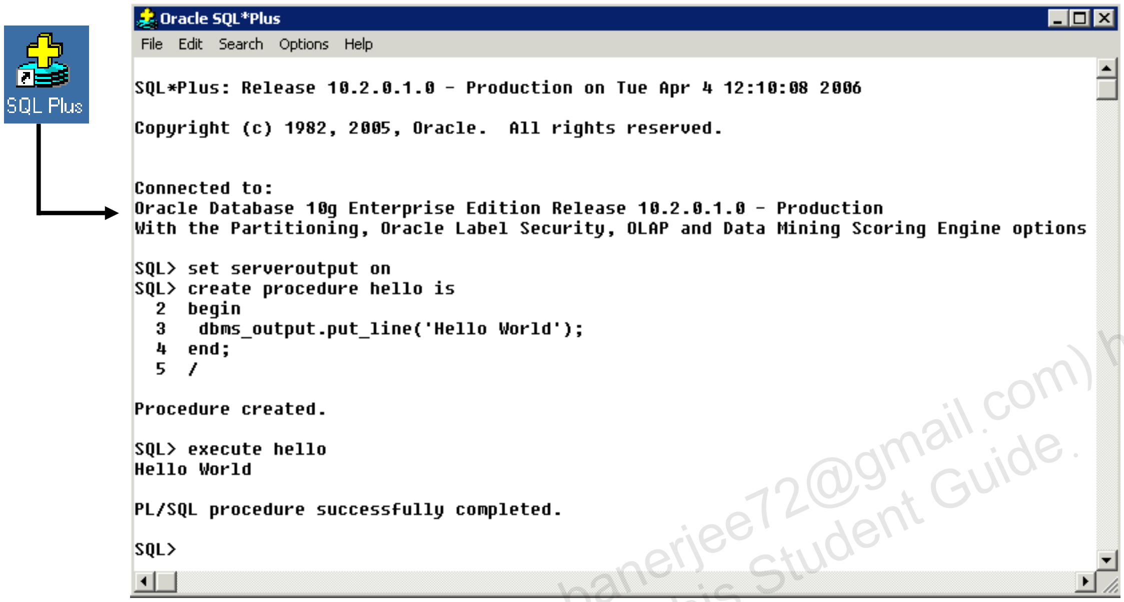
*i*SQL*Plus is:

- Shipped with the database
- Installed in the middle tier
- Accessed from a Web browser by using a URL format that is similar to the following example:
  `http://host:port/isqlplus`
  The `host` and `port` are for the Web server name and HTTP listener port.

When coding PL/SQL subprograms in the *i*SQL*Plus tool, consider 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 SQL*Plus



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.

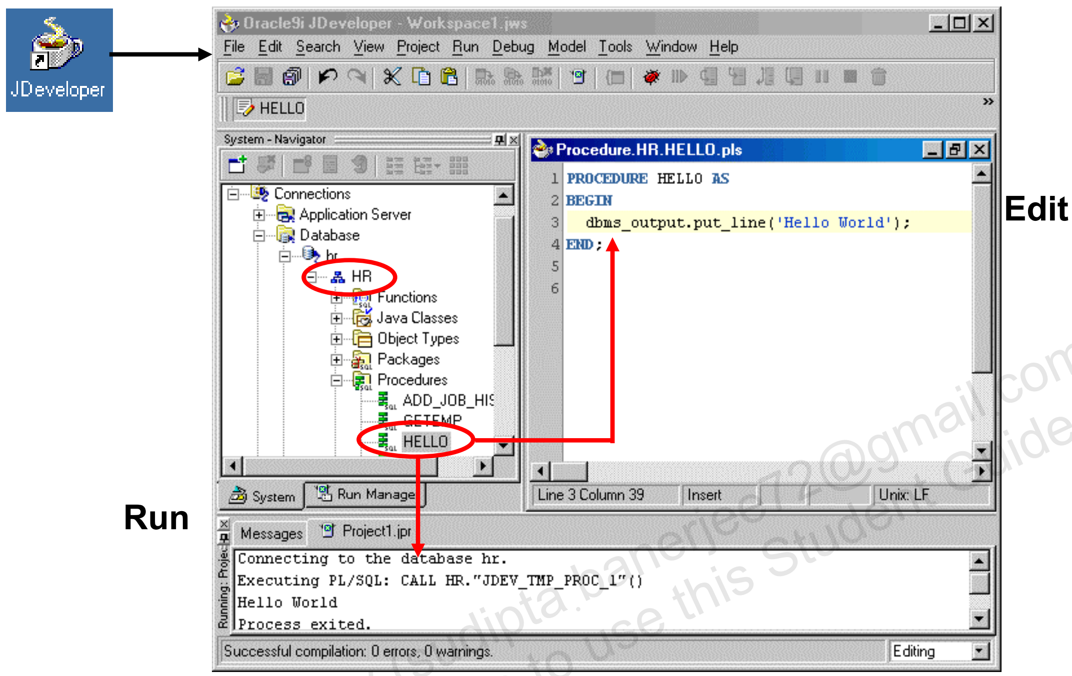
SQL*Plus is:

- 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, consider 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



ORACLE

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.

Summary

In this lesson, you should have learned how to:

- Declare named PL/SQL blocks, including procedures, functions, packages, and triggers
- Use anonymous (unnamed) PL/SQL blocks to invoke stored procedures and functions
- Use *i*SQL*Plus or SQL*Plus to develop PL/SQL code
- Explain the PL/SQL execution environment:
  - The client-side PL/SQL engine for executing PL/SQL code in Oracle Forms and Oracle Reports
  - The server-side PL/SQL engine for executing PL/SQL code stored in an Oracle database

ORACLE

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 I: Overview

This practice covers the following topics:

- Browsing the HR tables
- Creating a simple PL/SQL procedure
- Creating a simple PL/SQL function
- Using an anonymous block to execute the PL/SQL procedure and function

Practice I: Overview

In this practice, you use *i*SQL*Plus to execute SQL statements to examine data in the HR schema. You also create a simple procedure and function that you invoke by using an anonymous block or the `EXECUTE` command in *i*SQL*Plus. Optionally, you can experiment by creating and executing the PL/SQL code in SQL*Plus.

Note: All written practices use *i*SQL*Plus as the development environment. However, you can use any of the tools that are provided in your course environment.

Practice I

1. Launch *i*SQL*Plus using the icon that is provided on your desktop.
   a. Log in to the database by using the username and database connect string details provided by your instructor (you may optionally write the information here for your records):
      Username: **`apps`**
      Password: **`apps`**
      Database Connect String/Tnsname: **`EG3463`**

```
      TNS Entry:
       EG3463 =
         (DESCRIPTION =
           (ADDRESS_LIST =
             (ADDRESS = (PROTOCOL = TCP)(HOST =
         eg3463.us.oracle.com)(PORT = 1521))
           )
           (CONNECT_DATA =
             (SERVICE_NAME = EG3463)
           )
         )
```

   b. Execute basic `SELECT` statements to query the data in the `DEPARTMENTS`, `EMPLOYEES`, and `JOBS` tables. Take a few minutes to familiarize yourself with the data, or consult Appendix B, which provides a description and some data from each table in the Human Resources schema.
2. Create a procedure called `HELLO` to display the text `Hello World`.
   a. Create a procedure called `HELLO`.
   b. In the executable section, use the `DBMS_OUTPUT.PUT_LINE` procedure to print the text `Hello World`, and save the code in the database.
      Note: If you get compile-time errors, correct the PL/SQL code and replace the `CREATE` keyword with the text `CREATE OR REPLACE`.
   c. Execute the `SET SERVEROUTPUT ON` command to ensure that the output from the `DBMS_OUTPUT.PUT_LINE` procedure is displayed in *i*SQL*Plus.
   d. Create an anonymous block to invoke the stored procedure.
3. Create a function called `TOTAL_SALARY` to compute the sum of all employee salaries.
   a. Create a function called `TOTAL_SALARY` that returns a `NUMBER`.
   b. In the executable section, execute a query to store the total salary of all employees in a local variable that you declare in the declaration section. Return the value stored in the local variable. Save and compile the code.
   c. Use an anonymous block to invoke the function. To display the result computed by the function, use the `DBMS_OUTPUT.PUT_LINE` procedure.
      Hint: Either nest the function call inside the `DBMS_OUTPUT.PUT_LINE` parameter, or store the function result in a local variable of the anonymous block and use the local variable in the `DBMS_OUTPUT.PUT_LINE` procedure.

Practice I (continued)

If you have time, complete the following exercise:

4. Launch SQL*Plus using the icon that is provided on your desktop.
   a. Invoke the procedure and function that you created in exercises 2 and 3.
   b. Create a new procedure called `HELLO_AGAIN` to print `Hello World again`.
   c. Invoke the `HELLO_AGAIN` procedure with an anonymous block.

1

Creating Stored Procedures

Objectives

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

- Describe and create a procedure
- Create procedures with parameters
- Differentiate between formal and actual parameters
- Use different parameter-passing modes
- Invoke a procedure
- Handle exceptions in procedures
- Remove a procedure

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.

What Is a Procedure?

A procedure:

- Is a type of subprogram that performs an action
- Can be stored in the database as a schema object
- Promotes reusability and maintainability

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.

Block Structure for PL/SQL Procedures

- Use `CREATE PROCEDURE` followed by the name, optional parameters, and keyword `IS` or `AS`.
- Add the `OR REPLACE` option to overwrite an existing procedure.
- Write a PL/SQL block containing local variables, a `BEGIN` statement, and an `END` statement (or `END` *`procedure_name`*).

```
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

ORACLE

Block Structure for PL/SQL Procedures

You create new procedures with the `CREATE PROCEDURE` statement, which may declare a list of parameters and must define the actions to be performed by the standard PL/SQL block. The `CREATE` clause enables you to create stand-alone procedures that are stored in an Oracle database.

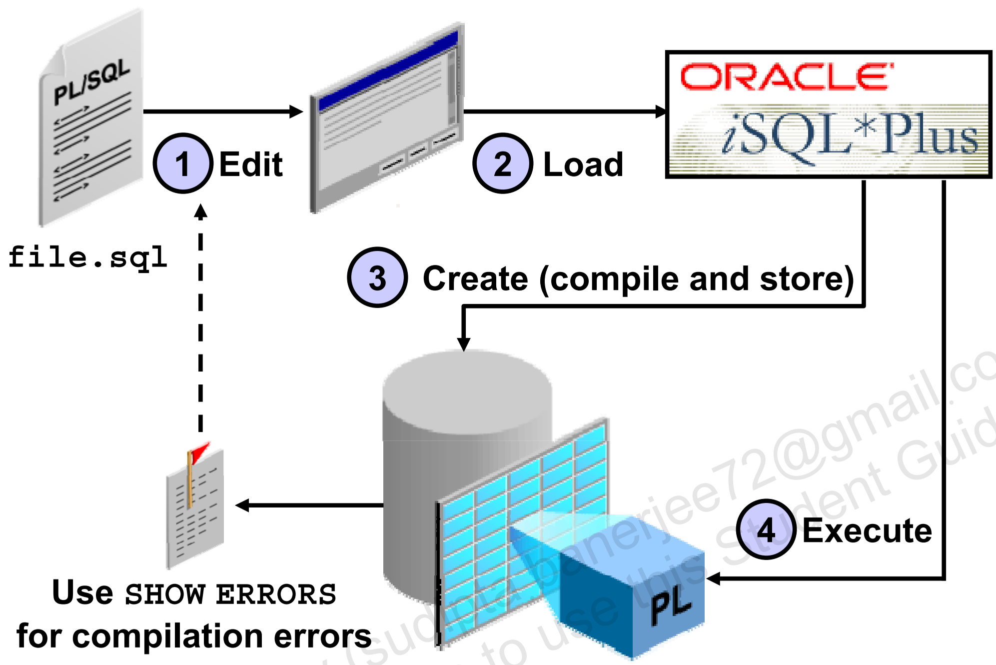
- PL/SQL blocks start with `BEGIN`, optionally preceded by the declaration of local variables. PL/SQL blocks end with either `END` or `END` *`procedure_name`*.
- The `REPLACE` option indicates that if the procedure exists, it is dropped and replaced with the new version created by the statement.

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.

Invoking a Procedure



Invoking a Procedure

To develop a stored procedure, perform the following steps:

1. Write the code to create a procedure in an editor or a word processor, and then save it as a SQL script file (typically with an `.sql` extension).
2. Load the code into one of the development tools such as SQL*Plus or *i*SQL*Plus.
3. Create the procedure in the database. The `CREATE PROCEDURE` statement compiles and stores source code and the compiled *m-code* in the database. 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. To view the compilation errors in SQL*Plus or *i*SQL*Plus, use:
   - `SHOW ERRORS` for the most recently (last) compiled procedure
   - `SHOW ERRORS PROCEDURE procedure_name` for any procedure compiled previously
4. After successful compilation, execute the procedure to perform the desired action. Use the `EXECUTE` command from *i*SQL*Plus or an anonymous PL/SQL block from environments that support PL/SQL.

Invoking a Procedure (continued)

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 and then execute the `CREATE PROCEDURE` statement.

A stored procedure can be called in similar ways from Forms, Java, C, etc. Host variables are used to pass the parameters from forms/Java/C to the stored PL/SQL procedure.

Also, you can invoke a stored procedure from an anonymous block or another stored procedure/ function.

CREATE OR REPLACE PROCEDURE Syntax

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


CREATE OR REPLACE PROCEDURE Syntax

You create new procedures with the `CREATE PROCEDURE` statement, which may declare a list of parameters and must define the actions to be performed by the standard PL/SQL block. The `CREATE` clause enables you to create stand-alone procedures that are stored in an Oracle database.

- 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.

What Are Parameters?

Parameters:

- 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 (the default) provides values for a subprogram to process.
  - An `OUT` parameter returns a value to the caller.
  - An `IN OUT` parameter supplies an input value, which may be returned (output) as a modified value.

ORACLE

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

  Example:

```
CREATE PROCEDURE raise_sal(id NUMBER,sal NUMBER) IS
BEGIN ...
END raise_sal;
```

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

  Example:

```
emp_id := 100;
raise_sal(emp_id, 2000)
```

ORACLE

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 `id` and `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 called subprogram. In the second example, a call is made to `raise_sal`, where the `emp_id` variable provides the actual parameter value for the `id` formal parameter and `2000` is supplied as the actual parameter value for `sal`. Actual parameters:

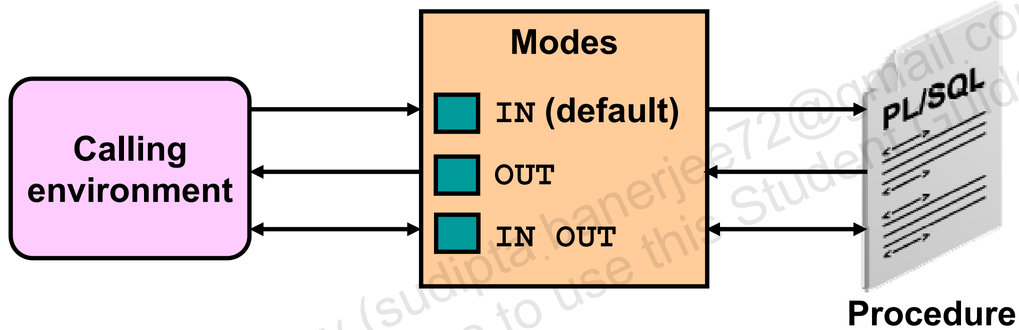
- Are associated with formal parameters during the subprogram call
- Can also be expressions, as in the following example:
  `raise_sal(emp_id, raise+100);`

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.

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 procedure(param [mode] datatype)
...
```



Procedural Parameter Modes

When you create the 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, with each separated by a comma.

Using `IN` Parameters: Example

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

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

ORACLE

Using `IN` Parameters: Example

The example shows a procedure with two `IN` parameters. Running this first statement in *i*SQL*Plus creates the `raise_salary` procedure in the database. The second 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 in *i*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 OUT Parameters: Example

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

```
DECLARE
  emp_name employees.last_name%TYPE;
  emp_sal  employees.salary%TYPE;
BEGIN
  query_emp(171, emp_name, emp_sal); ...
END;
```


Using OUT Parameters: Example

In this 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 code box in the lower portion of the slide. The procedure accepts an employee ID value through the id parameter. The emp_name and emp_salary variables are populated with the information retrieved from the query into their two corresponding OUT parameters.

If you print the values returned into PL/SQL variables of the calling block shown in the second block of code, then the variables contain the following:

- emp_name holds the value Smith.
- emp_salary holds the value 7600.

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

Attempting to use or read OUT parameters inside the procedure that declares them results in a compilation error. The OUT parameters can be assigned values only in the body of the procedure in which they are declared.

Viewing OUT Parameters with *i*SQL*Plus

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

```
SET SERVEROUTPUT ON
DECLARE
  emp_name employees.last_name%TYPE;
  emp_sal  employees.salary%TYPE;
BEGIN
  query_emp(171, emp_name, emp_sal);
  DBMS_OUTPUT.PUT_LINE('Name: ' || emp_name);
  DBMS_OUTPUT.PUT_LINE('Salary: ' || emp_sal);
END;
```

- Use *i*SQL*Plus host variables, execute QUERY_EMP using host variables, and print the host variables.

```
VARIABLE name VARCHAR2(25)
VARIABLE sal  NUMBER
EXECUTE query_emp(171, :name, :sal)
PRINT name sal
```


Viewing OUT Parameters with *i*SQL*Plus

The examples show two ways to view the values returned from OUT parameters.

- The first technique uses PL/SQL variables in an anonymous block to retrieve the OUT parameter values. The DBMS_OUPUT.PUT_LINE procedure is called to print the values held in the PL/SQL variables. The SET SERVEROUPUT must be ON.
- The second technique shows how to use *i*SQL*Plus variables that are created using the VARIABLE command. The *i*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 *i*SQL*Plus PRINT command followed by the name of the *i*SQL*Plus variable (without the colon because this is not a PL/SQL command or context).

To use *i*SQL*Plus and host variables when calling a procedure with OUT parameters, perform the following steps:

1. Create an *i*SQL*Plus script file by using an editor.
2. Add commands to create the variables, execute the procedure, and print the variables.
3. Load and execute the *i*SQL*Plus script file.

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

Calling PL/SQL Using Host Variables

A host variable (also known as a *bind* or a *global* variable):

- Is declared and exists externally to the PL/SQL subprogram. A host variable can be created in:
  - *i*SQL*Plus by using the `VARIABLE` command
  - Oracle Forms internal and UI variables
  - Java variables
- Is preceded by a colon (`:`) when referenced in PL/SQL code
- Can be referenced in an anonymous block but not in a stored subprogram
- Provides a value to a PL/SQL block and receives a value from a PL/SQL block

Calling PL/SQL Using Host Variables

The PL/SQL code that is stored in the database can be called from a variety of environments, such as:

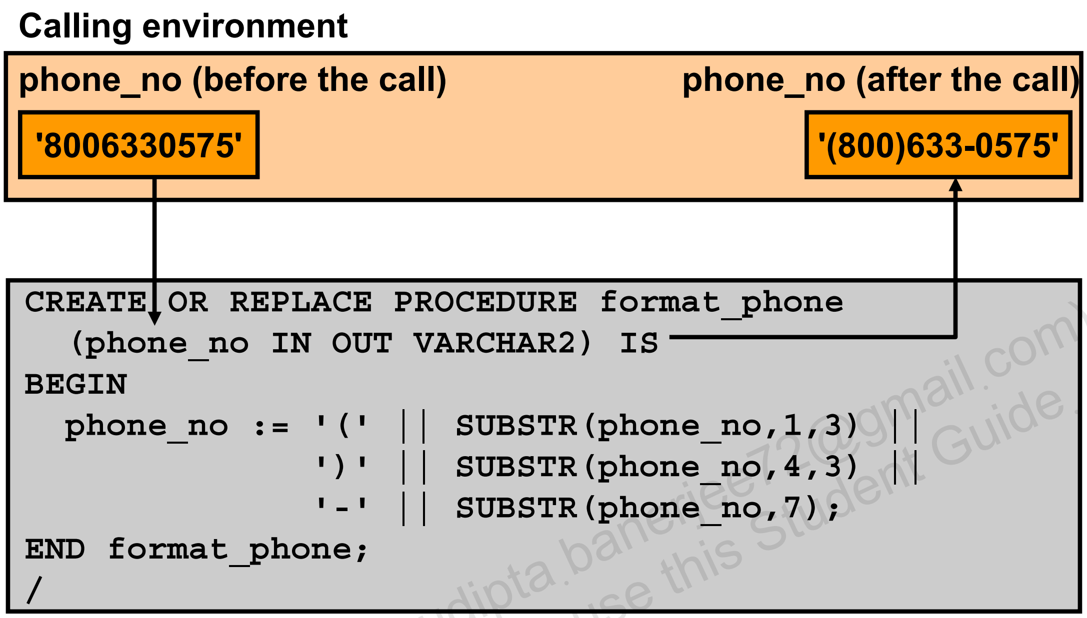
- SQL*Plus or *i*SQL*Plus
- Oracle Forms and Oracle Reports
- Java and C applications

Each of the preceding environments provides ways to declare variables to store data in memory. The variable values in these applications are defined and held external to stored PL/SQL code. Each environment provides a way to pass the variable data to PL/SQL and receive updated values from the PL/SQL code. In general, most languages host calls to PL/SQL blocks or subprograms. The PL/SQL engine uses a technique called binding to associate values supplied from external locations to PL/SQL variables or parameters declared in the PL/SQL subprograms.

Unlike in Java, PL/SQL recognizes host variables by the presence of a colon prefixed to the external variable name when it is used in a PL/SQL block.

You cannot store PL/SQL code with host variables because the compiler cannot resolve references to host variables. The binding process is done at run time.

Using IN OUT Parameters: Example



ORACLE

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 as either of the following:

- The original unchanged value
- A new value that is set within the procedure

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

The example in the slide 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 phone_no host variable of *i*SQL*Plus to provide the input value passed to the FORMAT_PHONE procedure. The procedure is executed and returns an updated string in the phone_no host variable.

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

Syntax for Passing Parameters

- 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
- Combination:
  - Lists some of the actual parameters as positional and some as named

Syntax for Passing Parameters

For a procedure that contains multiple parameters, you can use a number of methods to specify the values of the parameters. The methods are:

- **Positional:** Lists the actual parameter values in the order in which the formal parameters are declared
- **Named:** Lists the actual values in arbitrary order and uses 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: =>.
- **Combination:** Lists the first parameter values by their position and the remainder by using the special syntax of the named method

The next page shows some examples of the first two methods.

Parameter Passing: Examples

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

- Passing by positional notation:

```
EXECUTE add_dept ('TRAINING', 2500)
```

- Passing by named notation:

```
EXECUTE add_dept (loc=>2400, name=>'EDUCATION')
```

ORACLE

Parameter Passing: Examples

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

Passing parameters by position is shown in the first call to execute `add_dept` below the procedure definition. The first actual parameter supplies the value `TRAINING` for the `name` parameter. The second actual parameter value of `2500` is assigned by position to the `loc` parameter.

Passing parameters using the named notation is shown in the last example. Here, the `loc` parameter, which is declared as the second formal parameter, is referenced by name in the call, where it is associated to the actual value of `2400`. The `name` parameter is associated to 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 Parameters

- Defines default values for parameters:

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

- Provides flexibility by combining the positional and named parameter-passing syntax:

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

ORACLE

Using the DEFAULT Option for Parameters

The code examples in the slide show two ways of assigning a default value to an IN parameter. The two ways shown use:

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

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 OUT and IN OUT parameters.

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 and the supplied value for the loc parameter.

Using the `DEFAULT` Option for Parameters (continued)

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(name=>'new dept', 'new location')
```

The following error message is generated:

```
ERROR at line 1:
ORA-06550: line 1, column 34:
PLS-00312: a positional parameter association may not follow a named association
ORA-06550: line 1, column 7:
PL/SQL: Statement ignored
```

Summary of 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

Summary of 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.

Invoking Procedures

You can invoke procedures by:
- Using anonymous blocks
- Using another procedure, as in the following example:

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

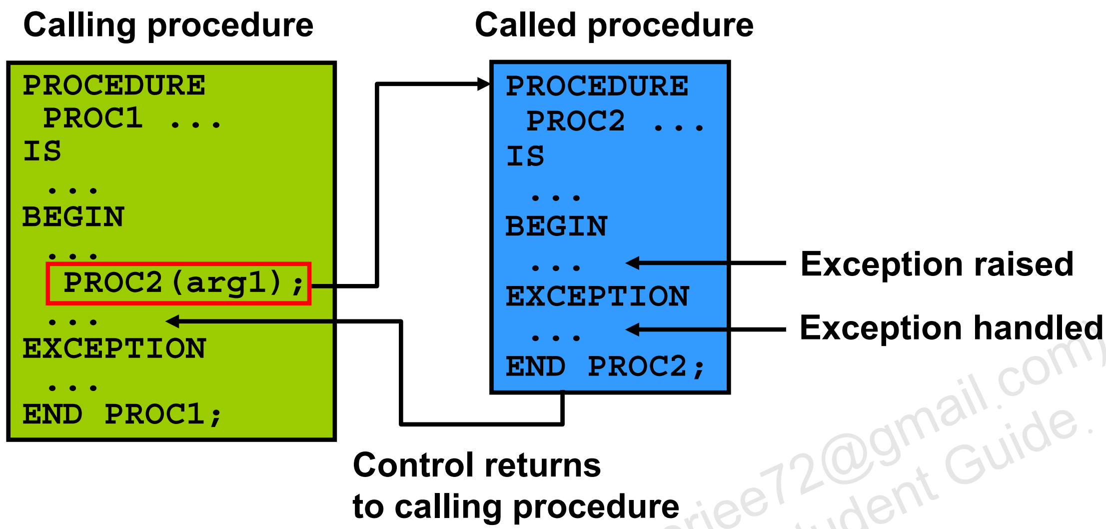

Invoking Procedures

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 *i*SQL*Plus).

This 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.

Handled Exceptions



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(
    name VARCHAR2, mgr NUMBER, loc NUMBER) IS
BEGIN
  INSERT INTO DEPARTMENTS (department_id,
    department_name, manager_id, location_id)
  VALUES (DEPARTMENTS_SEQ.NEXTVAL, name, mgr, loc);
  DBMS_OUTPUT.PUT_LINE('Added Dept: '||name);
EXCEPTION
 WHEN OTHERS THEN
  DBMS_OUTPUT.PUT_LINE('Err: adding dept: '||name);
END;
```

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

ORACLE

Handled Exceptions: Example

The two procedures in the example are the following:

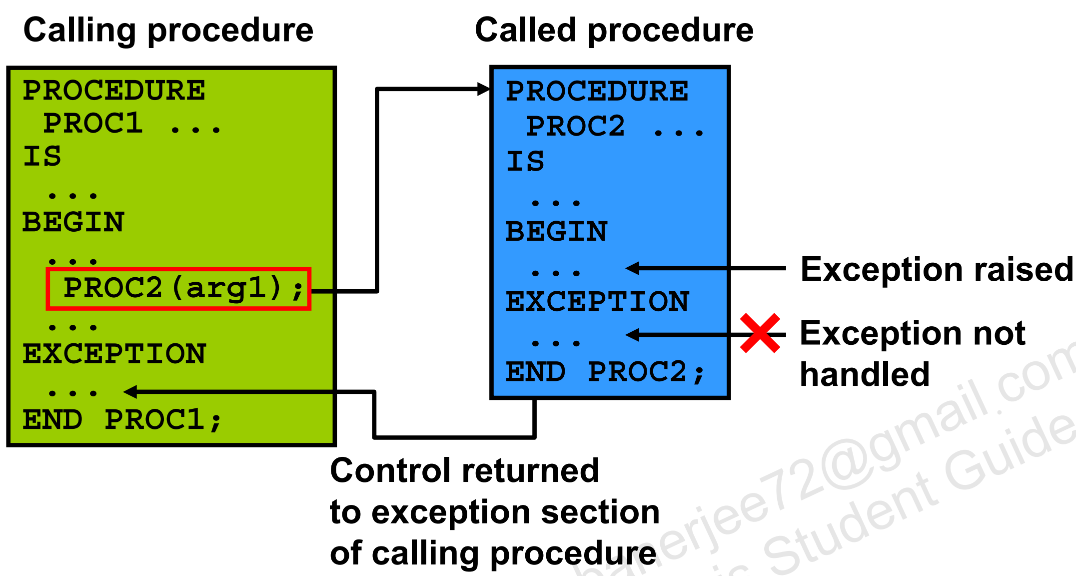
- The `add_department` procedure creates a new department record by allocating a new department number from an Oracle sequence, and sets the `department_name`, `manager_id`, and `location_id` column values using the `name`, `mgr`, and `loc` parameters, respectively.
- The `create_departments` procedure 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 `manager_id` of `99` is not inserted because of a foreign key integrity constraint violation on the `manager_id`. 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



Exceptions Not Handled

As discussed, 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(
    name VARCHAR2, mgr NUMBER, loc NUMBER) IS
BEGIN
  INSERT INTO DEPARTMENTS (department_id,
    department_name, manager_id, location_id)
  VALUES (DEPARTMENTS_SEQ.NEXTVAL, name, mgr, loc);
  DBMS_OUTPUT.PUT_LINE('Added Dept: '||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;
```


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:

```
Added Dept: Media
BEGIN create_departments_noex; END;
*
ERROR at line 1:
ORA-02291: integrity constraint (ORA1.DEPT_MGR_FK)
violated - parent key not
found
ORA-06512: at "ORA1.ADD_DEPARTMENT_NOEX", line 4
ORA-06512: at "ORA1.CREATE_DEPARTMENTS_NOEX", line 4
ORA-06512: at line 1
```

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

You can remove a procedure that is stored in the database.

- Syntax:

```
DROP PROCEDURE procedure_name
```

- Example:

```
DROP PROCEDURE raise_salary;
```


ORACLE

Removing Procedures

When a stored procedure is no longer required, you can use the `DROP PROCEDURE` SQL statement to remove it.

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.

Viewing Procedures in the Data Dictionary

Information for PL/SQL procedures is saved in the following data dictionary views:

- View source code in the USER_SOURCE table to view the subprograms that you own, or the ALL_SOURCE table for procedures that are owned by others who have granted you the EXECUTE privilege.

```
SELECT text
FROM   user_source
WHERE  name='ADD_DEPARTMENT' and type='PROCEDURE'
ORDER BY line;
```

```
SELECT object_name
FROM   user_objects
WHERE  object_type = 'PROCEDURE';
```


Viewing Procedures 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.

Benefits of Subprograms

- Easy maintenance
- Improved data security and integrity
- Improved performance
- Improved code clarity

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.

Summary

In this lesson, you should have learned how to:

- Write a procedure to perform a task or an action
- Create, compile, and save procedures in the database by using the `CREATE PROCEDURE` SQL command
- Use parameters to pass data from the calling environment to the procedure by using three different parameter modes: `IN` (the default), `OUT`, and `IN OUT`
- Recognize the effect of handling and not handling exceptions on transactions and calling procedures

Summary

A procedure is a subprogram that performs a specified action. You can compile and save a procedure as a stored procedure in the database. A procedure can return zero or more values through its parameters to its calling environment. There are three parameter modes: `IN`, `OUT`, and `IN OUT`.

You should be able to handle and not handle exceptions, and you should understand how managing exceptions affects transactions and calling procedures. The exceptions are handled in the exception section of a subprogram.

Summary

In this lesson, you should have learned how to:

- Remove procedures from the database by using the `DROP PROCEDURE` SQL command
- Modularize your application code by using procedures as building blocks

Summary (continued)

You can modify and remove procedures. Procedures are modular components that form the building blocks of an application. You can also create client-side procedures that can be used by client-side applications.

Practice 1: Overview

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

ORACLE

Practice 1: Overview

In this practice, you create procedures that issue DML and query commands.

If you encounter compilation errors when you are using *i*SQL*Plus, use the `SHOW ERRORS` command.

If you correct any compilation errors in *i*SQL*Plus, do so in the original script file (rather than in the buffer) and then rerun the new version of the file. This saves a new version of the procedure to the data dictionary.

Note: It is recommended to use *i*SQL*Plus for this practice.

Practice 1

Note: You can find table descriptions and sample data in Appendix B, "Table Descriptions and Data." Click the Save Script button to save your subprograms as .sql files in your local file system.

Remember to enable SERVEROUTPUT if you have previously disabled it.

1. Create and invoke the ADD_JOB procedure and consider the results.
   a. Create a procedure called ADD_JOB to insert a new job into the JOBS table. Provide the ID and title of the job using two parameters.
   b. Compile the code; invoke the procedure with IT_DBA as job ID and Database Administrator as job title. Query the JOBS table to view the results.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_DBA	Database Administrator		

   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 code; invoke the procedure to change the job title of the job ID IT_DBA to Data Administrator. Query the JOBS table to view the results.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_DBA	Data Administrator		

   Also check the exception handling by trying to update a job that does not exist. (You can use the job ID IT_WEB and the job title Web Master.)

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 if no job is deleted.
   b. Compile the code; invoke the procedure using the job ID IT_DBA. Query the JOBS table to view the results.

```
no rows selected
```

   Also, check the exception handling by trying to delete a job that does not exist. (Use the IT_WEB job ID.) You should get the message that you used in the exception-handling section of the procedure as output.

Practice 1 (continued)

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 the syntax errors.
   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.

SALARY
8000

JOB
ST_MAN

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

2

Creating Stored Functions

Objectives

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

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

Lesson Aim

In this lesson, you learn how to create and invoke 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

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.

Syntax for 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

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.

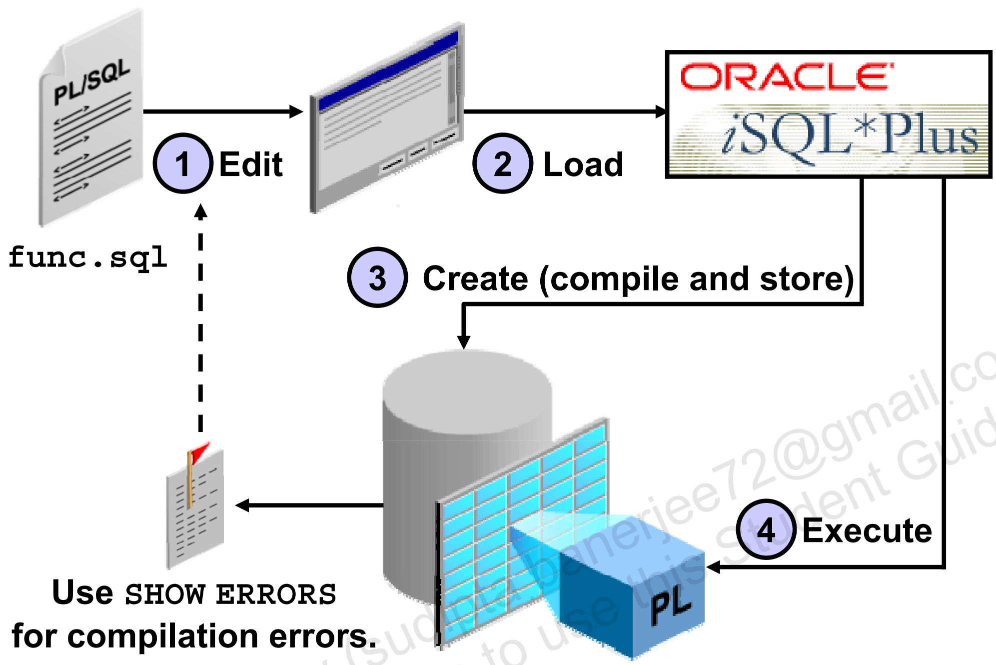
You create new functions with the `CREATE FUNCTION` statement, which may declare a list of parameters, must return one value, and must define the actions to be performed by the standard PL/SQL block.

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.

Developing Functions



How to Develop Stored Functions

The diagram illustrates the basic steps involved in developing a stored function. To develop a stored function, perform the following steps:

1. Create a file by using your favorite text or code editor to edit the function syntax, and saving the code in a file typically with a `.sql` extension.
2. Load the function code from the file into the buffer by using *i*SQL*Plus as the PL/SQL development environment.
3. Execute the `CREATE FUNCTION` statement to compile and store the function in the database.
4. After successful compilation, invoke the function from a PL/SQL environment or application.

Returning a Value

- Add a `RETURN` clause with the data type in the header of the function.
- Include one `RETURN` statement in the executable section.

Multiple `RETURN` statements are allowed in a function (usually within an `IF` statement). Only one `RETURN` statement is executed because after the value is returned, processing of the block ceases.

Use the `SHOW ERRORS` or `SHOW ERRORS FUNCTION function_name` *i*SQL*Plus commands to view compilation errors.

Stored Function: Example

- Create the function:

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

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

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


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 *i*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.

Ways to Execute Functions

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

```
VARIABLE salary NUMBER
EXECUTE :salary := get_sal(100)
```

  – Using a local variable to obtain the result:

```
DECLARE sal employees.salary%type;
BEGIN
  sal := get_sal(100); ...
END;
```

- Use as a parameter to another subprogram

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

- Use in a SQL statement (subject to restrictions)

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


Ways to Execute Functions

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

- **As part of PL/SQL expressions:** You can use host or local variables to hold the returned value from a function. The first example in the slide uses a host variable and the second example uses a local variable in an anonymous block.
- **As a parameter to another subprogram:** The third example in the slide demonstrates this usage. The `get_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 10g: 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.

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

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

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

Function in SQL Expressions: Example

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

```
Function created.
```

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.
```


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%.

In *i*SQL*Plus, 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.

Locations to Call User-Defined Functions

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

ORACLE

Locations to Call User-Defined Functions

A PL/SQL user-defined function can be called from any SQL expression where a built-in single-row function can be called.

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

...

10 rows selected.

Restrictions on Calling Functions from SQL Expressions

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

ORACLE

Restrictions on Calling Functions from SQL Expressions

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

- The function must be stored in the database.
- The function parameters must be input only and 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.

ORACLE

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(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', sal);
  RETURN (sal + 100);
END;
```

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

```
UPDATE employees SET salary = dml_call_sql(2000)
                 *
ERROR at line 1:
ORA-04091: table PLSQL.EMPLOYEES is mutating,
trigger/function may not see it
ORA-06512: at "PLSQL.DML_CALL_SQL", line 4
```

ORACLE

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(a NUMBER)
   RETURN NUMBER IS
   s NUMBER;
 BEGIN
   SELECT salary INTO s FROM employees
   WHERE employee_id = 170;
   RETURN (s + 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;
```

Removing Functions

Removing a stored function:

- You can drop a stored function by using the following syntax:

```
DROP FUNCTION function_name
```

Example:

```
DROP FUNCTION get_sal;
```

- All the privileges that are granted on a function are revoked when the function is dropped.
- The CREATE OR REPLACE syntax is equivalent to dropping a function and re-creating it. Privileges granted on the function remain the same when this syntax is used.

Removing Functions

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

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.

Viewing Functions in the Data Dictionary

Information for PL/SQL functions is stored in the following Oracle data dictionary views:

- You can view source code in the `USER_SOURCE` table for subprograms that you own, or the `ALL_SOURCE` table for functions owned by others who have granted you the `EXECUTE` privilege.

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

- You can view the names of functions by using `USER_OBJECTS`.

```
SELECT object_name
FROM   user_objects
WHERE  object_type = 'FUNCTION';
```


Viewing Functions in the Data Dictionary

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 first query example shows how to display the source code for all the functions in your schema. The second query, which uses the `USER_OBJECTS` data dictionary view, lists the names of all functions that you own.

Procedures Versus 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 return values (if any) in output parameters	Must return a single value
Can contain a `RETURN` statement without a value	Must contain at least one `RETURN` statement

How Procedures and Functions Differ

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.

Summary

In this lesson, you should have learned how to:

- Write a PL/SQL function to compute and return a value by using the `CREATE FUNCTION` SQL statement
- Invoke a function as part of a PL/SQL expression
- Use stored PL/SQL functions in SQL statements
- Remove a function from the database by using the `DROP FUNCTION` SQL statement

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 2: 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

Practice 2: Overview

If you encounter compilation errors when using *i*SQL*Plus, use the `SHOW ERRORS` command.

If you correct any compilation errors in *i*SQL*Plus, do so in the original script file, not in the buffer, and then rerun the new version of the file. This saves a new version of the program unit to the data dictionary.

Note: It is recommended to use *i*SQL*Plus for this practice.

Practice 2

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 TITLE, allowing a length of 35 characters. Invoke the function with SA_REP job ID to return the value in the host variable. Print the host variable to view the result.

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. Develop and store the GET_ANNUAL_COMP function, accepting parameter values for 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:

   ```
   (salary*12) + (commission_pct*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 VALID_DEPTID to validate a specified department ID and return a BOOLEAN value of TRUE if the department exists.
   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 (with defaults specified in parentheses): first_name, last_name, email, job (SA_REP), mgr (145), sal (1000), comm (0), and deptid (30). Use the EMPLOYEES_SEQ sequence to set the employee_id column, and set hire_date 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?

3 Creating Packages

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

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.

PL/SQL Packages: Overview

PL/SQL packages:

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

- Enable the Oracle server to read multiple objects into memory at once

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.

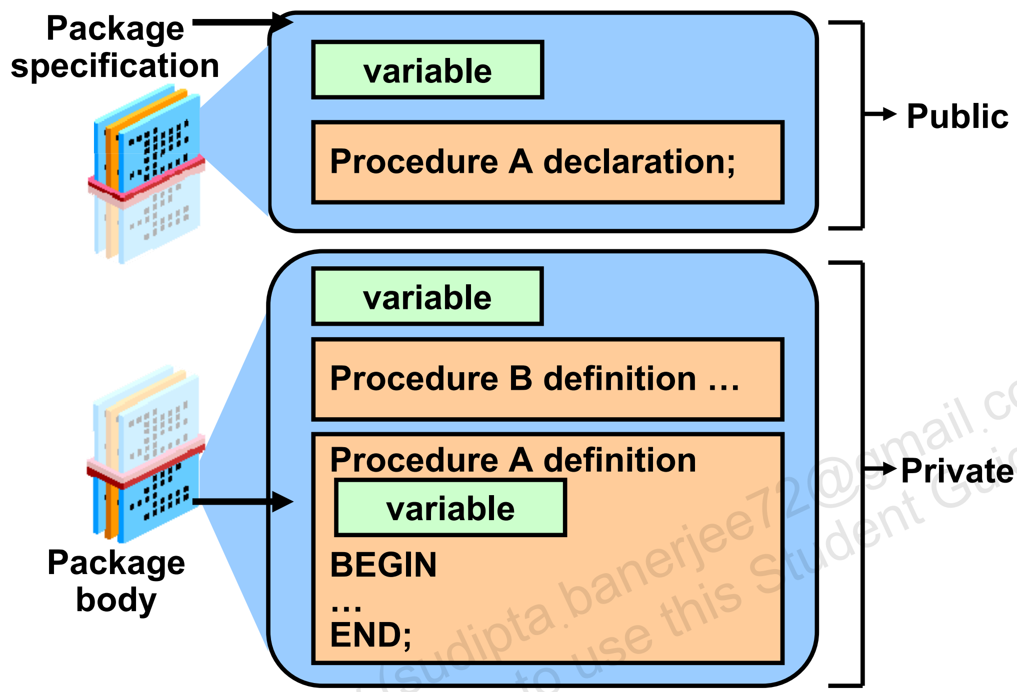
A package usually consists of two parts stored separately in the database:

- 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 do not require disk input/output (I/O).

Components of a PL/SQL Package



Components of a PL/SQL Package

You create a package in two parts:

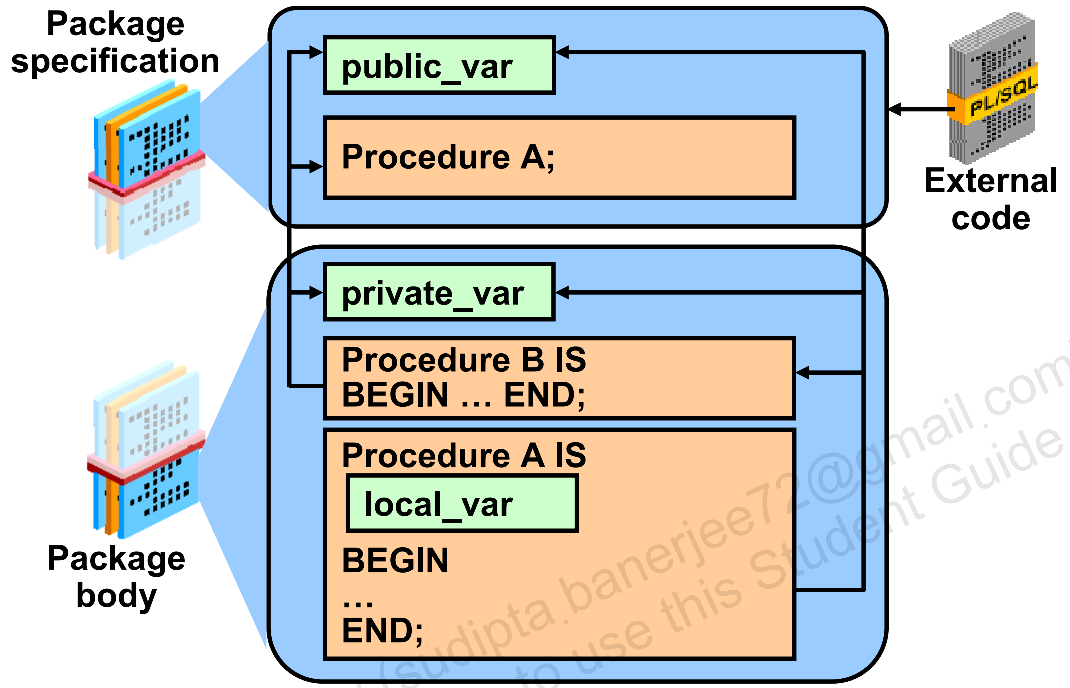
- The **package specification** is the interface to your applications. It declares the public types, variables, constants, exceptions, cursors, and subprograms available for use. The package specification may also include `PRAGMA`s, which are directives to the compiler.
- The **package body** defines 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.

Visibility of Package Components



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 the following:

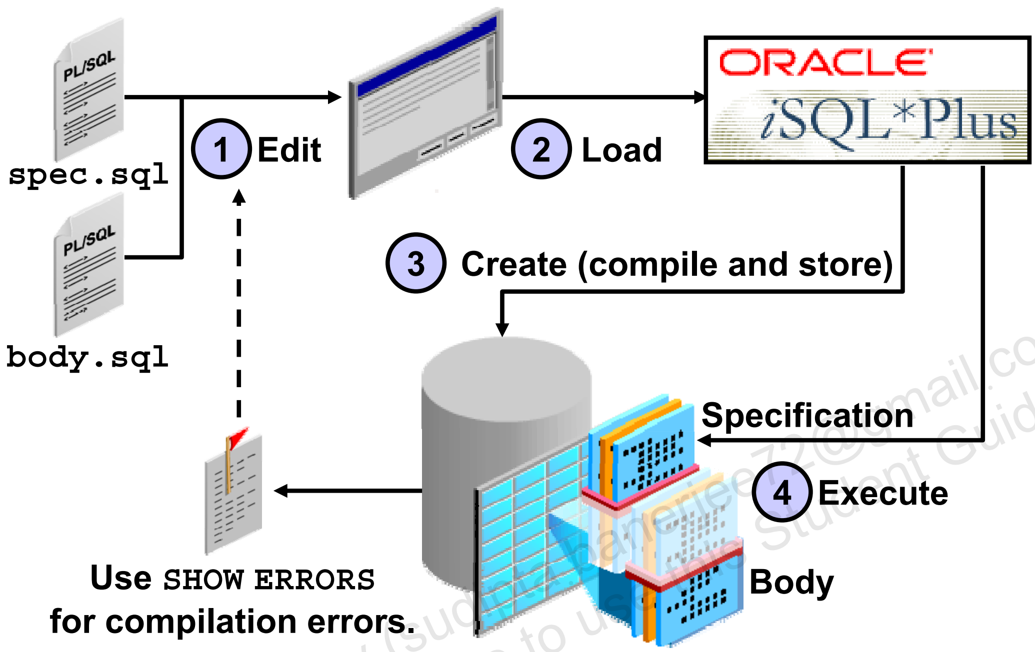
- Variables defined in a subprogram can be referenced within that subprogram, and are not visible to external components—for example, `local_var` can be used in procedure `A`.
- Private package variables, which are declared in a package body, can be referenced by other components in the same package 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



Developing PL/SQL Packages

To develop a package, perform the following steps:

1. Edit the text for the specification by using the `CREATE PACKAGE` statement within a SQL script file. Edit the text for the body (only if required; see the guidelines below) by using the `CREATE PACKAGE BODY` statement within a SQL script file.
2. Load the script files into a tool such as *i*SQL*Plus.
3. Execute the script files to create (that is, to compile and store) the package and package body in the database.
4. Execute any public construct within the package specification from an Oracle server environment.

Guidelines for Developing Packages

- Consider saving the text for a package specification and a package body in two different script files to facilitate easier modifications to the package or its body.
- A package specification can exist without a package body—that is, when the package specification does not declare subprograms, a body is not required. However, a package body cannot exist without a package specification.

Note: The Oracle server 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

Syntax:

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

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

Creating the Package Specification

To create packages, you declare all public constructs within the package specification.

- Specify the OR REPLACE option, if overwriting an existing package specification.
- Initialize a variable with a constant value or formula within the declaration, if required; otherwise, the variable is initialized implicitly to NULL.

The following are 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.

Note: 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.

Example of Package Specification: `comm_pkg`

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

- `STD_COMM` is a 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.

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 `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

Syntax:

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

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

Creating the Package Body

Create a package body to define and implement all public subprograms and 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 Package Body: `comm_pkg`

```
CREATE OR REPLACE PACKAGE BODY comm_pkg IS
  FUNCTION validate(comm NUMBER) RETURN BOOLEAN IS
    max_comm employees.commission_pct%type;
  BEGIN
    SELECT MAX(commission_pct) INTO max_comm
    FROM   employees;
    RETURN (comm BETWEEN 0.0 AND max_comm);
  END validate;
  PROCEDURE reset_comm (new_comm NUMBER) IS BEGIN
    IF validate(new_comm) THEN
      std_comm := new_comm; -- reset public var
    ELSE  RAISE_APPLICATION_ERROR(
            -20210, 'Bad Commission');
    END IF;
  END reset_comm;
END comm_pkg;
```

ORACLE

Example of 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 lesser than the highest commission among existing employees. The `reset_comm` procedure invokes the private validation function before changing the standard commission in `std_comm`. In the example, note the following:

- The `std_comm` variable referenced in the `reset_comm` procedure is a public variable. Variables declared in the package specification, such as `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 `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 Package Subprograms

- Invoke a function within the same package:

```
CREATE OR REPLACE PACKAGE BODY comm_pkg IS ...
  PROCEDURE reset_comm(new_comm NUMBER) IS
  BEGIN
    IF validate(new_comm) THEN
      std_comm := new_comm;
    ELSE ...
    END IF;
  END reset_comm;
END comm_pkg;
```

- Invoke a package procedure from *i*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)
```

ORACLE

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 *i*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 *i*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)
```

Creating and Using Bodiless Packages

```
CREATE OR REPLACE PACKAGE global_consts IS
  mile_2_kilo    CONSTANT  NUMBER  :=  1.6093;
  kilo_2_mile    CONSTANT  NUMBER  :=  0.6214;
  yard_2_meter   CONSTANT  NUMBER  :=  0.9144;
  meter_2_yard   CONSTANT  NUMBER  :=  1.0936;
END global_consts;
```

```
BEGIN  DBMS_OUTPUT.PUT_LINE('20 miles = ' ||
        20 * global_consts.mile_2_kilo || ' km');
END;
```

```
CREATE FUNCTION mtr2yrd(m NUMBER) RETURN NUMBER IS
BEGIN
  RETURN (m * global_consts.meter_2_yard);
END mtr2yrd;
/
EXECUTE DBMS_OUTPUT.PUT_LINE(mtr2yrd(1))
```

ORACLE

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 `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 `mtr2yrd` to convert meters to yards, and uses the constant conversion rate `meter_2_yard` declared in the `global_consts` package. The function is invoked in `DBMS_OUTPUT.PUT_LINE()`.

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

- To remove the package specification and the body, use the following syntax:

```
DROP PACKAGE package_name;
```

- To remove the package body, use the following syntax:

```
DROP PACKAGE BODY package_name;
```


Removing Packages

When a package is no longer required, you can use a SQL statement in *i*SQL*Plus 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 in the Data Dictionary

The source code for PL/SQL packages is maintained and is viewable through the USER_SOURCE and ALL_SOURCE tables in the data dictionary.

- To view the package specification, use:

```
SELECT  text
FROM    user_source
WHERE   name = 'COMM_PKG' AND type = 'PACKAGE';
```

- To view the package body, use:

```
SELECT  text
FROM    user_source
WHERE   name = 'COMM_PKG' AND type = 'PACKAGE BODY';
```


Viewing Packages in the Data Dictionary

The source code for PL/SQL packages is also stored in the data dictionary tables such as stand-alone procedures and functions. The source code is viewable in the data dictionary when you execute a `SELECT` statement on the `USER_SOURCE` and `ALL_SOURCE` tables.

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

Note: The values of the `NAME` and `TYPE` columns must be uppercase.

Guidelines for Writing Packages

- Construct 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.
- Changes to the package specification require recompilation of each referencing subprogram.
- The package specification should contain as few constructs as possible.

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.

Changes to the package body do not require recompilation of dependent constructs, whereas changes to the package specification require recompilation of every stored subprogram that references the package. To reduce the need for recompiling when code is changed, place as few constructs as possible in a package specification.

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.

ORACLE

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 ease of 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. Then 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 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

ORACLE

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."

Summary

In this lesson, you should have learned how to:

- Improve code organization, management, security, and performance by using packages
- Create and remove package specifications and bodies
- Group related procedures and functions together in a package
- Encapsulate the code in a package body
- Define and use components in bodiless packages
- Change a package body without affecting a package specification

Summary

You group related procedures and function together 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.

Summary

Command	Task
`CREATE [OR REPLACE] PACKAGE`	Create (or modify) an existing package specification.
`CREATE [OR REPLACE] PACKAGE BODY`	Create (or modify) an existing package body.
`DROP PACKAGE`	Remove both the package specification and package body.
`DROP PACKAGE BODY`	Remove only the package body.

Summary (continued)

You can create, delete, and modify packages. You can remove both package specification and body by using the `DROP PACKAGE` command. You can drop the package body without affecting its specification.

Practice 3: Overview

This practice covers the following topics:

- Creating packages
- Invoking package program units

Practice 3: Overview

In this practice, you create package specifications and package bodies. You 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. If you are using SQL*Plus or *i*SQL*Plus to create your stored code, use the `SHOW ERRORS` to view compile errors.

Practice 3

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.
   Tip: Consider saving the package specification and body in two separate files (for example, p3q1_s.sql and p3q1_b.sql for the package specification and body, respectively). Include a SHOW ERRORS after the CREATE PACKAGE statement in each file. Alternatively, place all code in one file.
   Note: Use the code in your previously saved script files when creating the package.
   a. Create the package specification including the procedures and function headings as public constructs.
      Note: Consider whether you still need the stand-alone procedures and functions you just packaged.
   b. Create the package body with the implementations for each of the subprograms.
   c. Invoke your ADD_JOB package procedure by passing the values IT_SYSAN and SYSTEMS ANALYST as parameters.
   d. Query the JOBS table to see the result.

JOB_ID	JOB_TITLE	MIN_SALARY	MAX_SALARY
IT_SYSAN	Systems Analyst		

2. Create and invoke a package that contains private and public constructs.
   a. Create a package specification and package body called EMP_PKG that contains your ADD_EMPLOYEE and GET_EMPLOYEE procedures as public constructs, and include your VALID_DEPTID function as a private construct.
   b. Invoke the EMP_PKG.ADD_EMPLOYEE procedure, using department ID 15 for employee Jane Harris with the e-mail 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 e-mail ID DASMITH.

4

Using More Package Concepts

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
- Wrap source code stored in the data dictionary so that it is not readable

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.

Overloading Subprograms

The overloading feature 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

Note: Overloading can be done with local subprograms, package subprograms, and type methods, but not with stand-alone subprograms.

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: Example

```
CREATE OR REPLACE PACKAGE dept_pkg IS
  PROCEDURE add_department(deptno NUMBER,
   name VARCHAR2 := 'unknown', loc NUMBER := 1700);
  PROCEDURE add_department(
   name VARCHAR2 := 'unknown', loc NUMBER := 1700);
END dept_pkg;
/
```


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.

Note: The example uses basic data types for its arguments to ensure that the example fits in the space provided. It is better to specify data types using the `%TYPE` attribute for variables that are used to populate columns in database tables, as in the following example:

```
PROCEDURE add_department
 (deptno departments.department_id%TYPE,
  name departments.department_name%TYPE := 'unknown',
  loc departments.location_id%TYPE := 1700);
```

Overloading: Example

```
CREATE OR REPLACE PACKAGE BODY dept_pkg  IS
  PROCEDURE add_department (deptno NUMBER,
   name VARCHAR2:='unknown', loc NUMBER:=1700) IS
  BEGIN
    INSERT INTO departments(department_id,
      department_name, location_id)
    VALUES  (deptno, name, loc);
  END add_department;

  PROCEDURE add_department (
    name VARCHAR2:='unknown', loc NUMBER:=1700) IS
  BEGIN
    INSERT INTO departments (department_id,
      department_name, location_id)
    VALUES (departments_seq.NEXTVAL, name, loc);
  END add_department;
 END dept_pkg;
/
```

ORACLE

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

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
320	Training		2400

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 you qualify the built-in subprogram with its package name.

ORACLE

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 redeclare 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 redeclare the TO_CHAR function to access the built-in function, then you refer to it as STANDARD.TO_CHAR.

If you redeclare 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.

Using Forward Declarations

- 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;
/
```


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 was a forward declaration, and its reference can be resolved by the compiler.

Using Forward Declarations

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;
```


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.

Package Initialization Block

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
  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 tax
   FROM     tax_rates
   WHERE    rate_name = 'TAX';
END taxes;
/
```


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 `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 and Restrictions

- Package functions can be used in SQL statements.
- Functions called from:
  – A query or DML statement must not end the current transaction, create or roll back to a savepoint, or alter the system or session
  – A query or a parallelized DML statement cannot execute a DML statement or modify the database
  – A DML statement cannot read or modify the table being changed by that DML statement

Note: A function calling subprograms that break the preceding restrictions is not allowed.

Using Package Functions in SQL and Restrictions

When executing a SQL statement that calls a stored function, the Oracle server must know the purity level of stored functions, that is, whether the functions are free of the restrictions listed in the slide. 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. Therefore, the following restrictions apply to stored functions called from SQL expressions:

- A function called from a query or DML statement cannot end the current transaction, create or roll back to a savepoint, or alter the system or session.
- A function called from a query statement or from a parallelized DML statement cannot execute a DML statement or otherwise modify the database.
- A function called from a DML statement cannot read or modify the particular table being modified by that DML statement.

Note: Prior to Oracle8*i*, the purity level was checked at compilation time by including `PRAGMA RESTRICT_REFERENCES` in the package specification. Since Oracle8*i*, the purity level of functions is checked at run time.

Package Function in SQL: Example

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

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


Package Function in SQL: Example

The first code box shows how to create the package specification and the body encapsulating the `tax` function in the `taxes_pkg` package. The second code box shows how to call the packaged `tax` function in the `SELECT` statement. The output results are similar to:

TAXES_PACK.TAX(SALARY)	SALARY	LAST_NAME
1920	24000	King
1360	17000	Kochhar
1360	17000	De Haan
720	9000	Hunold
480	6000	Ernst
422.4	5280	Austin
422.4	5280	Pataballa
369.6	4620	Lorentz
960	12000	Greenberg

■ ■ ■

109 rows selected.

Note: If you are using Oracle versions prior to 8*i*, then you must assert the purity level of the function in the package specification by using `PRAGMA RESTRICT_REFERENCES`. If this is not specified, you get an error message saying that the `TAX` function does not guarantee that it will not update the database while invoking the package function in a query.

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

ORACLE

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 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.

Note: If you add `PRAGMA SERIALLY_RESUABLE` 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 Package Variables: Example

Time	Events	-Scott- STD	-Scott- MAX	-Jones- STD	-Jones- MAX
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

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 `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 `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 `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 `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

```
CREATE OR REPLACE PACKAGE BODY curs_pkg IS
  CURSOR c IS SELECT employee_id FROM employees;
  PROCEDURE open IS
  BEGIN
    IF NOT c%ISOPEN THEN   OPEN c;   END IF;
  END open;
  FUNCTION next(n NUMBER := 1) RETURN BOOLEAN IS
    emp_id employees.employee_id%TYPE;
  BEGIN
    FOR count IN 1 .. n LOOP
      FETCH c INTO emp_id;
      EXIT WHEN c%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE('Id: ' ||(emp_id));
    END LOOP;
    RETURN c%FOUND;
  END next;
  PROCEDURE close IS BEGIN
    IF c%ISOPEN THEN  CLOSE c;  END IF;
  END close;
END curs_pkg;
```


Persistent State of a Package Cursor

The code in the slide shows the package body for CURS_PKG to support the following package specification:

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

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

- Call the `open` procedure to open the cursor.
- 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`.
- 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 `CURS_PKG`

```
SET SERVEROUTPUT ON
EXECUTE curs_pkg.open
DECLARE
  more BOOLEAN := curs_pkg.next(3);
BEGIN
  IF NOT more THEN
    curs_pkg.close;
  END IF;
END;
/
RUN  -- repeats execution on the anonymous block
EXECUTE curs_pkg.close
```


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 `SET SERVEROUTPUT ON` command prepares *i*SQL*Plus to display output results. 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 `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
```

The `RUN` command executes the anonymous block again, and the next three rows are displayed:

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

The `EXECUTE curs_pkg.close` command closes the cursor in the package.

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(emps OUT emp_table_type);
END emp_pkg;
/
```

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


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 *i*SQL*Plus, you can invoke the get_employees procedure in an anonymous PL/SQL block by using the employees variable, as shown in the following example:

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

This results in the following output:

```
Emp 4: Ernst
```

PL/SQL Wrapper

- 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

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 relink 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

The command-line syntax is:

```
WRAP INAME=input_file_name [ONAME=output_file_name]
```

- 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
```

ORACLE

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 *i*SQL*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 ...
/
```


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.

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 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 `amp` does not exist:

```
CREATE PROCEDURE raise_salary (emp_id INTEGER, amount
NUMBER) AS
BEGIN
   UPDATE amp  -- 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.
- As contents are not readable, the output file should not be edited. To change wrapped object, you need to modify the original source code and wrap the code again.

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
- Use the PL/SQL wrapper to wrap code

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 4: Overview

This practice covers the following topics:

- Using overloaded subprograms
- Creating a package initialization block
- Using a forward declaration
- Using the WRAP utility to prevent the source code from being deciphered by humans

Practice 4: 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. You use the WRAP command-line utility to prevent the source code from being readable in the data dictionary tables.

Practice 4

1. Copy and modify the code for the EMP_PKG package that you created in Practice 3, Exercise 2, and overload the ADD_EMPLOYEE procedure.
   a. In the package specification, add a new procedure called ADD_EMPLOYEE that accepts three parameters: the first name, last name, and department ID. Save and compile the changes.
   b. Implement the new ADD_EMPLOYEE procedure in the package body so that it formats the e-mail address in uppercase characters, using the first letter of the first name concatenated with the first seven letters of the last name. The procedure should call the existing ADD_EMPLOYEE procedure to perform the actual INSERT operation using its parameters and formatted e-mail to supply the values. Save and compile the changes.
   c. Invoke the new ADD_EMPLOYEE procedure using the name Samuel Joplin to be added to department 30.
2. In the EMP_PKG package, create two overloaded functions called GET_EMPLOYEE.
   a. In the specification, add a GET_EMPLOYEE function that accepts the parameter called emp_id based on the employees.employee_id%TYPE type, and a second GET_EMPLOYEE function that accepts the parameter called family_name of type employees.last_name%TYPE. Both functions should return an EMPLOYEES%ROWTYPE. Save and compile the changes.
   b. In the package body, implement the first GET_EMPLOYEE function to query an employee by his or her ID, and the second to use the equality operator on the value supplied in the family_name parameter. Save and compile the changes.
   c. Add a utility procedure PRINT_EMPLOYEE to the package that accepts an EMPLOYEES%ROWTYPE as a parameter and displays the department_id, employee_id, first_name, last_name, job_id, and salary for an employee on one line, using DBMS_OUTPUT. Save and compile the changes.
   d. 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 improve 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.
   a. In the package specification, create a procedure called INIT_DEPARTMENTS with no parameters.
   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. 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. Declare the valid_departments variable and its type definition boolean_tabtype before all procedures in the body.

Practice 4 (continued)

c. In the body, create an initialization block that calls the INIT_DEPARTMENTS procedure to initialize the table. Save and compile the changes.

4. Change VALID_DEPTID validation processing to use the private PL/SQL table of department IDs.
   a. Modify VALID_DEPTID to perform its validation by using the PL/SQL table of department ID values. Save and compile the changes.
   b. Test your code by calling ADD_EMPLOYEE using the name James Bond in department 15. What happens?
   c. Insert a new department with ID 15 and name Security, and commit 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.
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. In *i*SQL*Plus, load and compile the package specification. What happens?
   b. Edit the package body and reorganize all subprograms alphabetically. In *i*SQL*Plus, load and compile the package specification. What happens?
   c. Fix the compilation error using a forward declaration in the body for the offending subprogram reference. Load and re-create the package body. What happens? Save the package code in a script file.

If you have time, complete the following exercise:

6. Wrap the EMP_PKG package body and re-create it.
   a. Query the data dictionary to view the source for the EMP_PKG body.
   b. Start a command window and execute the WRAP command-line utility to wrap the body of the EMP_PKG package. Give the output file name a .plb extension.
      Hint: Copy the file (which you saved in step 5c) containing the package body to a file called emp_pkb_b.sql.
   c. Using *i*SQL*Plus, load and execute the .plb file containing the wrapped source.
   d. Query the data dictionary to display the source for the EMP_PKG package body again. Are the original source code lines readable?

5

Using Oracle-Supplied Packages in Application Development

ORACLE

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
- Use the HTP package to generate a simple Web page
- Describe the main features of UTL_MAIL
- Call the DBMS_SCHEDULER package to schedule PL/SQL code for execution

Lesson Aim

In this lesson, you learn how to use some of the Oracle-supplied packages and their capabilities. This lesson focuses on the packages that generate text-based and Web-based output, e-mail processing, and the provided scheduling capabilities.

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.

ORACLE

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 know about this package if you attended the course *Oracle Database 10g: PL/SQL Fundamentals*.

List of Some Oracle-Supplied Packages

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

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

ORACLE

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 *PL/SQL Packages and Types Reference 10g* (previously known as the *PL/SQL Supplied Packages Reference)*. This lesson covers the last five packages in this list.

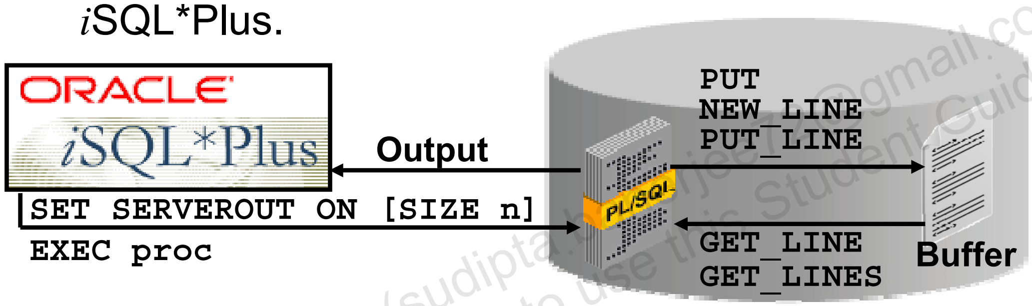
The following is a brief description about all the listed packages:

- `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 e-mail messages.
- `DBMS_SCHEDULER` enables scheduling and automated execution of PL/SQL blocks, stored procedures, and external procedures and executables.

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 sender completes.
- Use `SET SERVEROUTPUT ON` to display messages in *i*SQL*Plus.



ORACLE

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 between 2,000 (the default) and 1,000,000 (1 million characters)
- An integer parameter between 2,000 and 1,000,000 in the `ENABLE` procedure

Practical Uses

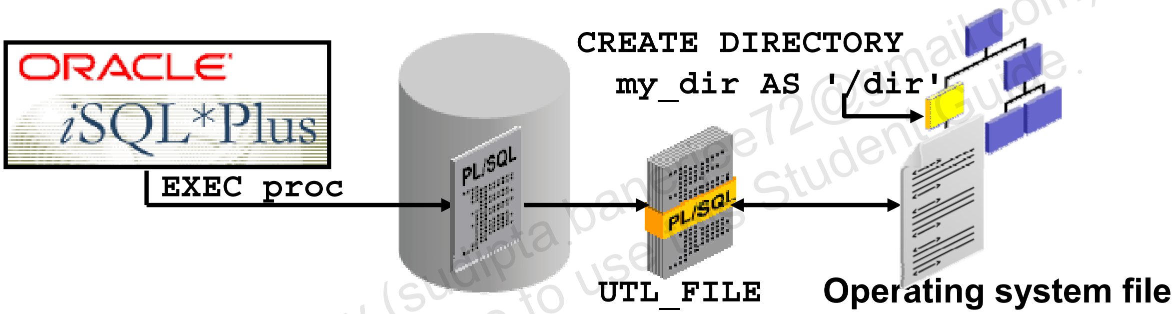
- You can output results to the window for debugging purposes.
- You can trace code execution path for a function or procedure.
- You can send messages between subprograms and triggers.

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

Interacting with Operating System Files

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

- 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. You can also use the utl_file_dir database parameter.



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.
```

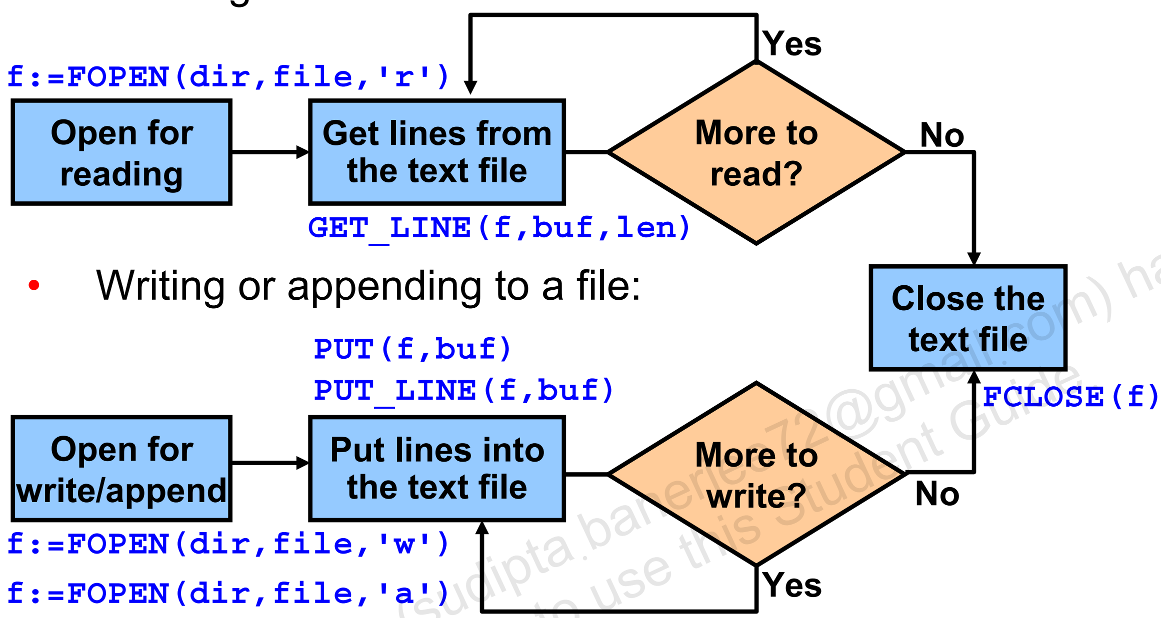
- The paths specified in the utl_file_dir database initialization parameter

The preferred approach is to use the directory alias created by the CREATE DIRECTORY statement, which does not require the database to be restarted. 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.

Note: The DBMS_LOB package can be used to read binary files on the operating system. DBMS_LOB is covered in the lesson titled “Manipulating Large Objects.”

File Processing Using the `UTL_FILE` Package

- Reading a file:
- Writing or appending to a file:



File Processing Using the `UTL_FILE` Package

Using the procedures and functions in the `UTL_FILE` package, open files with the `FOPEN` function. You 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.

Exceptions in the UTL_FILE Package

You may have to handle one of these exceptions when using UTL_FILE subprograms:

- INVALID_PATH
- INVALID_MODE
- INVALID_FILEHANDLE
- INVALID_OPERATION
- READ_ERROR
- WRITE_ERROR
- INTERNAL_ERROR

Other exceptions not in the UTL_FILE package are:

- NO_DATA_FOUND and VALUE_ERROR

ORACLE

Exceptions in the UTL_FILE Package

The UTL_FILE package declares seven exceptions that indicate an error condition in the operating system file processing. The UTL_FILE exceptions are:

- INVALID_PATH if the file location or file name was invalid
- INVALID_MODE if the OPEN_MODE parameter in FOPEN was invalid
- INVALID_FILEHANDLE if the file handle was invalid
- INVALID_OPERATION if the file could not be opened or operated on as requested
- READ_ERROR if an operating system error occurred during the read operation
- WRITE_ERROR if an operating system error occurred during the write operation
- INTERNAL_ERROR if an unspecified error occurred in PL/SQL

Note: These exceptions must always be prefaced 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 Function Parameters

```
FUNCTION FOPEN (location IN VARCHAR2,
                filename IN VARCHAR2,
                open_mode IN VARCHAR2)
RETURN UTL_FILE.FILE_TYPE;
```

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

Example:

```
CREATE PROCEDURE read_file(dir VARCHAR2, filename
VARCHAR2) IS file UTL_FILE.FILE_TYPE;
...
BEGIN
  ...
  IF NOT UTL_FILE.IS_OPEN(file) THEN
   file := UTL_FILE.FOPEN (dir, filename, 'R');
   ...
  END IF;
END read_file;
```

ORACLE

FOPEN and IS_OPEN Function Parameters

The parameters include the following:

- `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
- `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.

Note: For the full syntax, refer to the *PL/SQL Packages and Types Reference*.

Using UTL_FILE: Example

```
CREATE OR REPLACE PROCEDURE sal_status(
  dir IN VARCHAR2, filename IN VARCHAR2) IS
  file UTL_FILE.FILE_TYPE;
 CURSOR empc IS
  SELECT last_name, salary, department_id
  FROM employees ORDER BY department_id;
 newdeptno employees.department_id%TYPE;
 olddeptno employees.department_id%TYPE := 0;
BEGIN
  file:= UTL_FILE.FOPEN (dir, filename, 'w');
  UTL_FILE.PUT_LINE(file,
   'REPORT: GENERATED ON ' || SYSDATE);
  UTL_FILE.NEW_LINE (file); ...
```

ORACLE

Using UTL_FILE: Example

In the 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 variable file 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 dir parameter for the name of the directory in which to write the text file
- The filename parameter to specify the name of the file

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

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

Note: The directory location used (MY_DIR) 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. DBMS_OUTPUT procedures do not produce output until the procedure is completed.

Using UTL_FILE: Example

```
  FOR emp_rec IN empc LOOP
    IF emp_rec.department_id <> olddeptno THEN
      UTL_FILE.PUT_LINE (file,
       'DEPARTMENT: ' || emp_rec.department_id);
      UTL_FILE.NEW_LINE (file);
    END IF;
    UTL_FILE.PUT_LINE (file,
       '   EMPLOYEE: ' || emp_rec.last_name ||
       ' earns: ' || emp_rec.salary);
    olddeptno := emp_rec.department_id;
    UTL_FILE.NEW_LINE (file);
  END LOOP;
  UTL_FILE.PUT_LINE(file,'*** END OF REPORT ***');
  UTL_FILE.FCLOSE (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;
/
```

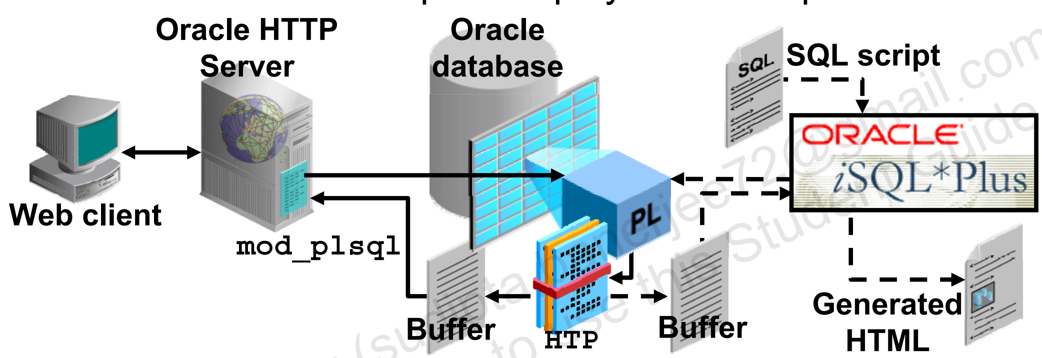

Using UTL_FILE: Example (continued)

The output for this report in the `salreport.txt` file is as follows:

```
SALARY REPORT: GENERATED ON 08-MAR-01
     DEPARTMENT: 10
          EMPLOYEE: Whalen earns: 4400
     DEPARTMENT: 20
          EMPLOYEE: Hartstein earns: 13000
          EMPLOYEE: Fay earns: 6000
     DEPARTMENT: 30
          EMPLOYEE: Raphaely earns: 11000
          EMPLOYEE: Khoo earns: 3100
          ...
     DEPARTMENT: 100
          EMPLOYEE: Greenberg earns: 12000
         ...
     DEPARTMENT: 110
          EMPLOYEE: Higgins earns: 12000
          EMPLOYEE: Gietz earns: 8300
          EMPLOYEE: Grant earns: 7000
     *** END OF REPORT ***
```

Generating Web Pages with the HTP Package

- The HTP package procedures generate HTML tags.
- The HTP package is used to generate HTML documents dynamically and can be invoked from:
  - A browser using Oracle HTTP Server and PL/SQL Gateway (mod_plsql) services
  - An *i*SQL*Plus script to display HTML output



Generating Web Pages with the HTP Package

The HTP package contains procedures that are used to generate HTML tags. The HTML tags that are generated typically enclose the data provided as parameters to the various procedures. The slide illustrates two ways in which the HTP package can be used:

- Most likely your procedures are invoked by the PL/SQL Gateway services, via the mod_plsql component supplied with Oracle HTTP Server, which is part of the Oracle Application Server product (represented by solid lines in the graphic).
- Alternatively (as represented by dotted lines in the graphic), your procedure can be called from *i*SQL*Plus that can display the generated HTML output, which can be copied and pasted to a file. This technique is used in this course because Oracle Application Server software is not installed as a part of the course environment.

Note: The HTP procedures output information to a session buffer held in the database server. In the Oracle HTTP Server context, when the procedure completes, the mod_plsql component automatically receives the buffer contents, which are then returned to the browser as the HTTP response. In SQL*Plus, you must manually execute:

- A SET SERVEROUTPUT ON command
- The procedure to generate the HTML into the buffer
- The OWA_UTIL.SHOWPAGE procedure to display the buffer contents

Using the HTP Package Procedures

- Generate one or more HTML tags. For example:

```
htp.bold('Hello');              -- <B>Hello</B>
htp.print('Hi <B>World</B>');   -- Hi <B>World</B>
```

- Are used to create a well-formed HTML document:

```
BEGIN                            -- Generates:
 htp.htmlOpen;    --------->   <HTML>
 htp.headOpen;    --------->   <HEAD>
 htp.title('Welcome');  -->    <TITLE>Welcome</TITLE>
 htp.headClose;   --------->   </HEAD>
 htp.bodyOpen;    --------->   <BODY>
 htp.print('My home page');    My home page
 htp.bodyClose;   --------->   </BODY>
 htp.htmlClose;   --------->   </HTML>
END;
```

ORACLE

Using the HTP Package Procedures

The HTP package is structured to provide a one-to-one mapping of a procedure to standard HTML tags. For example, to display bold text on a Web page, the text must be enclosed in the HTML tag pair <B> and </B>. The first code box in the slide shows how to generate the word Hello in HTML bold text by using the equivalent HTP package procedure—that is, HTP.BOLD. The HTP.BOLD procedure accepts a text parameter and ensures that it is enclosed in the appropriate HTML tags in the HTML output that is generated.

The HTP.PRINT procedure copies its text parameter to the buffer. The example in the slide shows how the parameter supplied to the HTP.PRINT procedure can contain HTML tags. This technique is recommended only if you need to use HTML tags that cannot be generated by using the set of procedures provided in the HTP package.

The second example in the slide provides a PL/SQL block that generates the basic form of an HTML document. The example serves to illustrate how each of the procedures generates the corresponding HTML line in the enclosed text box on the right.

The benefit of using the HTP package is that you create well-formed HTML documents, eliminating the need to manually type the HTML tags around each piece of data.

Note: For information about all the HTP package procedures, refer to the *PL/SQL Packages and Types Reference*.

Creating an HTML File with *i*SQL*Plus

To create an HTML file with *i*SQL*Plus, perform the following steps:

1. Create a SQL script with the following commands:

```
SET SERVEROUTPUT ON
ACCEPT procname PROMPT "Procedure: "
EXECUTE &procname
EXECUTE owa_util.showpage
UNDEFINE proc
```

2. Load and execute the script in *i*SQL*Plus, supplying values for substitution variables.
3. Select, copy, and paste the HTML text that is generated in the browser to an HTML file.
4. Open the HTML file in a browser.

Creating an HTML File with *i*SQL*Plus

The slide example shows the steps for generating HTML by using any procedure and saving the output into an HTML file. You should perform the following steps:

1. Turn on server output with the `SET SERVEROUTPUT ON` command. Without this, you receive exception messages when running procedures that have calls to the `HTP` package.
2. Execute the procedure that contains calls to the `HTP` package.
   Note: This does *not* produce output, unless the procedure has calls to the `DBMS_OUTPUT` package.
3. Execute the `OWA_UTIL.SHOWPAGE` procedure to display the text. This call actually displays the HTML content that is generated from the buffer.

The `ACCEPT` command prompts for the name of the procedure to execute. The call to `OWA_UTIL.SHOWPAGE` displays the HTML tags in the browser window. You can then copy and paste the generated HTML tags from the browser window into an HTML file, typically with a `.htm` or `.html` extension.

Note: If you are using SQL*Plus, then you can use the `SPOOL` command to direct the HTML output directly to an HTML file. The `SPOOL` command is not supported in *i*SQL*Plus; therefore, the copy-and-paste technique is the only option.

Using UTL_MAIL

The UTL_MAIL package:
- Is a utility for managing e-mail that includes such commonly used e-mail features as attachments, CC, BCC, and return receipt
- Requires the SMTP_OUT_SERVER database initialization parameter to be set
- 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

ORACLE

Using UTL_MAIL

The UTL_MAIL package is a utility for managing e-mail that includes commonly used e-mail 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 *i*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 e-mail. 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
```

Installing and Using UTL_MAIL

- As SYSDBA, using *i*SQL*Plus:
  – Set the SMTP_OUT_SERVER (requires DBMS restart).

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

  – Install the UTL_MAIL package.

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

- 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;
```


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 e-mail address (in this case, otn@oracle.com)
- The recipients e-mail 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 e-mail, 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 *PL/SQL Packages and Types Reference*.

Sending E-Mail with a Binary Attachment

Use the `UTL_MAIL.SEND_ATTACH_RAW` procedure:

```
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;
/
```

ORACLE

Sending E-Mail with a Binary Attachment

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 e-mail 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 details about working with a `BFILE` are covered in the lesson titled “Manipulating Large Objects.” The code for `get_image` is shown on the following page.

Sending E-Mail with a Binary Attachment (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 *i*SQL*Plus:

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

Note: You need the `CREATE ANY DIRECTORY` system privilege to execute this statement.

Sending E-Mail with a Text Attachment

Use the `UTL_MAIL.SEND_ATTACH_VARCHAR2` procedure:

```
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;
/
```


Sending E-Mail 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 E-Mail 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 *i*SQL*Plus:

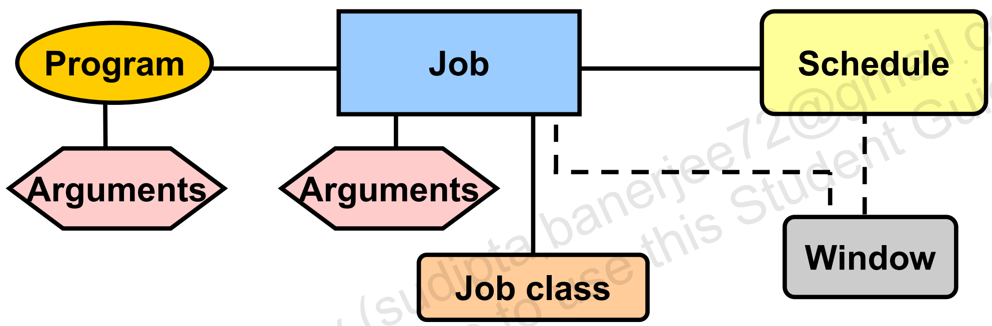
```
CREATE DIRECTORY temp AS 'e:\temp';
```

Note: The CREATE ANY DIRECTORY system privilege is required to execute this statement.

DBMS_SCHEDULER Package

The database Scheduler comprises several components to enable jobs to be run. Use the DBMS_SCHEDULER package to create each job with:

- A unique job name
- A program (“what” should be executed)
- A schedule (“when” it should run)



DBMS_SCHEDULER Package

Oracle Database 10*g* provides a collection of subprograms in the DBMS_SCHEDULER package to simplify management and to provide a rich set of functionality for complex scheduling tasks. Collectively, these subprograms are called the Scheduler and can be called from any PL/SQL program. The Scheduler enables database administrators and application developers to control when and where various tasks take place. By ensuring that many routine database tasks occur without manual intervention, you can lower operating costs, implement more reliable routines, and minimize human error.

The diagram shows the following architectural components of the Scheduler:

- A **job** is the combination of a program and a schedule. Arguments required by the program can be provided with the program or the job. All job names have the format `[schema.]name`. When you create a job, you specify the job name, a program, a schedule, and (optionally) job characteristics that can be provided through a **job class**.
- A **program** determines what should be run. Every automated job involves a particular executable, whether it is a PL/SQL block, a stored procedure, a native binary executable, or a shell script. A program provides metadata about a particular executable and may require a list of arguments.
- A **schedule** specifies when and how many times a job is executed.

`DBMS_SCHEDULER` Package (continued)

- A **job class** defines a category of jobs that share common resource usage requirements and other characteristics. At any given time, each job can belong to only a single job class. A job class has the following attributes:
  - A database **service** name. The jobs in the job class will have an affinity to the particular service specified—that is, the jobs will run on the instances that cater to the specified service.
  - A **resource consumer group**, which classifies a set of user sessions that have common resource-processing requirements. At any given time, a user session or job class can belong to a single resource consumer group. The resource consumer group that the job class associates with determines the resources that are allocated to the job class.
- A **window** is represented by an interval of time with a well-defined beginning and end, and is used to activate different resource plans at different times.

The slide focuses on the job component as the primary entity. However, a program, a schedule, a window, and a job class are components that can be created as individual entities that can be associated with a job to be executed by the Scheduler. When a job is created, it may contain all the information needed in-line—that is, in the call that creates the job. Alternatively, creating a job may reference a program or schedule component that was previously defined. Examples of this are discussed in the next few pages.

For more information about the Scheduler, see the Online Course titled *Oracle Database 10g: Configure and Manage Jobs with the Scheduler*.

Creating a Job

A job can be created in several ways by using a combination of in-line parameters, named `Programs`, and named `Schedules`. You can create a job with the `CREATE_JOB` procedure by:

- Using in-line information with the "what" and the schedule specified as parameters
- Using a named (saved) program and specifying the schedule in-line
- Specifying what should be done in-line and using a named Schedule
- Using named Program and Schedule components

Note: Creating a job requires the `CREATE JOB` system privilege.

Creating a Job

The component that causes something to be executed at a specified time is called a **job**. Use the `DBMS_SCHEDULER.CREATE_JOB` procedure of the `DBMS_SCHEDULER` package to create a job, which is in a disabled state by default. A job becomes active and scheduled when it is explicitly enabled. To create a job, you:

- Provide a name in the format `[schema.]name`
- Need the `CREATE JOB` privilege

Note: A user with the `CREATE ANY JOB` privilege can create a job in any schema except the `SYS` schema. Associating a job with a particular class requires the `EXECUTE` privilege for that class.

In simple terms, a job can be created by specifying all the job details—the program to be executed (what) and its schedule (when)—in the arguments of the `CREATE_JOB` procedure. Alternatively, you can use predefined Program and Schedule components. If you have a named Program and Schedule, then these can be specified or combined with in-line arguments for maximum flexibility in the way a job is created.

A simple logical check is performed on the schedule information (that is, checking the date parameters when a job is created). The database checks whether the end date is after the start date. If the start date refers to a time in the past, then the start date is changed to the current date.

Creating a Job with In-Line Parameters

Specify the type of code, code, start time, and frequency of the job to be run in the arguments of the CREATE_JOB procedure.

Here is an example that schedules a PL/SQL block every hour:

```
BEGIN
  DBMS_SCHEDULER.CREATE_JOB(
   job_name => 'JOB_NAME',
   job_type => 'PLSQL_BLOCK',
   job_action => 'BEGIN ...; END;',
   start_date => SYSTIMESTAMP,
   repeat_interval=>'FREQUENCY=HOURLY;INTERVAL=1',
   enabled => TRUE);
END;
/
```


Creating a Job with In-Line Parameters

You can create a job to run a PL/SQL block, stored procedure, or external program by using the DBMS_SCHEDULER.CREATE_JOB procedure. The CREATE_JOB procedure can be used directly without requiring you to create Program or Schedule components.

The example in the slide shows how you can specify all the job details in-line. The parameters of the CREATE_JOB procedure define "what" is to be executed, the schedule, and other job attributes. The following parameters define what is to be executed:

- The job_type parameter can be one of three values:
  - PLSQL_BLOCK for any PL/SQL block or SQL statement. This type of job cannot accept arguments.
  - STORED_PROCEDURE for any stored stand-alone or packaged procedure. The procedures can accept arguments that are supplied with the job.
  - EXECUTABLE for an executable command-line operating system application
- The schedule is specified by using the following parameters:
  - The start_date accepts a time stamp, and the repeat_interval is string-specified as a calendar or PL/SQL expression. An end_date can be specified.

Note: String expressions that are specified for repeat_interval are discussed later. The example specifies that the job should run every hour.

Creating a Job Using a Program

- Use CREATE_PROGRAM to create a program:

```
BEGIN
  DBMS_SCHEDULER.CREATE_PROGRAM(
   program_name => 'PROG_NAME',
   program_type => 'PLSQL_BLOCK',
   program_action => 'BEGIN ...; END;');
END;
```

- Use overloaded CREATE_JOB procedure with its program_name parameter:

```
BEGIN
  DBMS_SCHEDULER.CREATE_JOB('JOB_NAME',
   program_name => 'PROG_NAME',
   start_date => SYSTIMESTAMP,
   repeat_interval => 'FREQ=DAILY',
   enabled => TRUE);
END;
```


Creating a Job Using a Program

The DBMS_SCHEDULER.CREATE_PROGRAM procedure defines a program that must be assigned a unique name. Creating the program separately for a job enables you to:

- Define the action once and then reuse this action within multiple jobs
- Change the schedule for a job without having to re-create the PL/SQL block
- Change the program executed without changing all the jobs

The program action string specifies a procedure, executable name, or PL/SQL block depending on the value of the program_type parameter, which can be:

- PLSQL_BLOCK to execute an anonymous block or SQL statement
- STORED_PROCEDURE to execute a stored procedure, such as PL/SQL, Java, or C
- EXECUTABLE to execute operating system command-line programs

The example shown in the slide demonstrates calling an anonymous PL/SQL block. You can also call an external procedure within a program, as in the following example:

```
DBMS_SCHEDULER.CREATE_PROGRAM(program_name =>
'GET_DATE',
    program_action => '/usr/local/bin/date',
    program_type => 'EXECUTABLE');
```

To create a job with a program, specify the program name in the program_name argument in the call to the DBMS_SCHEDULER.CREATE_JOB procedure, as shown in the slide.

Creating a Job for a Program with Arguments

- Create a program:

```
DBMS_SCHEDULER.CREATE_PROGRAM(
  program_name => 'PROG_NAME',
  program_type => 'STORED_PROCEDURE',
  program_action => 'EMP_REPORT');
```

- Define an argument:

```
DBMS_SCHEDULER.DEFINE_PROGRAM_ARGUMENT(
  program_name => 'PROG_NAME',
  argument_name => 'DEPT_ID',
  argument_position=> 1, argument_type=> 'NUMBER',
  default_value => '50');
```

- Create a job specifying the number of arguments:

```
DBMS_SCHEDULER.CREATE_JOB('JOB_NAME', program_name
  => 'PROG_NAME', start_date => SYSTIMESTAMP,
  repeat_interval => 'FREQ=DAILY',
  number_of_arguments => 1, enabled => TRUE);
```

ORACLE

Creating a Job for a Program with Arguments

Programs, such as PL/SQL or external procedures, may require input arguments. Using the `DBMS_SCHEDULER.DEFINE_PROGRAM_ARGUMENT` procedure, you can define an argument for an existing program. The `DEFINE_PROGRAM_ARGUMENT` procedure parameters include the following:

- The `program_name` specifies an existing program that is to be altered.
- The `argument_name` specifies a unique argument name for the program.
- The `argument_position` specifies the position in which the argument is passed when the program is called.
- The `argument_type` specifies the data type of the argument value that is passed to the called program.
- The `default_value` specifies a default value that is supplied to the program if the job that schedules the program does not provide a value.

The slide shows how to create a job executing a program with one argument. The program argument default value is 50. To change the program argument value for a job, use:

```
DBMS_SCHEDULER.SET_JOB_ARGUMENT_VALUE(
  job_name => 'JOB_NAME',
  argument_name => 'DEPT_ID', argument_value => '80');
```

Creating a Job Using a Schedule

- Use `CREATE_SCHEDULE` to create a schedule:

```
BEGIN
  DBMS_SCHEDULER.CREATE_SCHEDULE('SCHED_NAME',
   start_date => SYSTIMESTAMP,
   repeat_interval => 'FREQ=DAILY',
   end_date => SYSTIMESTAMP +15);
END;
```

- Use `CREATE_JOB` by referencing the schedule in the `schedule_name` parameter:

```
BEGIN
  DBMS_SCHEDULER.CREATE_JOB('JOB_NAME',
   schedule_name => 'SCHED_NAME',
   job_type => 'PLSQL_BLOCK',
   job_action => 'BEGIN ...; END;',
   enabled => TRUE);
END;
```


Creating a Job Using a Schedule

You can create a common schedule that can be applied to different jobs without having to specify the schedule details each time. The following are the benefits of creating a schedule:

- It is reusable and can be assigned to different jobs.
- Changing the schedule affects all jobs using the schedule. The job schedules are changed once, not multiple times.

A schedule is precise to only the nearest second. Although the `TIMESTAMP` data type is more accurate, the Scheduler rounds off anything with a higher precision to the nearest second.

The start and end times for a schedule are specified by using the `TIMESTAMP` data type. The `end_date` for a saved schedule is the date after which the schedule is no longer valid. The schedule in the example is valid for 15 days after using it with a specified job.

The `repeat_interval` for a saved schedule must be created by using a calendaring expression. A `NULL` value for `repeat_interval` specifies that the job runs only once.

Note: You cannot use PL/SQL expressions to express the repeat interval for a saved schedule.

Setting the Repeat Interval for a Job

- Using a calendaring expression:

```
repeat_interval=> 'FREQ=HOURLY; INTERVAL=4'
repeat_interval=> 'FREQ=DAILY'
repeat_interval=> 'FREQ=MINUTELY;INTERVAL=15'
repeat_interval=> 'FREQ=YEARLY;
                   BYMONTH=MAR,JUN,SEP,DEC;
                   BYMONTHDAY=15'
```

- Using a PL/SQL expression:

```
repeat_interval=> 'SYSDATE + 36/24'
repeat_interval=> 'SYSDATE + 1'
repeat_interval=> 'SYSDATE + 15/(24*60)'
```

ORACLE

Setting the Repeat Interval for a Job

When scheduling repeat intervals for a job, you can specify either a PL/SQL expression (if it is within a job argument) or a calendaring expression.

The examples in the slide include the following:

- `FREQ=HOURLY;INTERVAL=4` indicates a repeat interval of every four hours.
- `FREQ=DAILY` indicates a repeat interval of every day, at the same time as the start date of the schedule.
- `FREQ=MINUTELY;INTERVAL=15` indicates a repeat interval of every 15 minutes.
- `FREQ=YEARLY;BYMONTH=MAR,JUN,SEP,DEC;BYMONTHDAY=15` indicates a repeat interval of every year on March 15, June 15, September 15, and December 15.

With a calendaring expression, the next start time for a job is calculated using the repeat interval and the start date of the job.

Note: If no repeat interval is specified (that is, if a `NULL` value is provided in the argument), the job runs only once on the specified start date.

Creating a Job Using a Named Program and Schedule

- Create a named program called `PROG_NAME` by using the `CREATE_PROGRAM` procedure.
- Create a named schedule called `SCHED_NAME` by using the `CREATE_SCHEDULE` procedure.
- Create a job referencing the named program and schedule:

```
BEGIN
  DBMS_SCHEDULER.CREATE_JOB('JOB_NAME',
   program_name => 'PROG_NAME',
   schedule_name => 'SCHED_NAME',
   enabled => TRUE);
END;
/
```


Creating a Job Using a Named Program and Schedule

The example in the slide shows the final form for using the `DBMS_SCHEDULER.CREATE_JOB` procedure. In this example, the named program (`PROG_NAME`) and schedule (`SCHED_NAME`) are specified in their respective parameters in the call to the `DBMS_SCHEDULER.CREATE_JOB` procedure.

With this example, you can see how easy it is to create jobs by using a predefined program and schedule.

Some jobs and schedules can be too complex to cover in this course. For example, you can create windows for recurring time plans and associate a resource plan with a window. A resource plan defines attributes about the resources required during the period defined by execution window.

For more information, refer to the Online Course titled *Oracle Database 10g: Configure and Manage Jobs with the Scheduler*.

Managing Jobs

- Run a job:

```
DBMS_SCHEDULER.RUN_JOB('SCHEMA.JOB_NAME');
```

- Stop a job:

```
DBMS_SCHEDULER.STOP_JOB('SCHEMA.JOB_NAME');
```

- Drop a job even if it is currently running:

```
DBMS_SCHEDULER.DROP_JOB('JOB_NAME', TRUE);
```


Managing Jobs

After a job has been created, you can:

- Run the job by calling the RUN_JOB procedure specifying the name of the job. The job is immediately executed in your current session.
- Stop the job by using the STOP_JOB procedure. If the job is running currently, it is stopped immediately. The STOP_JOB procedure has two arguments:
  - **job_name:** Is the name of the job to be stopped
  - **force:** Attempts to gracefully terminate a job. If this fails and force is set to TRUE, then the job slave is terminated. (Default value is FALSE.) To use force, you must have the MANAGE SCHEDULER system privilege.
- Drop the job with the DROP_JOB procedure. This procedure has two arguments:
  - **job_name:** Is the name of the job to be dropped
  - **force:** Indicates whether the job should be stopped and dropped if it is currently running (Default value is FALSE.)

  If the DROP_JOB procedure is called and the job specified is currently running, then the command fails unless the force option is set to TRUE. If the force option is set to TRUE, then any instance of the job that is running is stopped and the job is dropped.

Note: To run, stop, or drop a job that belongs to another user, you need ALTER privileges on that job or the CREATE ANY JOB system privilege.

Data Dictionary Views

- [DBA | ALL | USER]_SCHEDULER_JOBS
- [DBA | ALL | USER]_SCHEDULER_RUNNING_JOBS
- [DBA | ALL]_SCHEDULER_JOB_CLASSES
- [DBA | ALL | USER]_SCHEDULER_JOB_LOG
- [DBA | ALL | USER]_SCHEDULER_JOB_RUN_DETAILS
- [DBA | ALL | USER]_SCHEDULER_PROGRAMS

Data Dictionary Views

The DBA_SCHEDULER_JOB_LOG view shows all completed job instances, both successful and failed.

To view the state of your jobs, use the following query:

```
SELECT job_name, program_name, job_type, state
FROM USER_SCHEDULER_JOBS;
```

To determine which instance a job is running on, use the following query:

```
SELECT owner, job_name, running_instance,
resource_consumer_group
FROM DBA_SCHEDULER_RUNNING_JOBS;
```

To determine information about how a job ran, use the following query:

```
SELECT job_name, instance_id, req_start_date,
actual_start_date, status
FROM ALL_SCHEDULER_JOB_RUN_DETAILS;
```

To determine the status of your jobs, use the following query:

```
SELECT job_name, status, error#, run_duration, cpu_used
FROM USER_SCHEDULER_JOB_RUN_DETAILS;
```

Summary

In this lesson, you should have learned how to:

- Use various preinstalled packages that are provided by the Oracle server
- Use the following packages:
  - DBMS_OUTPUT to buffer and display text
  - UTL_FILE to write operating system text files
  - HTP to generate HTML documents
  - UTL_MAIL to send messages with attachments
  - DBMS_SCHEDULER to automate processing
- Create packages individually or by using the catproc.sql script

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 *i*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, generate HTML reports with the HTP package, send e-mail with or without binary or text attachments by using the UTL_MAIL package, and schedule PL/SQL and external code for execution with the DBMS_SCHEDULER package.

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

Practice 5: Overview

This practice covers the following topics:

- Using `UTL_FILE` to generate a text report
- Using `HTP` to generate a Web page report
- Using `DBMS_SCHEDULER` to automate report processing

Practice 5: Overview

In this practice, you use `UTL_FILE` to generate a text file report of employees in each department. You create a procedure to generate an HTML version of the employee report, and write a SQL script file to spool the results to a text file. You use the `DBMS_SCHEDULER` to run the first report that creates a text file every five minutes.

Practice 5

1. Create a procedure called EMPLOYEE_REPORT that generates an employee report in a file in the operating system, using the UTL_FILE package. 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. Invoke the program, using the second parameter with a name such as sal_rpt*xx*.txt, where *xx* represents your user number (for example, 01, 15, and so on). The following is a sample output from the report file:

```
Employees who earn more than average salary:
REPORT GENERATED ON 27-FEB-09
Hartstein                     20      $13,000.00
Raphaely                      30      $11,000.00
Marvis                        40      $6,500.00
      ...
      *** END OF REPORT ***
```

   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.

2. Create a new procedure called WEB_EMPLOYEE_REPORT that generates the same data as the EMPLOYEE_REPORT.
   a. First, execute SET SERVEROUTPUT ON, and then execute htp.print('hello') followed by executing OWA_UTIL.SHOWPAGE. The exception messages generated can be ignored.
   b. Write the WEB_EMPLOYEE_REPORT procedure by using the HTP package to generate an HTML report of employees with a salary greater than the average for their departments. If you know HTML, create an HTML table; otherwise, create simple lines of data.
   Hint: Copy the cursor definition and the FOR loop from the EMPLOYEE_REPORT procedure for the basic structure for your Web report.
   c. Execute the procedure using *i*SQL*Plus to generate the HTML data into a server buffer, and execute the OWA_UTIL.SHOWPAGE procedure to display contents of the buffer. Remember that SERVEROUTPUT should be ON before you execute the code.
   d. Create an HTML file called web_employee_report.htm containing the output result text that you select and copy from the opening <HTML> tag to the closing </HTML> tag. Paste the copied text into the file and save it to disk. Double-click the file to display the results in your default browser.

3. Your boss wants to run the employee report frequently. You create a procedure that uses the DBMS_SCHEDULER package to schedule the EMPLOYEE_REPORT procedure for execution. You should use parameters to specify a frequency, and an optional argument to specify the number of minutes after which the scheduled job should be terminated.

   a. Create a procedure called SCHEDULE_REPORT that provides the following two parameters:
   - interval: To specify a string indicating the frequency of the scheduled job
   - minutes: To specify the total life in minutes (default of 10) for the scheduled job, after which it is terminated. The code divides the duration by the quantity (24 × 60) when it is added to the current date and time to specify the termination time.

   When the procedure creates a job, with the name of EMPSAL_REPORT by calling DBMS_SCHEDULER.CREATE_JOB, the job should be enabled and scheduled for the PL/SQL block to start immediately. You must schedule an anonymous block to invoke the EMPLOYEE_REPORT procedure so that the file name can be updated with a new time, each time the report is executed. The EMPLOYEE_REPORT is given the directory name supplied by your instructor for task 1, and the file name parameter is specified in the following format: sal_rptxx_hh24-mi-ss.txt, where xx is your assigned user number and hh24-mi-ss represents the hours, minutes, and seconds.

   Use the following local PL/SQL variable to construct a PL/SQL block:

```
plsql_block VARCHAR2(200) :=
'BEGIN'||
' EMPLOYEE_REPORT(''UTL_FILE'','||
'''sal_rptXX_''||to_char(sysdate,''HH24-MI-
SS'')||''.txt'');'||
'END;';
```

   This code is provided to help you because it is a nontrivial PL/SQL string to construct. In the PL/SQL block, **XX** is your student number.

   b. Test the SCHEDULE_REPORT procedure by executing it with a parameter specifying a frequency of every two minutes and a termination time 10 minutes after it starts.
   Note: You must connect to the database server by using PSFTP to check whether your files are created.

   c. During and after the process, you can query the job_name and enabled columns from the USER_SCHEDULER_JOBS table to check whether the job still exists.
   Note: This query should return no rows after 10 minutes have elapsed.

6

Dynamic SQL and Metadata

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 (that is, with `EXECUTE IMMEDIATE` statements)
- Describe the `DBMS_SQL` package
- Compare Native Dynamic SQL with the `DBMS_SQL` package approach

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. You compare Native Dynamic SQL to the `DBMS_SQL` package, which provides similar capabilities.

You learn how to use the `DBMS_METADATA` package to retrieve metadata from the database dictionary as Extensible Markup Language (XML) or creation DDL and to submit the XML to re-create the object.

Execution Flow of SQL

- All SQL statements go through various stages:
  - Parse
  - Bind
  - Execute
  - Fetch
- Some stages may not be relevant for all statements—for example, the fetch phase is applicable to queries.

Note: For embedded SQL statements (`SELECT`, DML, `COMMIT`, and `ROLLBACK`), the parse and bind phases are done at compile time. For dynamic SQL statements, all phases are performed at run time.

ORACLE

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 nonquery 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.

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 within the application
- Is a SQL statement with varying column data, or different conditions with or without placeholders (bind variables)
- Enables data-definition, data-control, or session-control statements to be written and executed from PL/SQL
- Is executed with Native Dynamic SQL statements or the `DBMS_SQL` package

ORACLE

Dynamic SQL

The embedded SQL statements available in PL/SQL are limited to `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `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`).

Native Dynamic SQL

- 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
- Is supported by the following PL/SQL statements:
  - `EXECUTE IMMEDIATE`
  - `OPEN-FOR`
  - `FETCH`
  - `CLOSE`

ORACLE

Native Dynamic SQL

In Oracle 8 and earlier releases, the only way to implement dynamic SQL in a PL/SQL application was by using the `DBMS_SQL` package. With Oracle 8*i* and later releases, the PL/SQL environment provides Native Dynamic SQL as an alternative.

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.
- Bind instances of any SQL data types supported in PL/SQL.
- 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 Native Dynamic SQL 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, if not specified.

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).

Dynamic SQL with a DDL Statement

- Create a table:

```
CREATE PROCEDURE create_table(
  table_name VARCHAR2, col_specs  VARCHAR2) IS
BEGIN
  EXECUTE IMMEDIATE 'CREATE TABLE '||table_name||
                    ' (' || col_specs || ')';
END;
/
```

- Call example:

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


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 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 PROCEDURE add_col(table_name VARCHAR2,
                         col_spec VARCHAR2) IS
  stmt VARCHAR2(100) := 'ALTER TABLE ' || table_name ||
                        ' ADD '||col_spec;
BEGIN
  EXECUTE IMMEDIATE 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(table_name VARCHAR2)
RETURN NUMBER IS
BEGIN
  EXECUTE IMMEDIATE 'DELETE FROM '||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(table_name VARCHAR2,
   id NUMBER, name VARCHAR2) IS
BEGIN
  EXECUTE IMMEDIATE 'INSERT INTO '||table_name||
        ' VALUES (:1, :2)' USING id, name;
END;
```


Dynamic SQL with DML Statements

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, but the order of the variable names (`id` and `name`) in the `USING` clause is associated to the bind variables by position, in the order of their respective appearance. Therefore, the PL/SQL variable `id` is assigned to the `:1` placeholder, and the `name` variable is assigned to the `:2` placeholder. Placeholder/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 of a single-row query:

```
CREATE FUNCTION get_emp(emp_id NUMBER)
RETURN employees%ROWTYPE IS
  stmt VARCHAR2(200);
  emprec employees%ROWTYPE;
BEGIN
  stmt := 'SELECT * FROM employees ' ||
          'WHERE employee_id = :id';
  EXECUTE IMMEDIATE stmt INTO emprec USING emp_id;
  RETURN emprec;
END;
/
```

```
DECLARE
  emprec employees%ROWTYPE := get_emp(100);
BEGIN
  DBMS_OUTPUT.PUT_LINE('Emp: '||emprec.last_name);
END;
/
```


Dynamic SQL with a Single-Row Query

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

Use OPEN-FOR, FETCH, and CLOSE processing:

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


Dynamic SQL with a Multirow Query

The example in the slide 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 a cursor type as REF CURSOR:

```
CREATE PROCEDURE process_data IS
  TYPE ref_ctype IS REF CURSOR; -- weak ref cursor
  TYPE emp_ref_ctype IS REF CURSOR -- strong
     RETURN employees%ROWTYPE;
  :
```

- Declare a cursor variable using the cursor type:

```
  :
  dept_csrvar ref_ctype;
  emp_csrvar  emp_ref_ctype;
BEGIN
  OPEN emp_csrvar FOR SELECT * FROM employees;
  OPEN dept_csrvar FOR SELECT * from departments;
  -- Then use as normal cursors
END;
```

ORACLE

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 ref_ctype is a generic reference cursor, known as a weak reference cursor. A weak reference cursor can be associated with any query.
- The emp_ref_ctype is a strong reference cursor type that must be associated with a type-compatible query: the query must return data that is compatible with the type specified after the RETURN keyword (for example, an EMPLOYEES row type).

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

Dynamically Executing a PL/SQL Block

Execute a PL/SQL anonymous block dynamically:

```
CREATE FUNCTION annual_sal(emp_id NUMBER)
RETURN NUMBER IS
  plsql varchar2(200) :=
    'DECLARE '||
    ' emprec employees%ROWTYPE; '||
    'BEGIN '||
    ' emprec := get_emp(:empid); ' ||
    ' :res := emprec.salary * 12; ' ||
    'END;';
  result NUMBER;
BEGIN
 EXECUTE IMMEDIATE plsql
         USING IN emp_id, OUT result;
  RETURN result;
END;
/
```

```
EXECUTE DBMS_OUTPUT.PUT_LINE(annual_sal(100))
```


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.

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(name VARCHAR2,
 plsql_type VARCHAR2, options VARCHAR2 := NULL) IS
  stmt varchar2(200) := 'ALTER '|| plsql_type ||
                        ' '|| name || ' COMPILE';
BEGIN
 IF options IS NOT NULL THEN
   stmt := stmt || ' ' || options;
 END IF;
 EXECUTE IMMEDIATE stmt;
END;
/
```


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')
```

Using the DBMS_SQL Package

The DBMS_SQL package is used to write dynamic SQL in stored procedures and to parse DDL statements. Some of the procedures and functions of the package include:

- OPEN_CURSOR
- PARSE
- BIND_VARIABLE
- EXECUTE
- FETCH_ROWS
- CLOSE_CURSOR

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. 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—that is, it checks the statement syntax and associates it with the opened cursor. 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 DBMS_SQL with a DML Statement

```
CREATE OR REPLACE FUNCTION delete_all_rows
  (table_name VARCHAR2) RETURN NUMBER IS
  csr_id INTEGER;
  rows_del    NUMBER;
BEGIN
  csr_id := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(csr_id,
    'DELETE FROM '||table_name, DBMS_SQL.NATIVE);
  rows_del := DBMS_SQL.EXECUTE (csr_id);
  DBMS_SQL.CLOSE_CURSOR(csr_id);
  RETURN rows_del;
END;
/
```

```
CREATE table temp_emp as select * from employees;
BEGIN
 DBMS_OUTPUT.PUT_LINE('Rows Deleted: ' ||
delete_all_rows('temp_emp'));
END;
/
```

ORACLE

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.

Using DBMS_SQL with a Parameterized DML Statement

```
CREATE PROCEDURE insert_row (table_name VARCHAR2,
 id VARCHAR2, name VARCHAR2, region NUMBER) IS
  csr_id     INTEGER;
  stmt       VARCHAR2(200);
  rows_added NUMBER;
BEGIN
  stmt := 'INSERT INTO '||table_name||
          ' VALUES (:cid, :cname, :rid)';
  csr_id := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(csr_id, stmt, DBMS_SQL.NATIVE);
  DBMS_SQL.BIND_VARIABLE(csr_id, ':cid', id);
  DBMS_SQL.BIND_VARIABLE(csr_id, ':cname', name);
  DBMS_SQL.BIND_VARIABLE(csr_id, ':rid', region);
  rows_added := DBMS_SQL.EXECUTE(csr_id);
  DBMS_SQL.CLOSE_CURSOR(csr_id);
  DBMS_OUTPUT.PUT_LINE(rows_added||' row added');
END;
/
```


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', 'ZA', 'South Africa', 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.

Advantages of Native Dynamic SQL over `DBMS_SQL` Package

Native Dynamic SQL:

- Is easier to use than `DBMS_SQL`
- Requires less code than `DBMS_SQL`
- Enhances performance because the PL/SQL interpreter provides native support for it
- Supports all types supported by static SQL in PL/SQL, including user-defined types
- Can fetch rows directly into PL/SQL records

Comparison of Native Dynamic SQL and the `DBMS_SQL` Package

Native Dynamic SQL provides the following advantages over the `DBMS_SQL` package.

Ease of use: Because Native Dynamic SQL is integrated with SQL, you can use it in the same way that you currently use static SQL within PL/SQL code. The code is typically more compact and readable compared with the code written with the `DBMS_SQL` package.

Performance improvement: Native Dynamic SQL performs significantly better than `DBMS_SQL`, in most circumstances, due to native support provided by the PL/SQL interpreter. The `DBMS_SQL` approach uses a procedural API and suffers from high procedure call and data copy overhead.

Support for user-defined types: Native Dynamic SQL supports all the types supported by static SQL in PL/SQL. Therefore, Native Dynamic SQL provides support for user-defined types such as user-defined objects, collections, and REFs. The `DBMS_SQL` package does not support these user-defined types. However, it has limited support for arrays.

Support for fetching into records: With Native Dynamic SQL, the rows resulting from a query can be directly fetched into PL/SQL records. The `DBMS_SQL` package does not support fetching into records structures.

Summary

In this lesson, you should have learned how to:

- Explain the execution flow of SQL statements
- Create SQL statements dynamically and execute them using either Native Dynamic SQL statements or the `DBMS_SQL` package
- Recognize the advantages of using Native Dynamic SQL compared to the `DBMS_SQL` package

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.

The lesson explored some differences and compared using Native Dynamic SQL to the `DBMS_SQL` package. If you are using Oracle8*i* or later releases, you should use Native Dynamic SQL for new projects.

The lesson also discussed using the `DBMS_METADATA` package to retrieve metadata from the database dictionary with results presented in XML or creational DDL format. The resulting XML data can be used for re-creating the object.

Practice 6: Overview

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

Practice 6: 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 6

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.
   a. Create a package specification with the following procedures:
      ```
      PROCEDURE make(table_name VARCHAR2, col_specs VARCHAR2)
      PROCEDURE add_row(table_name VARCHAR2, col_values
      VARCHAR2,
        cols VARCHAR2 := NULL)
      PROCEDURE upd_row(table_name VARCHAR2, set_values
      VARCHAR2,
        conditions VARCHAR2 := NULL)
      PROCEDURE del_row(table_name VARCHAR2,
       conditions VARCHAR2 := NULL);
      PROCEDURE remove(table_name VARCHAR2)
      ```
      Ensure that subprograms manage optional default parameters with NULL values.
   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 that should be written using the DBMS_SQL package.
   c. Execute the package MAKE 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,''Geoff Gallus''','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.
   g. Execute the DEL_ROW package procedure to delete a contact with ID value 1.
   h. Execute the UPD_ROW procedure with the following row data:
      ```
      upd_row('my_contacts','name=''Nancy Greenberg''','id=2');
      ```
   i. Select the data from the MY_CONTACTS table again to view the changes.
   j. Drop the table by using the remove procedure and describe the MY_CONTACTS table.
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 body, the MAKE procedure should call a private function named GET_TYPE to determine the PL/SQL object type from the data dictionary, and return the type name (use PACKAGE for a package with a body) if the object exists; otherwise, it should return a NULL. If the object exists, MAKE dynamically compiles it with the ALTER statement.
   c. Use the COMPILE_PKG.MAKE procedure to compile the EMPLOYEE_REPORT procedure, the EMP_PKG package, and a nonexistent object called EMP_DATA.

Design Considerations for PL/SQL Code

Objectives

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

- Use package specifications to create standard constants and exceptions
- Write and call local subprograms
- Track run time errors
- Pass parameters by reference using a `NOCOPY` hint

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. This lesson also covers some performance considerations that can be applied to PL/SQL applications, such as the `NOCOPY` hints.

Standardizing Constants and Exceptions

Constants and exceptions are typically implemented using a bodiless package (that is, in 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

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 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;
```


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;
/
```

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
  fk_err        EXCEPTION;
  seq_nbr_err   EXCEPTION;
  PRAGMA EXCEPTION_INIT (fk_err, -2292);
  PRAGMA EXCEPTION_INIT (seq_nbr_err, -2277);
  ...
END error_pkg;
/
```


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.fk_err THEN
  ...
  WHEN OTHERS THEN
  ...
END;
/
```

Local Subprograms

- A local subprogram is a PROCEDURE or FUNCTION defined in the declarative section.

```
CREATE PROCEDURE employee_sal(id NUMBER) IS
   emp employees%ROWTYPE;
   FUNCTION tax(salary VARCHAR2) RETURN NUMBER IS
   BEGIN
     RETURN salary * 0.825;
   END tax;
BEGIN
   SELECT * INTO emp
   FROM EMPLOYEES WHERE employee_id = id;
   DBMS_OUTPUT.PUT_LINE('Tax: '||tax(emp.salary));
END;
```

- The local subprogram must be defined at the end of the declarative section.

ORACLE

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.

Track Run-time Errors with Exceptions

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

ORACLE

Track Run-time Errors with an exception handling package

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.

Using the NOCOPY Hint

The NOCOPY hint:

- Is a request to 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 emptabtype IS TABLE OF employees%ROWTYPE;
  emp_tab emptabtype;
  PROCEDURE populate(tab IN OUT NOCOPY emptabtype)
  IS BEGIN ... END;
BEGIN
  populate(emp_tab);
END;
/
```


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 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.

ORACLE

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, 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.

NOCOPY Hint Can Be Ignored

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

NOCOPY Hint Can Be Ignored

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.

Summary

In this lesson, you should have learned how to:

- Create standardized constants and exceptions using packages
- Develop and invoke local subprograms
- Track run time errors using exception packages
- Pass parameters by reference using a `NOCOPY` hint

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.

You should understand how to obtain performance gains by using the `NOCOPY` hint, bulk binding and the `RETURNING` clauses in SQL statements.

Practice 7: 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
- Testing `AUTHID` functionality

Practice 7: 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.

Finally, you make the package use `AUTHID` of `CURRENT_USER` and test the behavior with any other student. You test the code first with definer's rights and then with invoker's rights.

Practice 7

1. Update EMP_PKG with a new procedure to query employees in a specified department.
   a. In the specification, declare a get_employees procedure, with its parameter called dept_id based on the employees.department_id column type. Define an index-by PL/SQL type as a TABLE OF EMPLOYEES%ROWTYPE.
   b. In the body of the package, define a private variable called emp_table based on the type defined in the specification to hold employee records. 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 and displays the contents of the private PL/SQL table variable (if any data exists).
   Hint: Use the print_employee procedure.
   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 E:\labs\PLPU\labs\lab_07_02_a.sql script to create a log table called LOG_NEWEMP, and a sequence called log_newemp_seq.
   b. In the package body, modify the add_employee procedure, which performs the actual INSERT operation, to have a local procedure called audit_newemp. The audit_newemp procedure must use an autonomous transaction to insert a log record into the LOG_NEWEMP table. Store the USER, the current time, and the new employee name in the log table row. Use log_newemp_seq to set the entry_id column.
   Note: Remember to perform a COMMIT operation in a procedure with an autonomous transaction.
   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 Exercise 2e: the first to check whether the employee rows for Smart and Kent have been removed, and the second to check the log records in the LOG_NEWEMP table. How many log records are present? Why?

Practice 7 (continued)

If you have time, complete the following exercise:

3. Modify the EMP_PKG package to use AUTHID of CURRENT_USER and test the behavior with any other student.
   Note: Verify whether the LOG_NEWEMP table exists from Exercise 2 in this practice.
   a. Grant the EXECUTE privilege on your EMP_PKG package to another student.
   b. Ask the other student to invoke your add_employee procedure to insert employee Jaco Pastorius in department 10. Remember to prefix the package name with the owner of the package. The call should operate with definer's rights.
   c. Now, execute a query of the employees in department 10. In which user's employee table did the new record get inserted?
   d. Modify your package EMP_PKG specification to use an AUTHID CURRENT_USER. Compile the body of EMP_PKG.
   e. Ask the same student to execute the add_employee procedure again, to add employee Joe Zawinal in department 10.
   f. Query your employees in department 10. In which table was the new employee added?
   g. Write a query to display the records added in the LOG_NEWEMP tables. Ask the other student to query his or her own copy of the table.

8

Managing Dependencies

Objectives

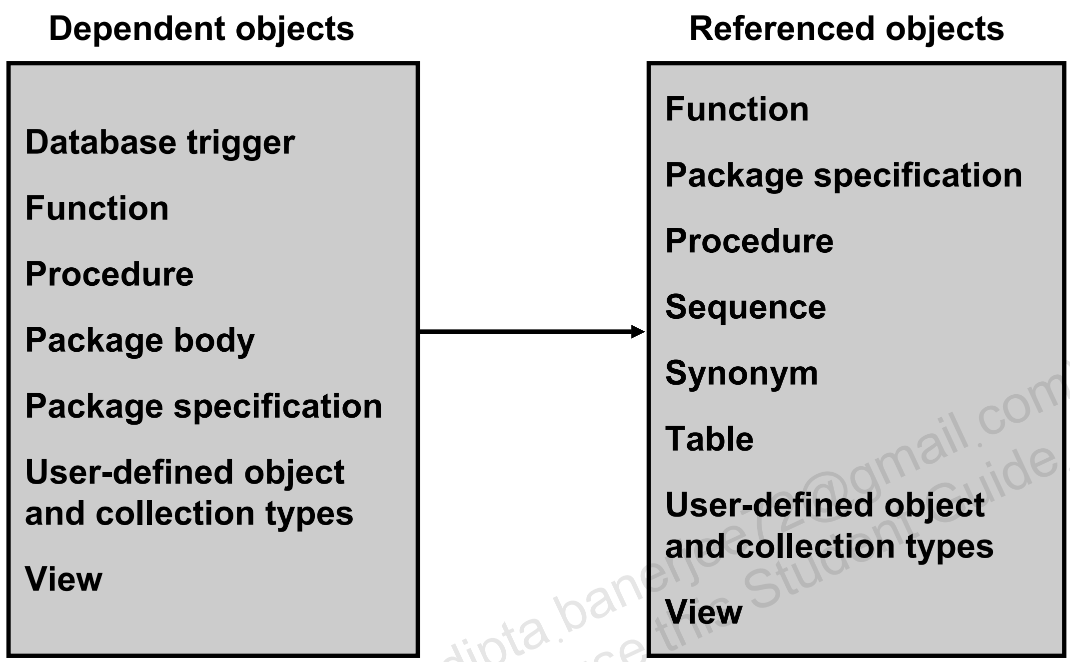
After completing this lesson, you should be able to do the following:

- Track procedural dependencies
- Predict the effect of changing a database object on stored procedures and functions
- Manage procedural dependencies

Lesson Aim

This lesson introduces you to object dependencies and implicit and explicit recompilation of invalid objects.

Understanding Dependencies



Dependent and Referenced Objects

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

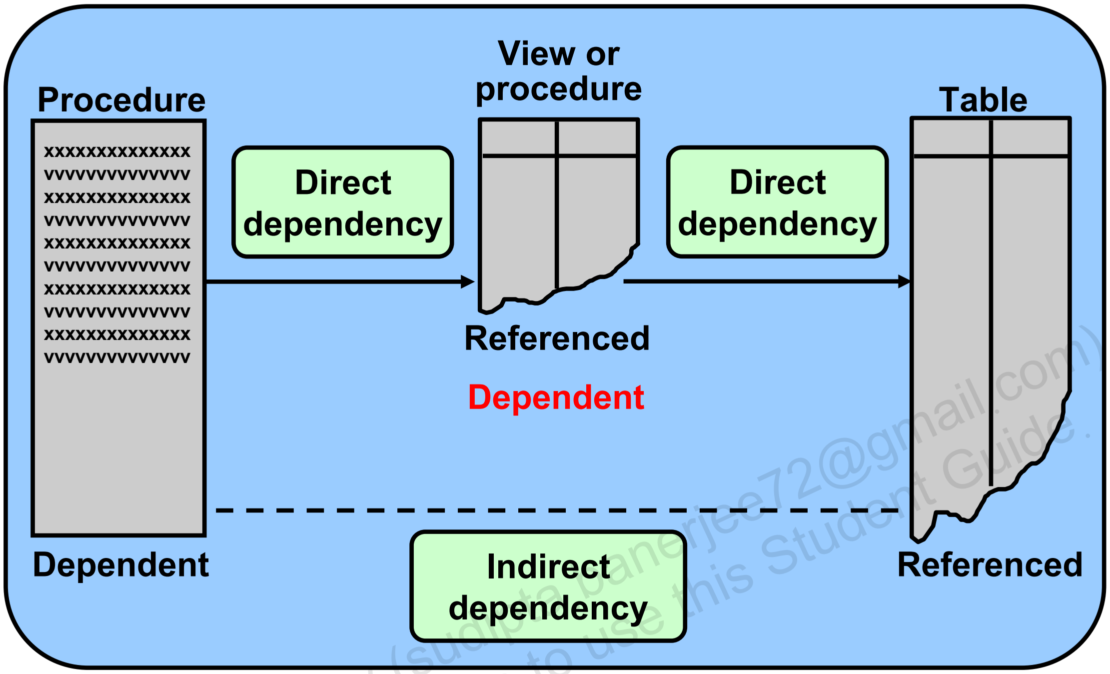
Dependency Issues

If you alter the definition of a referenced object, dependent objects may or may not continue to work properly. For example, if the table definition is changed, 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.

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

Dependencies

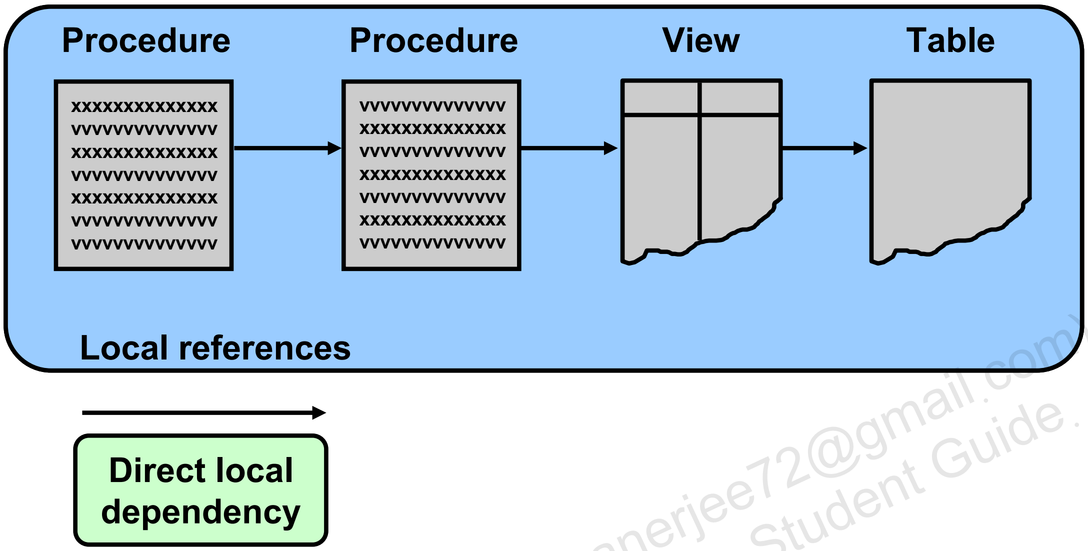


Dependent and Referenced Objects (continued)

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

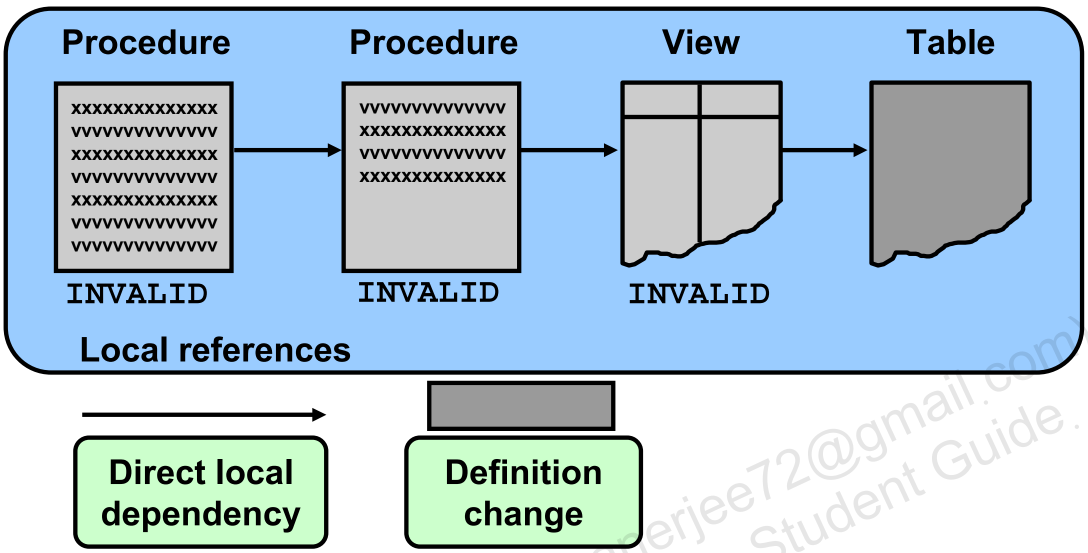
Local Dependencies



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 invalidated. The next time an invalidated object is called, the Oracle server automatically recompiles it.

Local Dependencies

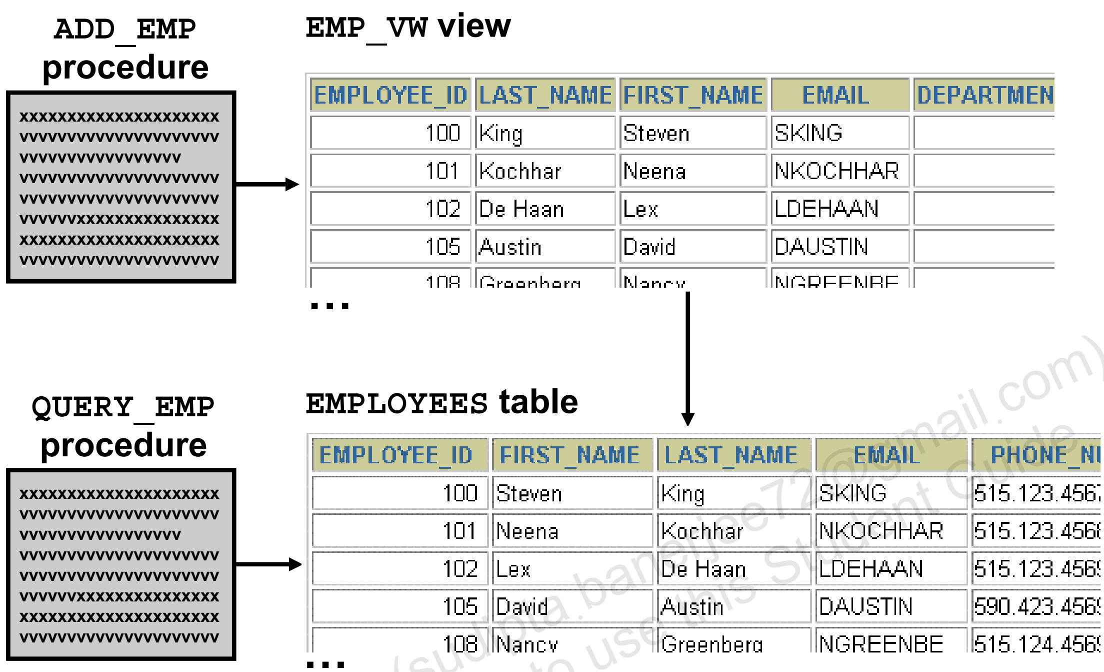


The Oracle server implicitly recompiles any `INVALID` object when the object is next called.

Managing Local Dependencies (continued)

Assume that the structure of the table on which a view is based is modified. When you describe the view by using the *i*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.

A Scenario of Local Dependencies



EMPLOYEE_ID	LAST_NAME	FIRST_NAME	EMAIL	DEPARTMEN
100	King	Steven	SKING	
101	Kochhar	Neena	NKOCHHAR	
102	De Haan	Lex	LDEHAAN	
105	Austin	David	DAUSTIN	
108	Greenberg	Nancy	NGREENBE	

EMPLOYEE_ID	FIRST_NAME	LAST_NAME	EMAIL	PHONE_NU
100	Steven	King	SKING	515.123.4567
101	Neena	Kochhar	NKOCHHAR	515.123.4568
102	Lex	De Haan	LDEHAAN	515.123.4569
105	David	Austin	DAUSTIN	590.423.4569
108	Nancy	Greenberg	NGREENBE	515.124.4569

ORACLE

Example

The QUERY_EMP procedure directly references the EMPLOYEES table. The ADD_EMP procedure updates the EMPLOYEES table indirectly by using the EMP_VW view.

In each of the following cases, is the ADD_EMP procedure invalidated and does it successfully recompile?

1. The internal logic of the QUERY_EMP procedure is modified.
2. A new column is added to the EMPLOYEES table.
3. The EMP_VW view is dropped.

Displaying Direct Dependencies by Using USER_DEPENDENCIES

```
SELECT name, type, referenced_name, referenced_type
FROM   user_dependencies
WHERE  referenced_name IN ('EMPLOYEES','EMP_VW' );
```

NAME	TYPE	REFERENCED_NAME	REFERENCED_T
EMP_DETAILS_VIEW	VIEW	EMPLOYEES	TABLE
...			
EMP_VW	VIEW	EMPLOYEES	TABLE
...			
QUERY_EMP	PROCEDURE	EMPLOYEES	TABLE
ADD_EMP	PROCEDURE	EMP_VW	VIEW

Displaying Direct Dependencies by Using USER_DEPENDENCIES

Determine which database objects to recompile manually by displaying direct dependencies from the USER_DEPENDENCIES data dictionary view.

Examine the ALL_DEPENDENCIES and DBA_DEPENDENCIES views, each of which contains the additional column OWNER, which references the owner of the object.

Column	Column Description
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

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.
2. Execute the `DEPTREE_FILL` procedure.

```
EXECUTE deptree_fill('TABLE','SCOTT','EMPLOYEES')
```


Displaying Direct and Indirect Dependencies by Using Views Provided by Oracle

Display direct and indirect dependencies from additional user views called DEPTREE and IDEPTREE; 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. (This script is supplied in the `lab` folder of your class files.)
2. Populate the `DEPTREE_TEMPTAB` table with information for a particular referenced object by invoking the `DEPTREE_FILL` procedure. There are three parameters for this procedure:

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

Displaying Dependencies

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	CHECK_SALARY
1	VIEW	EMP_VW
2	PROCEDURE	ADD_EMP
1	PACKAGE	MGR_CONSTRAINTS_PKG
2	TRIGGER	CHECK_PRES_TITLE
...		

Displaying Dependencies

Example

Display a tabular representation of all dependent objects by querying the DEPTREE view.

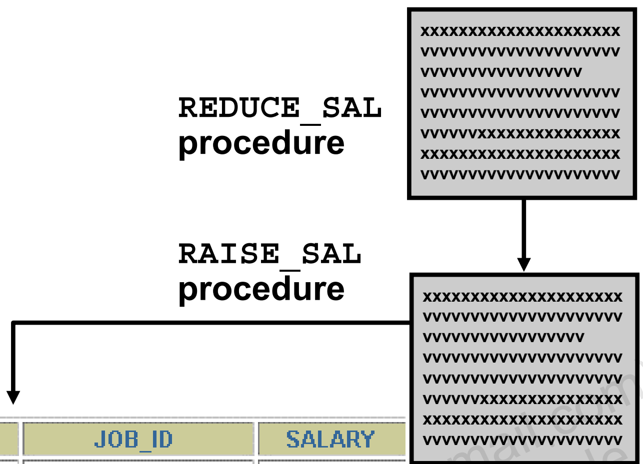
Display an indented representation of the same information by querying the IDEPTREE view, which consists of a single column named DEPENDENCIES.

For example,

```
SELECT *
FROM   ideptree;
```

provides a single column of indented output of the dependencies in a hierarchical structure.

Another Scenario of Local Dependencies



EMPLOYEES table

EMPLOYEE_ID	LAST_NAME	JOB_ID	SALARY
100	King	AD_PRES	24000
101	Kochhar	AD_VP	17000
102	De Haan	AD_VP	17000
103	Hunold	IT_PROG	9000
104	Ernst	IT_PROG	6000

...

ORACLE

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.

Suppose 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.

A Scenario of Local Naming Dependencies

QUERY_EMP procedure

EMPLOYEES public synonym

EMPLOYEE_ID	LAST_NAME	JOB_ID	SALARY
100	King	AD_PRES	24000
101	Kochhar	AD_VP	17000
102	De Haan	AD_VP	17000
103	Hunold	IT_PROG	9000
104	Ernst	IT_PROG	6000

...

EMPLOYEES table

EMPLOYEE_ID	LAST_NAME	JOB_ID	SALARY
100	King	AD_PRES	24000
101	Kochhar	AD_VP	17000
102	De Haan	AD_VP	17000
103	Hunold	IT_PROG	9000
104	Ernst	IT_PROG	6000

...

A Scenario of Local Naming Dependencies

Example 2

Be aware of the subtle case in which the creation of a table, view, or synonym may unexpectedly invalidate a dependent object because it interferes with the Oracle server hierarchy for resolving name references.

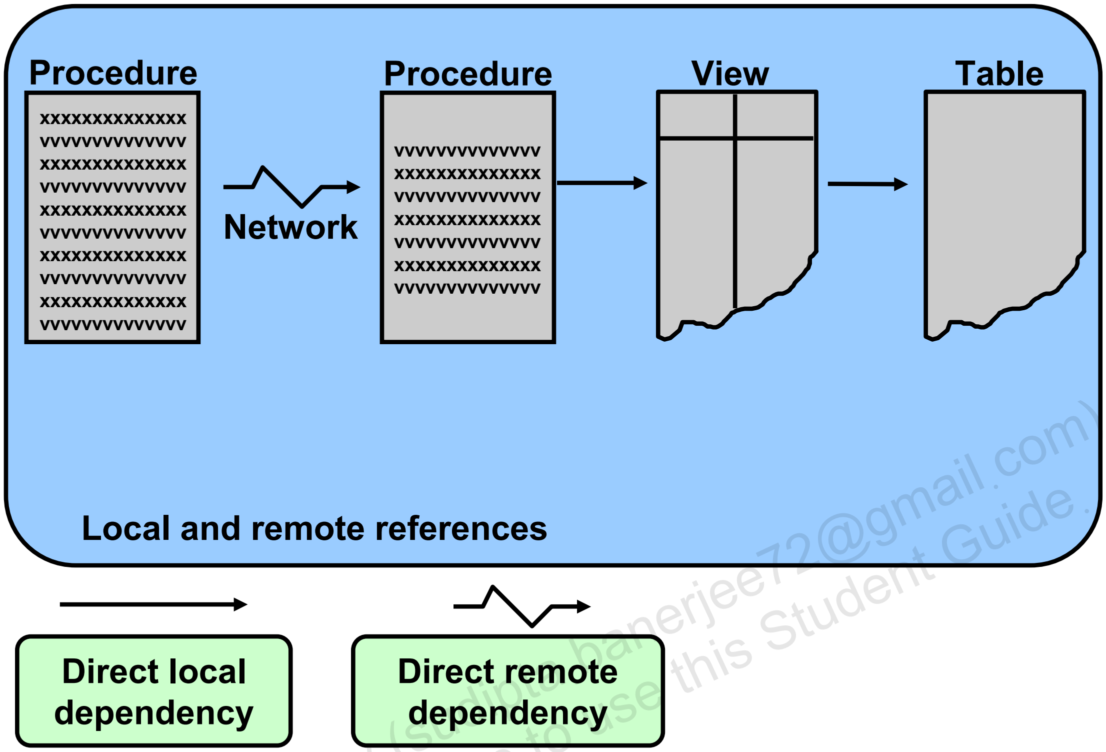
Predict the effect that the name of a new object has upon a dependent procedure.

Suppose that your QUERY_EMP procedure originally referenced a public synonym called EMPLOYEES. However, you have just created a new table called EMPLOYEES within your own schema. Does this change invalidate the procedure? Which of the two EMPLOYEES objects does QUERY_EMP reference when the procedure recompiles?

Now suppose that you drop your private EMPLOYEES table. Does this invalidate the procedure? What happens when the procedure recompiles?

You can track security dependencies in the USER_TAB_PRIVS data dictionary view.

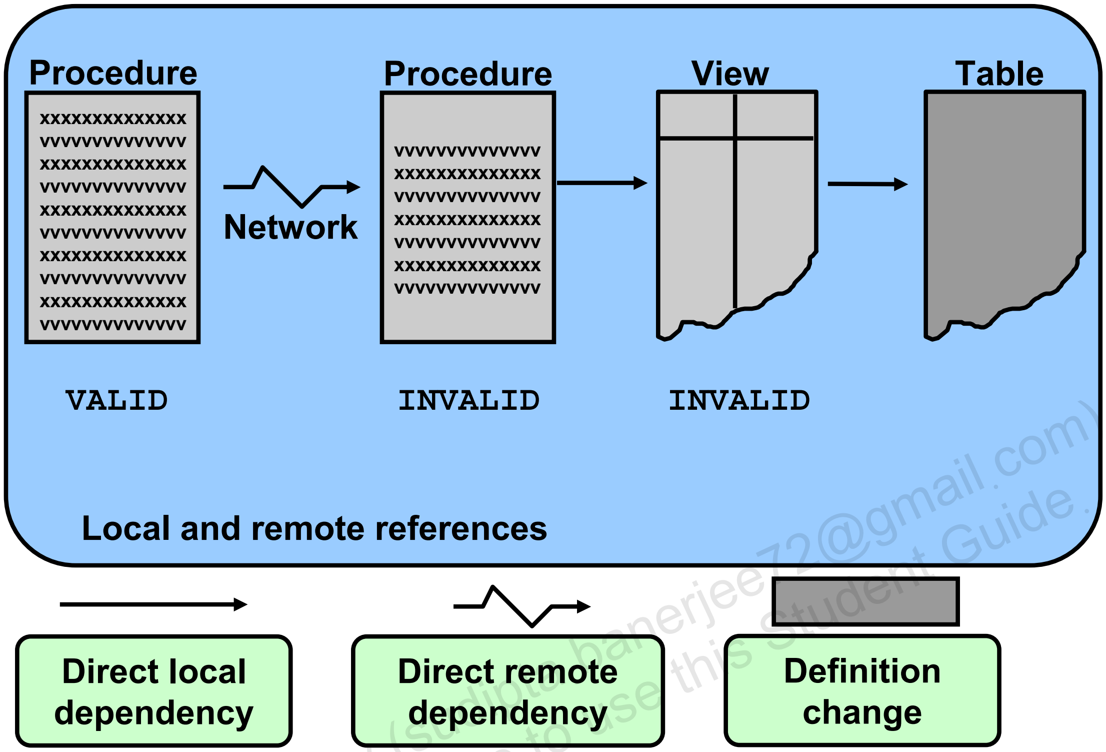
Understanding Remote Dependencies



Understanding 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.

Understanding Remote Dependencies



Understanding Remote Dependencies (continued)

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

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.

REMOTE_DEPENDENCIES_MODE Parameter

Setting REMOTE_DEPENDENCIES_MODE:

- 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

REMOTE_DEPENDENCIES_MODE Parameter

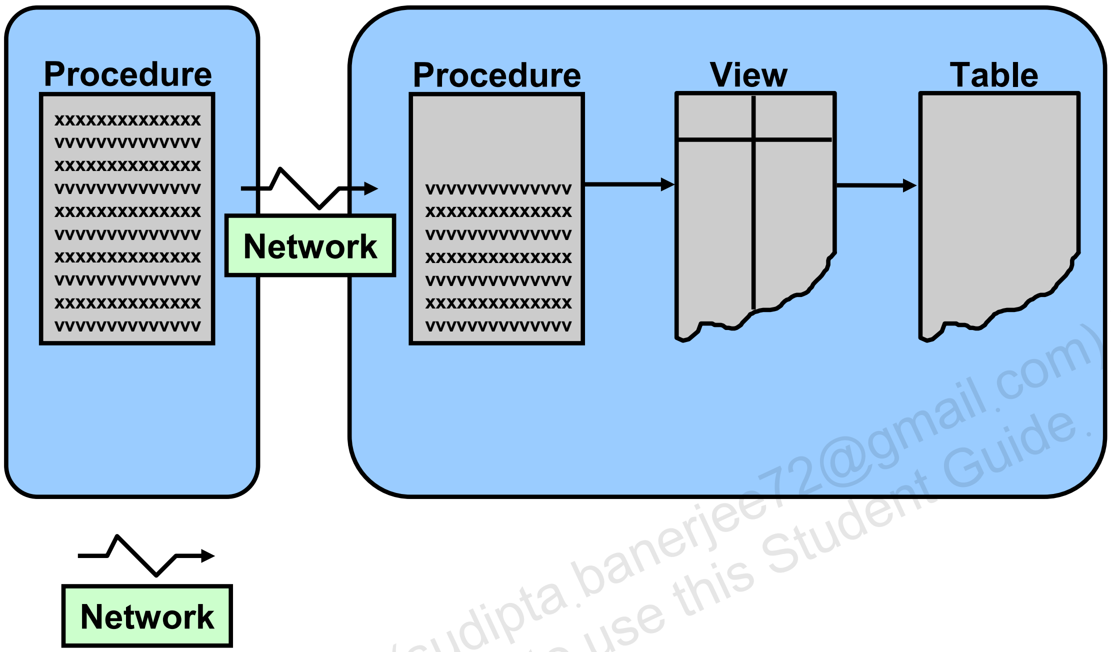
Setting the REMOTE_DEPENDENCIES_MODE

value	TIMESTAMP SIGNATURE

Specify the value of the REMOTE_DEPENDENCIES_MODE parameter using one of the three methods described in the slide.

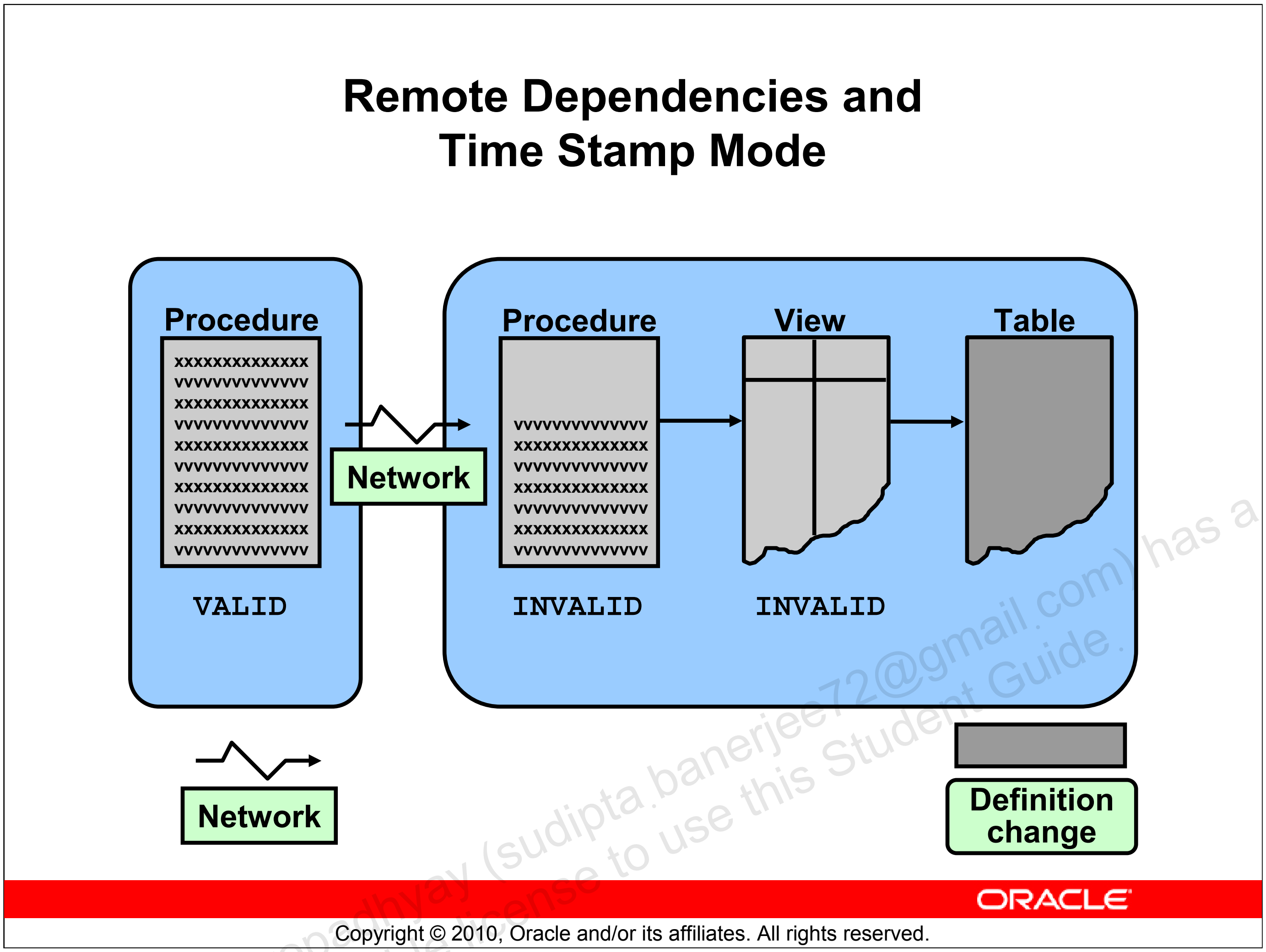
Note: The calling site determines the dependency model.

Remote Dependencies and Time Stamp Mode



Remote Dependencies and Time Stamp Mode

If time stamps are used to handle dependencies among PL/SQL program units, then whenever you alter a program unit or a relevant schema object, all its dependent units are marked as invalid and must be recompiled before they can be run.

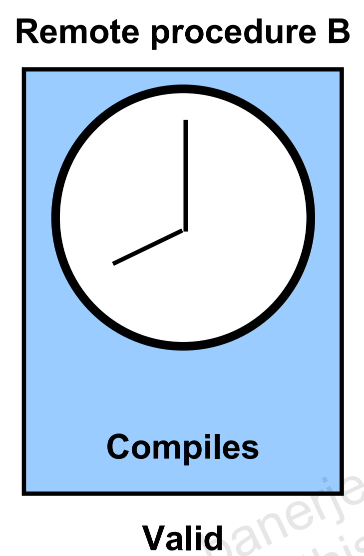


Remote Dependencies and Time Stamp Mode (continued)

In the example in the slide, the definition of the table changes. Therefore, all its dependent units are marked as invalid and must be recompiled before they can be run.

- When remote objects change, it is strongly recommended that you recompile local dependent objects manually in order to avoid disrupting production.
- The remote dependency mechanism is different from the automatic local dependency mechanism already discussed. The first time a recompiled remote subprogram is invoked by a local subprogram, you get an execution error and the local subprogram is invalidated; the second time it is invoked, implicit automatic recompilation takes place.

Remote Procedure B Compiles at 8:00 a.m.



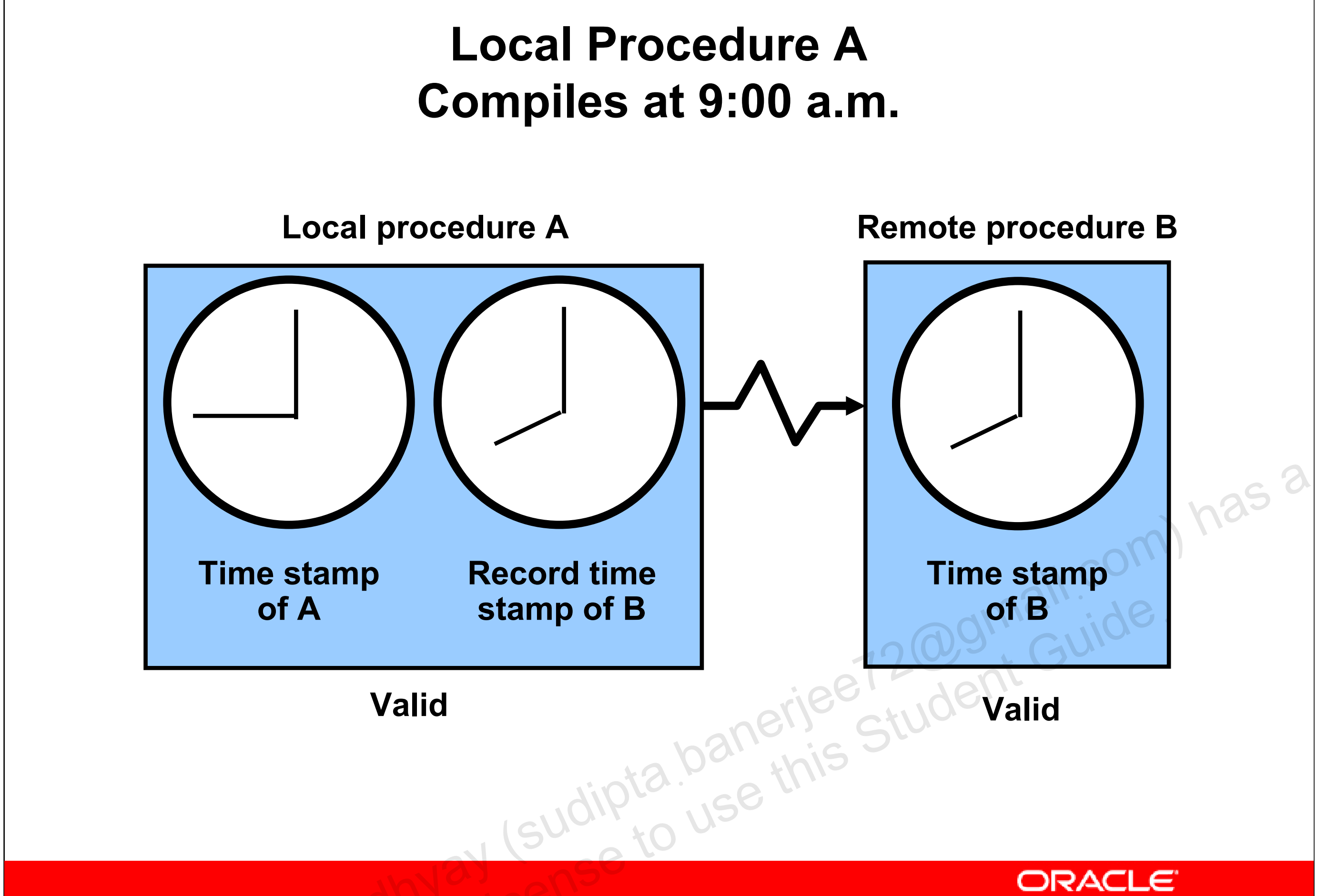
Local Procedures Referencing Remote Procedures

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 a.m., this time is recorded as its time stamp.

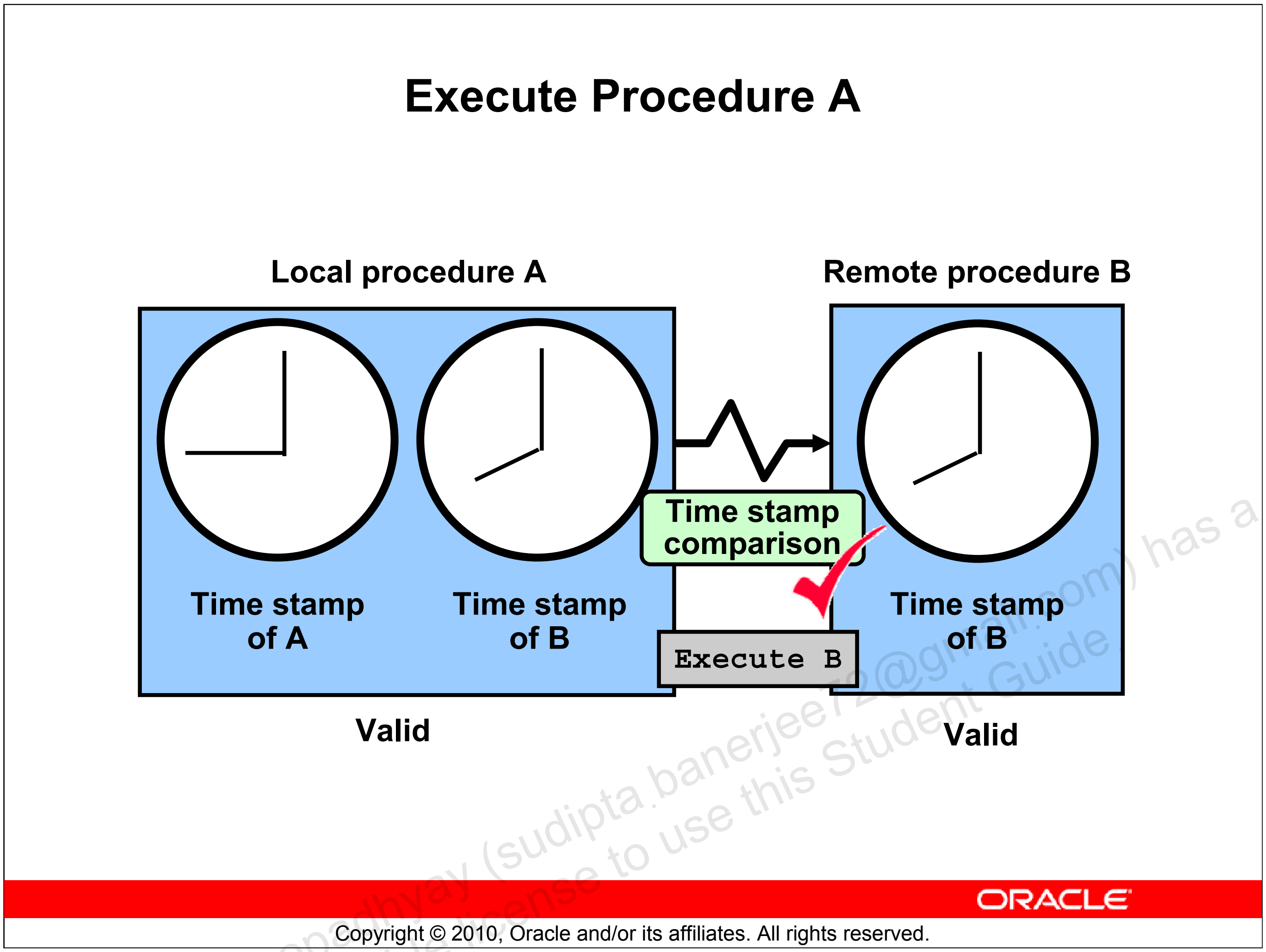


Local Procedures Referencing Remote Procedures (continued)

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 a.m. The time stamps of both procedure A and remote procedure B are recorded in the `P` code of procedure A.



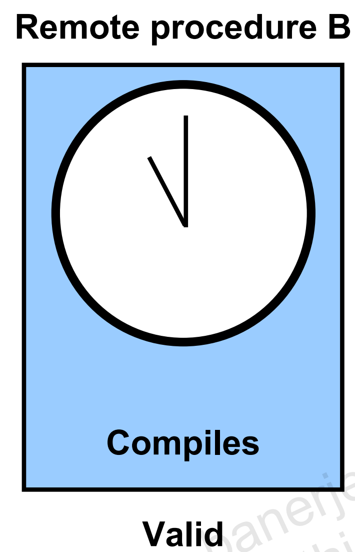
Automatic Remote Dependency

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.

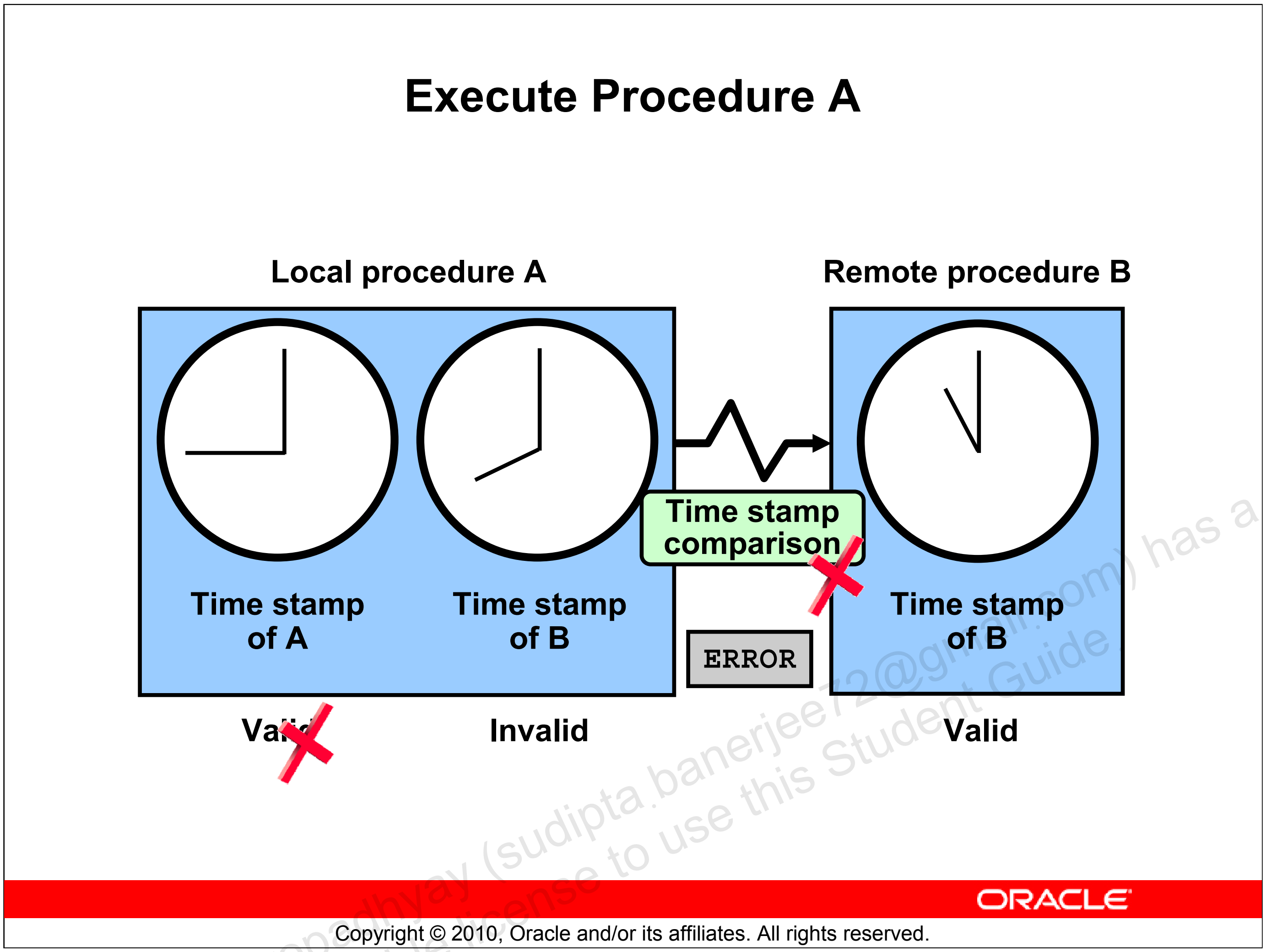
In the example in the slide, the time stamp recorded with the `P` code of remote procedure B is the same as that recorded with local procedure A. Therefore, local procedure A is valid.

Remote Procedure B Recompiled at 11:00 a.m.



Local Procedures Referencing Remote Procedures

Assume that remote procedure B is successfully recompiled at 11:00 a.m. The new time stamp is recorded along with its `P` code.



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 a.m. and this time is recorded as its time stamp in the `P` code. The `P` code of local procedure A still has 8:00 a.m. 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.

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]];
```


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

ORACLE

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

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.

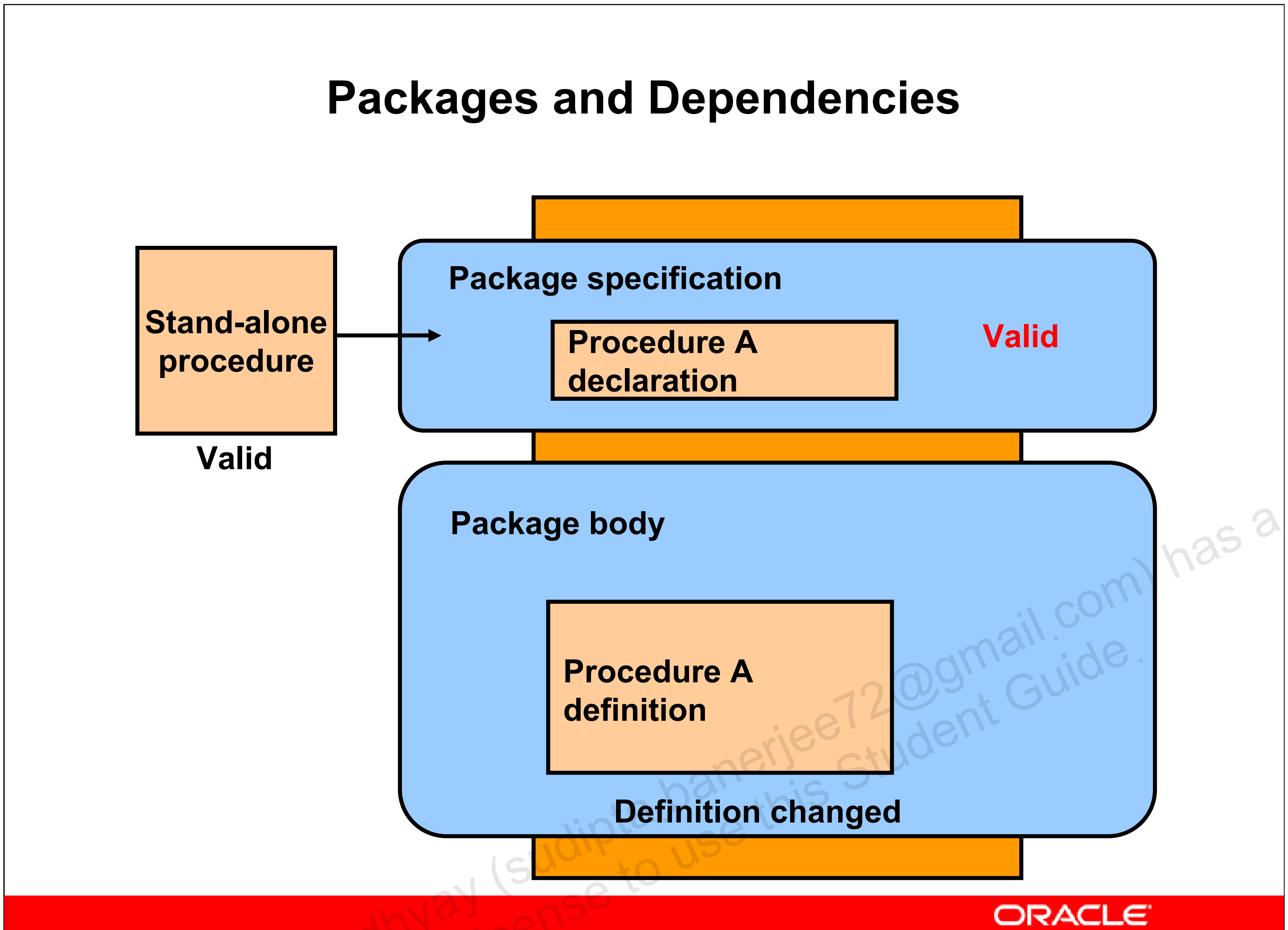
Recompilation of Procedures

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

Recompilation of Procedures

You can minimize recompilation failure by following the guidelines that are shown in the slide.

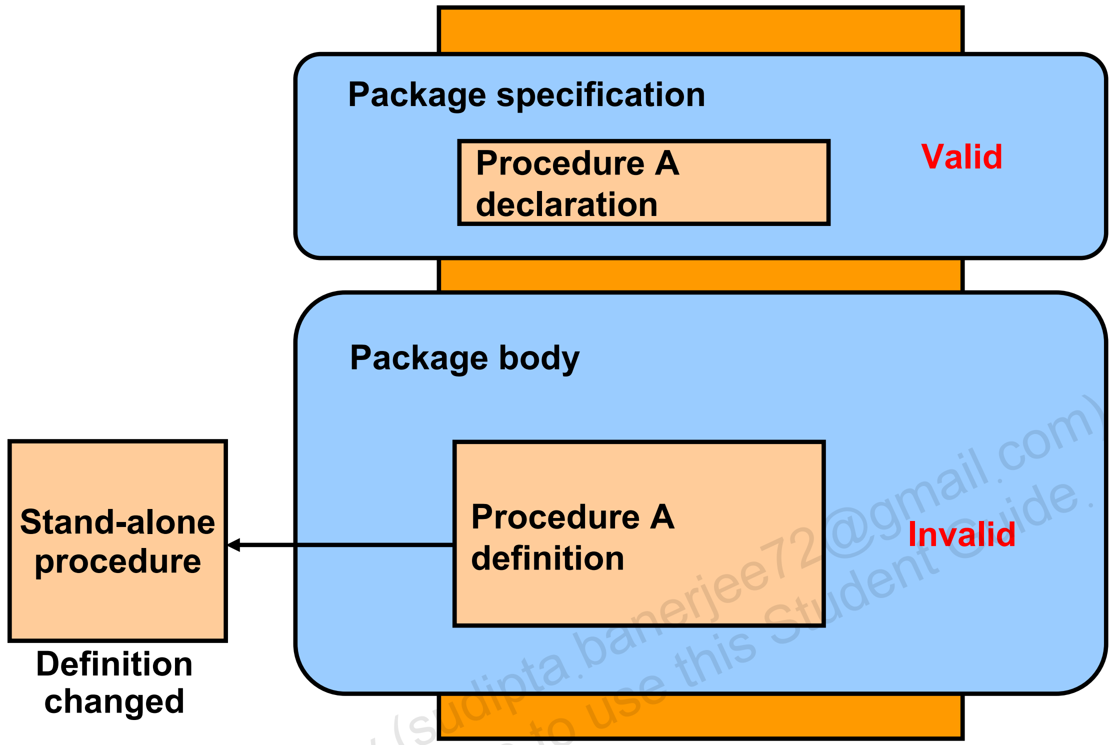


Managing Dependencies

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



Managing Dependencies (continued)

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.

Summary

In this lesson, you should have learned how to:

- Keep track of dependent procedures
- Recompile procedures manually as soon as possible after the definition of a database object changes

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.

Situation	Automatic Recompilation
Procedure depends on a local object.	Yes, at first reexecution
Procedure depends on a remote procedure.	Yes, but at second reexecution. Use manual recompilation for first reexecution, or reinvoke it a second time.
Procedure depends on a remote object other than a procedure.	No

Practice 8: Overview

This practice covers the following topics:

- Using DEPTREE_FILL and IDEPTREE to view dependencies
- Recompiling procedures, functions, and packages

Practice 8: 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 8

1. Answer the following questions:
   a. Can a table or a synonym be invalidated?
   b. Consider the following dependency example:
      The stand-alone procedure MY_PROC depends on the MY_PROC_PACK package procedure. The MY_PROC_PACK procedure's definition is changed by recompiling the package body. The MY_PROC_PACK procedure's declaration is not altered in the package specification.
      In this scenario, is the stand-alone procedure MY_PROC invalidated?
2. 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 titled "Creating Stored Functions." You can run the solution scripts for Practice 2 if you need to create the procedure and function.
   a. Load and execute the utldtree.sql script, which is located in the E:\lab\PLPU\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:

3. 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 6 in the lesson titled "Dynamic SQL and Metadata"), 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 3c to check the status column value. Do you still have objects with an INVALID status?

9

Manipulating Large Objects

Objectives

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

- Compare and contrast LONG and LOB (large object) data types
- Create and maintain LOB data types
- Differentiate between internal and external LOBs
- Use the DBMS_LOB PL/SQL package
- Describe the use of temporary LOBs

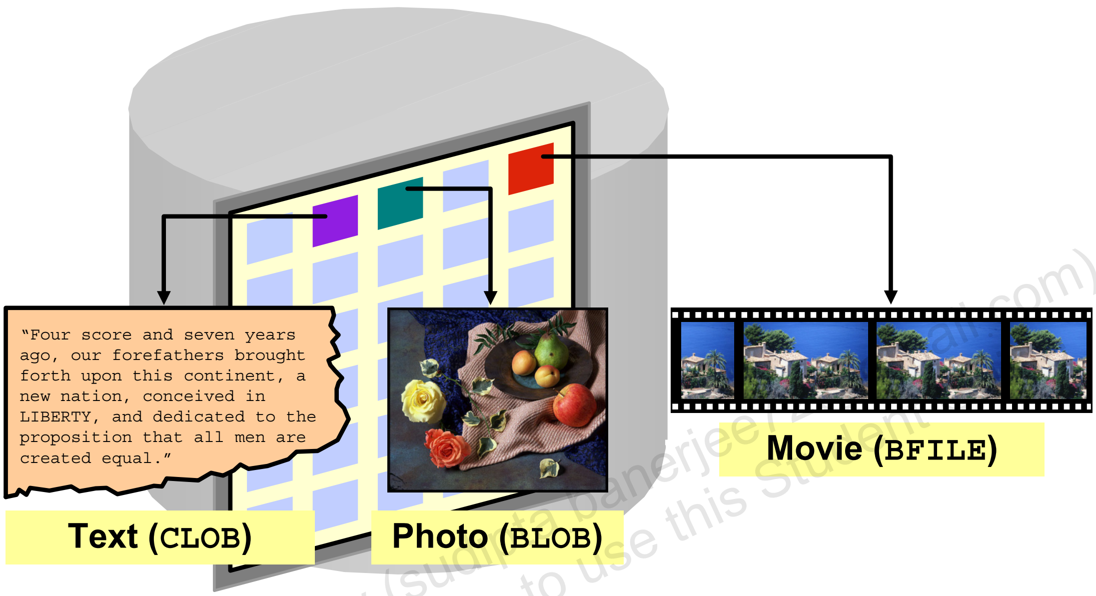
Lesson Aim

Databases have long been used to store large objects. However, the mechanisms built into databases have never been as useful as the large object (LOB) data types that have been provided since Oracle8. This lesson describes the characteristics of the new data types, comparing and contrasting them with earlier data types. Examples, syntax, and issues regarding the LOB types are also presented.

Note: A LOB is a data type and should not be confused with an object type.

What Is a LOB?

LOBs are used to store large unstructured data such as text, graphic images, films, and sound waveforms.



LOB: Overview

A LOB is a data type that is used to store large, unstructured data such as text, graphic images, video clippings, and so on. Structured data, such as a customer record, may be a few hundred bytes, but even small amounts of multimedia data can be thousands of times larger. Also, multimedia data may reside in operating system (OS) files, which may need to be accessed from a database.

There are four large object data types:

- BLOB represents a binary large object, such as a video clip.
- CLOB represents a character large object.
- NCLOB represents a multibyte character large object.
- BFILE represents a binary file stored in an OS binary file outside the database. The BFILE column or attribute stores a file locator that points to the external file.

LOBs are characterized in two ways, according to their interpretations by the Oracle server (binary or character) and their storage aspects. LOBs can be stored internally (inside the database) or in host files. There are two categories of LOBs:

- **Internal LOBs (CLOB, NCLOB, BLOB):** Stored in the database
- **External files (BFILE):** Stored outside the database

LOB: Overview (continued)

Oracle Database 10*g* performs implicit conversion between CLOB and VARCHAR2 data types. The other implicit conversions between LOBs are not possible. For example, if the user creates a table T with a CLOB column and a table S with a BLOB column, the data is not directly transferable between these two columns.

BFILEs can be accessed only in read-only mode from an Oracle server.

Contrasting LONG and LOB Data Types

LONG and LONG RAW	LOB
Single LONG column per table	Multiple LOB columns per table
Up to 2 GB	Up to 4 GB
SELECT returns data	SELECT returns locator
Data stored in-line	Data stored in-line or out-of-line
Sequential access to data	Random access to data

LONG and LOB Data Types

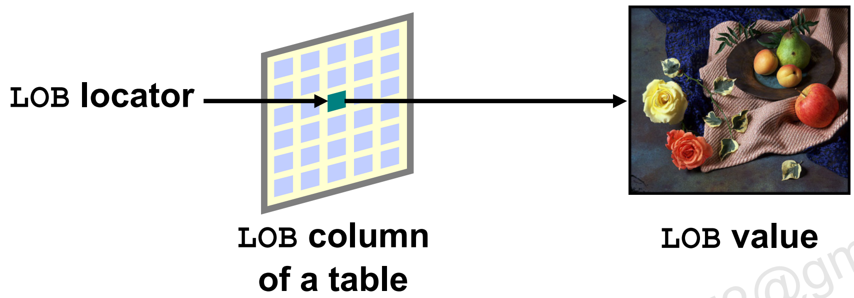
LONG and LONG RAW data types were previously used for unstructured data such as binary images, documents, or geographical information. These data types are superseded by the LOB data types. Oracle Database 10*g* provides a LONG-to-LOB application programming interface (API) to migrate from LONG columns to LOB columns. The following bulleted list compares the LOB functionality with the older types, where LONGs refer to LONG and LONG RAW, and LOBs refer to all LOB data types:

- A table can have multiple LOB columns and object type attributes. A table can have only one LONG column.
- The maximum size of LONGs is 2 GB; LOBs can be up to 4 GB.
- LOBs return the locator; LONGs return the data.
- LOBs store a locator in the table and the data in a different segment, unless the data is less than 4,000 bytes; LONGs store all data in the same data block. In addition, LOBs allow data to be stored in a separate segment and tablespace, or in a host file.
- LOBs can be object type attributes; LONGs cannot be object type attributes.
- LOBs support random piecewise access to the data through a file-like interface; LONGs are restricted to sequential piecewise access.

The TO_LOB function can be used to convert LONG and LONG RAW values in a column to LOB values. You use this in the SELECT list of a subquery in an INSERT statement.

Anatomy of a LOB

The LOB column stores a locator to the LOB's value.



Components of a LOB

There are two distinct parts to a LOB:

- **LOB value:** The data that constitutes the real object being stored
- **LOB locator:** A pointer to the location of the LOB value stored in the database

Regardless of where the value of LOB is stored, a locator is stored in the row. You can think of a LOB locator as a pointer to the actual location of the LOB value.

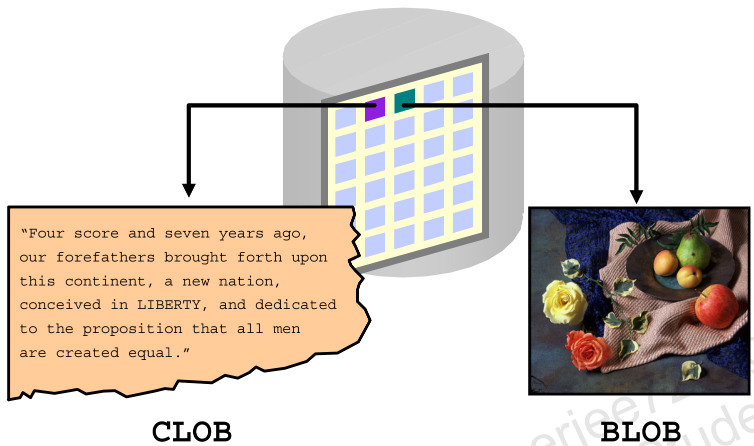
A LOB column does not contain the data; it contains the locator of the LOB value.

When a user creates an internal LOB, the value is stored in the LOB segment and a locator to the out-of-line LOB value is placed in the LOB column of the corresponding row in the table. External LOBs store the data outside the database, so only a locator to the LOB value is stored in the table.

To access and manipulate LOBs without SQL data manipulation language (DML), you must create a LOB locator. The programmatic interfaces operate on the LOB values, using these locators in a manner similar to OS file handles.

Internal LOBs

The LOB value is stored in the database.



Features of Internal LOBs

The internal LOB is stored in the Oracle server. A BLOB, NCLOB, or CLOB can be one of the following:

- An attribute of a user-defined type
- A column in a table
- A bind or host variable
- A PL/SQL variable, parameter, or result

Internal LOBs can take advantage of Oracle features such as:

- Concurrency mechanisms
- Redo logging and recovery mechanisms
- Transactions with COMMIT or ROLLBACK

The BLOB data type is interpreted by the Oracle server as a bitstream, similar to the LONG RAW data type.

The CLOB data type is interpreted as a single-byte character stream.

The NCLOB data type is interpreted as a multiple-byte character stream, based on the byte length of the database national character set.

Managing Internal LOBs

- To interact fully with LOB, file-like interfaces are provided in:
  - PL/SQL package DBMS_LOB
  - Oracle Call Interface (OCI)
  - Oracle Objects for object linking and embedding (OLE)
  - Pro*C/C++ and Pro*COBOL precompilers
  - Java Database Connectivity (JDBC)
- The Oracle server provides some support for LOB management through SQL.

How to Manage LOBs

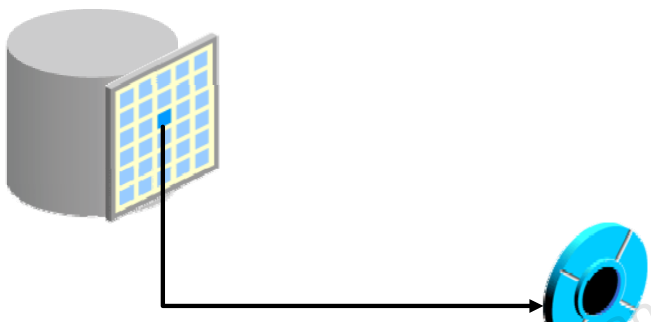
To manage an internal LOB, perform the following steps:

1. Create and populate the table containing the LOB data type.
2. Declare and initialize the LOB locator in the program.
3. Use SELECT FOR UPDATE to lock the row containing the LOB into the LOB locator.
4. Manipulate the LOB with DBMS_LOB package procedures, OCI calls, Oracle Objects for OLE, Oracle precompilers, or JDBC using the LOB locator as a reference to the LOB value.
   You can also manage LOBs through SQL.
5. Use the COMMIT command to make any changes permanent.

What Are BFILEs?

The BFILE data type supports an external or file-based large object as:

- Attributes in an object type
- Column values in a table



What Are BFILEs?

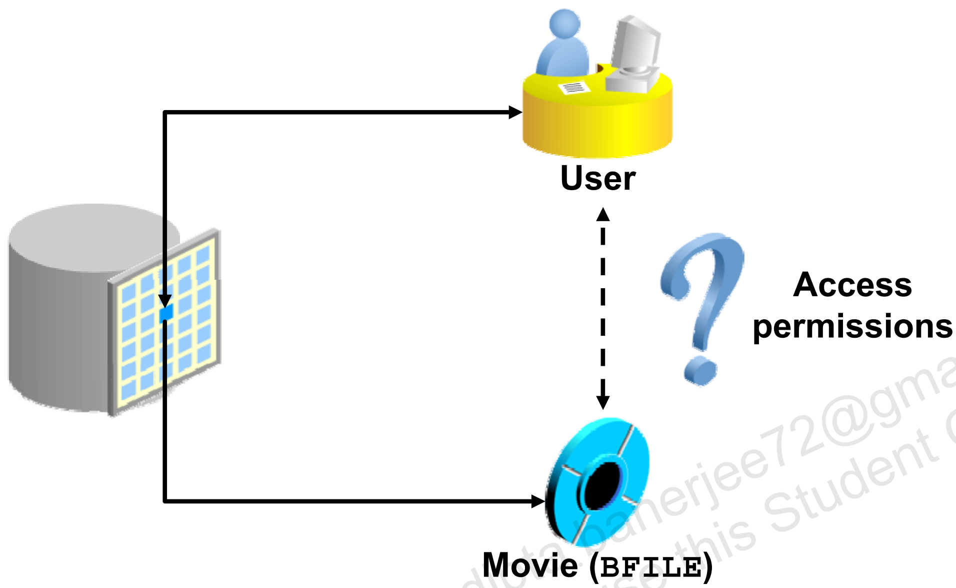
BFILEs are external large objects (LOBs) stored in OS files that are external to database tables. The BFILE data type stores a locator to the physical file. A BFILE can be in GIF, JPEG, MPEG, MPEG2, text, or other formats. The external LOBs may be located on hard disks, CD-ROMs, photo CDs, or other media, but a single LOB cannot extend from one medium or device to another. The BFILE data type is available so that database users can access the external file system. Oracle Database 10*g* provides:

- Definition of BFILE objects
- Association of BFILE objects to corresponding external files
- Security for BFILEs

The remaining operations that are required for using BFILEs are possible through the DBMS_LOB package and OCI. BFILEs are read-only; they do not participate in transactions. Support for integrity and durability must be provided by the operating system. The file must be created and placed in the appropriate directory, giving the Oracle process privileges to read the file. When the LOB is deleted, the Oracle server does not delete the file. Administration of the files and the OS directory structures can be managed by the database administrator (DBA), system administrator, or user. The maximum size of an external large object depends on the operating system but cannot exceed 4 GB.

Note: BFILEs are available with the Oracle8 database and later releases.

Securing BFILEs



Securing BFILEs

Unauthenticated access to files on a server presents a security risk. Oracle Database 10*g* can act as a security mechanism to shield the operating system from unsecured access while removing the need to manage additional user accounts on an enterprise computer system.

File Location and Access Privileges

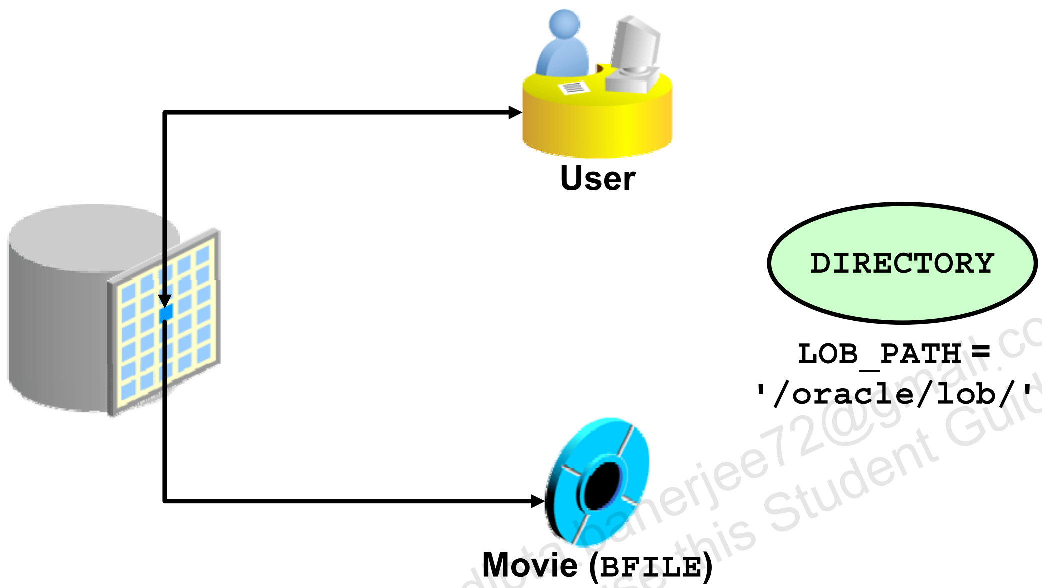
The file must reside on the machine where the database exists. A timeout to read a nonexistent `BFILE` is based on the OS value.

You can read a `BFILE` in the same way as you read an internal `LOB`. However, there could be restrictions related to the file itself, such as:

- Access permissions
- File system space limits
- Non-Oracle manipulations of files
- OS maximum file size

Oracle Database 10*g* does not provide transactional support on `BFILE`s. Any support for integrity and durability must be provided by the underlying file system and the OS. Oracle backup and recovery methods support only the `LOB` locators, not the physical `BFILE`s.

A New Database Object: DIRECTORY



A New Database Object: DIRECTORY

A DIRECTORY is a nonschema database object that enables the administration of access and usage of BFILEs in Oracle Database 10*g*.

A DIRECTORY specifies an alias for a directory on the file system of the server under which a BFILE is located. By granting suitable privileges for these items to users, you can provide secure access to files in the corresponding directories on a user-by-user basis (certain directories can be made read-only, inaccessible, and so on).

Furthermore, these directory aliases can be used while referring to files (open, close, read, and so on) in PL/SQL and OCI. This provides application abstraction from hard-coded path names and gives flexibility in portably managing file locations.

The DIRECTORY object is owned by SYS and created by the DBA (or a user with the CREATE ANY DIRECTORY privilege). The directory objects have object privileges, unlike any other nonschema object. Privileges to the DIRECTORY object can be granted and revoked. Logical path names are not supported.

The permissions for the actual directory depend on the operating system. They may differ from those defined for the DIRECTORY object and could change after the creation of the DIRECTORY object.

Guidelines for Creating DIRECTORY Objects

- Do not create DIRECTORY objects on paths with database files.
- Limit the number of people who are given the following system privileges:
  - CREATE ANY DIRECTORY
  - DROP ANY DIRECTORY
- All DIRECTORY objects are owned by SYS.
- Create directory paths and properly set permissions before using the DIRECTORY object so that the Oracle server can read the file.

Guidelines for Creating DIRECTORY Objects

To associate an OS file with a BFILE, you should first create a DIRECTORY object that is an alias for the full path name to the OS file.

Create DIRECTORY objects by using the following guidelines:

- Directories should point to paths that do not contain database files because tampering with these files could corrupt the database. Currently, only the READ privilege can be given for a DIRECTORY object.
- The CREATE ANY DIRECTORY and DROP ANY DIRECTORY system privileges should be used carefully and not granted to users indiscriminately.
- DIRECTORY objects are not schema objects; all are owned by SYS.
- Create the directory paths with appropriate permissions on the OS before creating the DIRECTORY object. Oracle does not create the OS path.

If you migrate the database to a different OS, then you may need to change the path value of the DIRECTORY object.

The DIRECTORY object information that you create by using the CREATE DIRECTORY command is stored in the DBA_DIRECTORIES and ALL_DIRECTORIES data dictionary views.

Managing BFILEs

The DBA or the system administrator:

1. Creates an OS directory and supplies files
2. Creates a DIRECTORY object in the database
3. Grants the READ privilege on the DIRECTORY object to appropriate database users

The developer or the user:

4. Creates an Oracle table with a column defined as a BFILE data type
5. Inserts rows into the table using the BFILENAME function to populate the BFILE column
6. Writes a PL/SQL subprogram that declares and initializes a LOB locator, and reads BFILE

How to Manage BFILEs

Managing BFILEs requires cooperation between the database administrator and the system administrator and then between the developer and the user of the files.

The database or system administrator should perform the following privileged tasks:

1. Create the operating system (OS) directory (as an Oracle user), and set permissions so that the Oracle server can read the contents of the OS directory. Load files into the OS directory.
2. Create a database DIRECTORY object that references the OS directory.
3. Grant the READ privilege on the database DIRECTORY object to database users requiring access to it.

The designer, application developer, or user should perform the following tasks:

4. Create a database table containing a column defined as the BFILE data type.
5. Insert rows into the table using the BFILENAME function to populate the BFILE column associating the field to an OS file in the named DIRECTORY.
6. Write PL/SQL subprograms that:
   a. Declare and initialize the BFILE LOB locator
   b. Select the row and column containing the BFILE into the LOB locator
   c. Read the BFILE with a DBMS_LOB function, using the locator file reference

Preparing to Use BFILEs

1. Create an OS directory to store the physical data files:

```
mkdir /temp/data_files
```

2. Create a DIRECTORY object by using the CREATE DIRECTORY command:

```
CREATE DIRECTORY data_files
              AS '/temp/data_files';
```

3. Grant the READ privilege on the DIRECTORY object to appropriate users:

```
GRANT READ ON DIRECTORY data_files
   TO SCOTT, MANAGER_ROLE, PUBLIC;
```


Preparing to Use BFILEs

To use a BFILE within an Oracle table, you must have a table with a column of the BFILE type. For the Oracle server to access an external file, the server needs to know the physical location of the file in the OS directory structure.

The database DIRECTORY object provides the means to specify the location of the BFILEs. Use the CREATE DIRECTORY command to specify the pointer to the location where your BFILEs are stored. You need the CREATE ANY DIRECTORY privilege.

Syntax definition: CREATE DIRECTORY *dir_name* AS *os_path*;

In this syntax, *dir_name* is the name of the directory database object, and *os_path* is the location of the BFILEs.

The slide examples show the commands to set up:

- The physical directory (for example /temp/data_files) in the OS
- A named DIRECTORY object, called data_files, that points to the physical directory in the OS
- The READ access right on the directory to be granted to users in the database, providing the privilege to read the BFILEs from the directory

Note: The value of the SESSION_MAX_OPEN_FILES database initialization parameter, which is set to 10 by default, limits the number of BFILEs that can be opened in a session.

Populating BFILE Columns with SQL

- Use the BFILENAME function to initialize a BFILE column. The function syntax is:

```
FUNCTION BFILENAME(directory_alias IN VARCHAR2,
                   filename IN VARCHAR2)
RETURN BFILE;
```

- Example:
  – Add a BFILE column to a table:

```
ALTER TABLE employees ADD video BFILE;
```

  – Update the column using the BFILENAME function:

```
UPDATE employees
  SET video = BFILENAME('DATA_FILES', 'King.avi')
WHERE employee_id = 100;
```

ORACLE

Populating BFILE Columns with SQL

The BFILENAME function is a built-in function that you use to initialize a BFILE column, using the following two parameters:

- *directory_alias* for the name of the DIRECTORY database object that references the OS directory containing the files
- *filename* for the name of the BFILE to be read

The BFILENAME function creates a pointer (or LOB locator) to the external file stored in a physical directory, which is assigned a directory alias name that is used in the first parameter of the function. Populate the BFILE column using the BFILENAME function in either of the following:

- The VALUES clause of an INSERT statement
- The SET clause of an UPDATE statement

An UPDATE operation can be used to change the pointer reference target of the BFILE. A BFILE column can also be initialized to a NULL value and updated later with the BFILENAME function, as shown in the slide.

After the BFILE columns have been associated with a file, subsequent read operations on the BFILE can be performed by using the PL/SQL DBMS_LOB package and OCI. However, these files are read-only when accessed through BFILEs. Therefore, they cannot be updated or deleted through BFILEs.

Populating a BFILE Column with PL/SQL

```
CREATE PROCEDURE set_video(
  dir_alias VARCHAR2, dept_id NUMBER) IS
  filename VARCHAR2(40);
  file_ptr BFILE;
  CURSOR emp_csr IS
    SELECT first_name FROM employees
    WHERE department_id = dept_id FOR UPDATE;
BEGIN
  FOR rec IN emp_csr LOOP
    filename := rec.first_name || '.gif';
    file_ptr := BFILENAME(dir_alias, filename);
    DBMS_LOB.FILEOPEN(file_ptr);
    UPDATE employees SET video = file_ptr
      WHERE CURRENT OF emp_csr;
    DBMS_OUTPUT.PUT_LINE('FILE: ' || filename ||
     ' SIZE: ' || DBMS_LOB.GETLENGTH(file_ptr));
    DBMS_LOB.FILECLOSE(file_ptr);
  END LOOP;
END set_video;
```


Populating a BFILE Column with PL/SQL

The example shows a PL/SQL procedure called `set_video`, which accepts the name of the directory alias referencing the OS file system as a parameter, and a department ID. The procedure performs the following tasks:

- Uses a cursor `FOR` loop to obtain each employee record
- Sets the `filename` by appending `.gif` to the employee's `first_name`
- Creates an in-memory LOB locator for the `BFILE` in the `file_ptr` variable
- Calls the `DBMS_LOB.FILEOPEN` procedure to verify whether the file exists, and to determine the size of the file using the `DBMS_LOB.GETLENGTH` function
- Executes an `UPDATE` statement to write the `BFILE` locator value to the `video` `BFILE` column
- Displays the file size returned from the `DBMS_LOB.GETLENGTH` function
- Closes the file using the `DBMS_LOB.FILECLOSE` procedure

Suppose that you execute the following call:

```
EXECUTE set_video('DATA_FILE', 60)
```

Sample results are:

```
FILE: Alexander.gif SIZE: 5213
FILE: Bruce.gif SIZE: 26059
  :
```

Using DBMS_LOB Routines with BFILEs

The DBMS_LOB.FILEEXISTS function can check whether the file exists in the OS. The function:

- Returns 0 if the file does not exist
- Returns 1 if the file does exist

```
CREATE FUNCTION get_filesize(file_ptr IN OUT BFILE)
RETURN NUMBER IS
  file_exists BOOLEAN;
  length NUMBER:= -1;
BEGIN
  file_exists := DBMS_LOB.FILEEXISTS(file_ptr)=1;
  IF file_exists THEN
    DBMS_LOB.FILEOPEN(file_ptr);
    length := DBMS_LOB.GETLENGTH(file_ptr);
    DBMS_LOB.FILECLOSE(file_ptr);
  END IF;
  RETURN length;
END;
/
```


Using DBMS_LOB Routines with BFILEs

The set_video procedure on the previous page will terminate with an exception if a file does not exist. To prevent the loop from prematurely terminating, you could create a function, such as get_filesize, to determine whether a given BFILE locator references a file that actually exists on the server's file system. The DBMS_LOB.FILEEXISTS function expects the BFILE locator as a parameter and returns an INTEGER with:

- A value 0 if the physical file does not exist
- A value 1 if the physical file exists

If the BFILE parameter is invalid, one of the three exceptions may be raised:

- NOEXIST_DIRECTORY if the directory does not exist
- NOPRIV_DIRECTORY if database processes do not have privileges for the directory
- INVALID_DIRECTORY if the directory was invalidated after the file was opened

In the get_filesize function, the output of the DBMS_LOB.FILEEXISTS function is compared with value 1 and the result of the condition sets the BOOLEAN variable file_exists. The DBMS_LOB.FILEOPEN call is performed only if the file does exist, preventing unwanted exceptions from occurring. The get_filesize function returns a value of –1 if a file does not exist; otherwise, it returns the size of the file in bytes. The caller can take appropriate action with this information.

DBMS_LOB Package

- Working with LOBs often requires the use of the Oracle-supplied DBMS_LOB package.
- DBMS_LOB provides routines to access and manipulate internal and external LOBs.
- Oracle Database 10*g* enables retrieving LOB data directly using SQL without a special LOB API.
- In PL/SQL, you can define a VARCHAR2 for a CLOB and a RAW for a BLOB.

DBMS_LOB Package

In releases prior to Oracle9*i*, you must use the DBMS_LOB package for retrieving data from LOBs. To create the DBMS_LOB package, the dbmslob.sql and prvtlob.plb scripts must be executed as SYS. The catproc.sql script executes the scripts. Then users can be granted appropriate privileges to use the package.

The package does not support any concurrency control mechanism for BFILE operations. The user is responsible for locking the row containing the destination internal LOB before calling any subprograms that involve writing to the LOB value. These DBMS_LOB routines do not implicitly lock the row containing the LOB.

The two constants, LOBMAXSIZE and FILE_READONLY, defined in the package specification are also used in the procedures and functions of DBMS_LOB—for example, use them to achieve the maximum level of purity to be used in SQL expressions.

The DBMS_LOB functions and procedures can be broadly classified into two types: mutators and observers.

- The mutators can modify LOB values: APPEND, COPY, ERASE, TRIM, WRITE, FILECLOSE, FILECLOSEALL, and FILEOPEN.
- The observers can read LOB values: COMPARE, FILEGETNAME, INSTR, GETLENGTH, READ, SUBSTR, FILEEXISTS, and FILEISOPEN.

DBMS_LOB Package

- Modify LOB values:
  APPEND, COPY, ERASE, TRIM, WRITE, LOADFROMFILE
- Read or examine LOB values:
  GETLENGTH, INSTR, READ, SUBSTR
- Specific to BFILEs:
  FILECLOSE, FILECLOSEALL, FILEEXISTS, FILEGETNAME, FILEISOPEN, FILEOPEN

DBMS_LOB Package (continued)

APPEND	Appends the contents of the source LOB to the destination LOB
COPY	Copies all or part of the source LOB to the destination LOB
ERASE	Erases all or part of a LOB
LOADFROMFILE	Loads BFILE data into an internal LOB
TRIM	Trims the LOB value to a specified shorter length
WRITE	Writes data to the LOB from a specified offset
GETLENGTH	Gets the length of the LOB value
INSTR	Returns the matching position of the *n*th occurrence of the pattern in the LOB
READ	Reads data from the LOB starting at the specified offset
SUBSTR	Returns part of the LOB value starting at the specified offset
FILECLOSE	Closes the file
FILECLOSEALL	Closes all previously opened files
FILEEXISTS	Checks whether the file exists on the server
FILEGETNAME	Gets the directory alias and file name
FILEISOPEN	Checks whether the file was opened using the input BFILE locators
FILEOPEN	Opens a file

DBMS_LOB Package

- NULL parameters get NULL returns.
- Offsets:
  - BLOB, BFILE: Measured in bytes
  - CLOB, NCLOB: Measured in characters
- There are no negative values for parameters.

Using the DBMS_LOB Routines

All functions in the DBMS_LOB package return NULL if any input parameters are NULL. All mutator procedures in the DBMS_LOB package raise an exception if the destination LOB/BFILE is input as NULL.

Only positive, absolute offsets are allowed. They represent the number of bytes or characters from the beginning of LOB data from which to start the operation. Negative offsets and ranges observed in SQL string functions and operators are not allowed. Corresponding exceptions are raised upon violation. The default value for an offset is 1, which indicates the first byte or character in the LOB value.

Similarly, only natural number values are allowed for the amount (BUFSIZ) parameter. Negative values are not allowed.

DBMS_LOB.READ and DBMS_LOB.WRITE

```
PROCEDURE READ (
  lobsrc IN BFILE|BLOB|CLOB ,
  amount IN OUT BINARY_INTEGER,
  offset IN INTEGER,
  buffer OUT RAW|VARCHAR2 )
```

```
PROCEDURE WRITE (
  lobdst IN OUT BLOB|CLOB,
  amount IN OUT BINARY_INTEGER,
  offset IN INTEGER := 1,
  buffer IN RAW|VARCHAR2 )  -- RAW for BLOB
```


DBMS_LOB.READ

Call the READ procedure to read and return piecewise a specified AMOUNT of data from a given LOB, starting from OFFSET. An exception is raised when no more data remains to be read from the source LOB. The value returned in AMOUNT is less than the one specified if the end of the LOB is reached before the specified number of bytes or characters can be read. In the case of CLOBs, the character set of data in BUFFER is the same as that in the LOB.

PL/SQL allows a maximum length of 32,767 for RAW and VARCHAR2 parameters. Ensure that the allocated system resources are adequate to support buffer sizes for the given number of user sessions. Otherwise, the Oracle server raises the appropriate memory exceptions.

Note: BLOB and BFILE return RAW; the others return VARCHAR2.

DBMS_LOB.WRITE

Call the WRITE procedure to write piecewise a specified AMOUNT of data into a given LOB, from the user-specified BUFFER, starting from an absolute OFFSET from the beginning of the LOB value.

Make sure (especially with multibyte characters) that the amount in bytes corresponds to the amount of buffer data. WRITE has no means of checking whether they match, and it will write AMOUNT bytes of the buffer contents into the LOB.

Initializing LOB Columns Added to a Table

- Create the table with columns using the LOB type, or add the LOB columns using ALTER TABLE.

```
ALTER TABLE employees
     ADD (resume CLOB, picture BLOB);
```

- Initialize the column LOB locator value with the DEFAULT option or DML statements using:
  - EMPTY_CLOB() function for a CLOB column
  - EMPTY_BLOB() function for a BLOB column

```
CREATE TABLE emp_hiredata (
   employee_id  NUMBER(6),
   full_name    VARCHAR2(45),
   resume       CLOB DEFAULT EMPTY_CLOB(),
   picture      BLOB DEFAULT EMPTY_BLOB());
```


Initializing LOB Columns Added to a Table

LOB columns are defined by using SQL data definition language (DDL), as in the ALTER TABLE statement in the slide. The contents of a LOB column are stored in the LOB segment, whereas the column in the table contains only a reference to that specific storage area, called the LOB locator. In PL/SQL, you can define a variable of the LOB type, which contains only the value of the LOB locator. You can initialize the LOB locators using:

- EMPTY_CLOB() function to a LOB locator for a CLOB column
- EMPTY_BLOB() function to a LOB locator for a BLOB column

Note: These functions create the LOB locator value and not the LOB content. In general, you use the DBMS_LOB package subroutines to populate the content. The functions are available in Oracle SQL DML, and are not part of the DBMS_LOB package.

The last example in the slide shows how you can use the EMPTY_CLOB() and EMPTY_BLOB() functions in the DEFAULT option in a CREATE TABLE statement. In this way, the LOB locator values are populated in their respective columns when a row is inserted into the table and the LOB columns have not been specified in the INSERT statement.

The next page shows how to use the functions in INSERT and UPDATE statements to initialize the LOB locator values.

Populating LOB Columns

- Insert a row into a table with LOB columns:

```
INSERT INTO emp_hiredata
  (employee_id, full_name, resume, picture)
 VALUES (405, 'Marvin Ellis', EMPTY_CLOB(), NULL);
```

- Initialize a LOB using the EMPTY_BLOB() function:

```
UPDATE emp_hiredata
 SET resume = 'Date of Birth: 8 February 1951',
    picture = EMPTY_BLOB()
 WHERE employee_id = 405;
```

- Update a CLOB column:

```
UPDATE emp_hiredata
 SET resume = 'Date of Birth: 1 June 1956'
 WHERE employee_id = 170;
```


Populating LOB Columns

You can insert a value directly into a LOB column by using host variables in SQL or in PL/SQL, 3GL-embedded SQL, or OCI. You can use the special EMPTY_BLOB() and EMPTY_CLOB() functions in INSERT or UPDATE statements of SQL DML to initialize a NULL or non-NULL internal LOB to empty. To populate a LOB column, perform the following steps:

1. Initialize the LOB column to a non-NULL value—that is, set a LOB locator pointing to an empty or populated LOB value. This is done by using EMPTY_BLOB() and EMPTY_CLOB() functions.
2. Populate the LOB contents by using the DBMS_LOB package routines.

However, as shown in the slide examples, the two UPDATE statements initialize the resume LOB locator value and populate its contents by supplying a literal value. This can also be done in an INSERT statement. A LOB column can be updated to:

- Another LOB value
- A NULL value
- A LOB locator with empty contents by using the EMPTY_*LOB() built-in function

You can update the LOB by using a bind variable in embedded SQL. When assigning one LOB to another, a new copy of the LOB value is created. Use a SELECT FOR UPDATE statement to lock the row containing the LOB column before updating a piece of the LOB.

Updating LOB by Using DBMS_LOB in PL/SQL

```
DECLARE
  lobloc CLOB;       -- serves as the LOB locator
  text   VARCHAR2(50) := 'Resigned = 5 June 2000';
  amount NUMBER ;    -- amount to be written
  offset INTEGER;    -- where to start writing
BEGIN
  SELECT resume INTO lobloc FROM emp_hiredata
  WHERE employee_id = 405 FOR UPDATE;
  offset := DBMS_LOB.GETLENGTH(lobloc) + 2;
  amount := length(text);
  DBMS_LOB.WRITE (lobloc, amount, offset, text);
  text := ' Resigned = 30 September 2000';
  SELECT resume INTO lobloc FROM emp_hiredata
  WHERE employee_id = 170 FOR UPDATE;
  amount := length(text);
  DBMS_LOB.WRITEAPPEND(lobloc, amount, text);
  COMMIT;
END;
```

ORACLE

Updating LOB by Using DBMS_LOB in PL/SQL

In the example in the slide, the LOBLOC variable serves as the LOB locator, and the AMOUNT variable is set to the length of the text you want to add. The SELECT FOR UPDATE statement locks the row and returns the LOB locator for the RESUME LOB column. Finally, the PL/SQL WRITE package procedure is called to write the text into the LOB value at the specified offset. WRITEAPPEND appends to the existing LOB value.

The example shows how to fetch a CLOB column in releases before Oracle9*i*. In those releases, it was not possible to fetch a CLOB column directly into a character column. The column value needed to be bound to a LOB locator, which is accessed by the DBMS_LOB package. An example later in this lesson shows that you can directly fetch a CLOB column by binding it to a character variable.

Note: Versions prior to Oracle9*i* did not allow LOBs in the WHERE clause of UPDATE and SELECT statements. Now SQL functions of LOBs are allowed in predicates of WHERE. An example is shown later in this lesson.

Selecting CLOB Values by Using SQL

```
SELECT employee_id, full_name , resume -- CLOB
FROM emp_hiredata
WHERE employee_id IN (405, 170);
```

EMPLOYEE_ID	FULL_NAME	RESUME
405	Marvin Ellis	Date of Birth: 8 February 1951 Resigned = 5 June 2000
170	Joe Fox	Date of Birth: 1 June 1956 Resigned = 30 September 2000

Selecting CLOB Values by Using SQL

It is possible to see the data in a CLOB column by using a SELECT statement. It is not possible to see the data in a BLOB or BFILE column by using a SELECT statement in *i*SQL*Plus. You have to use a tool that can display binary information for a BLOB, as well as the relevant software for a BFILE—for example, you can use Oracle Forms.

Selecting `CLOB` Values by Using `DBMS_LOB`

- `DBMS_LOB.SUBSTR` (lob, amount, start_pos)
- `DBMS_LOB.INSTR` (lob, pattern)

```
SELECT DBMS_LOB.SUBSTR (resume, 5, 18),
       DBMS_LOB.INSTR (resume,' = ')
FROM   emp_hiredata
WHERE  employee_id IN (170, 405);
```

DBMS_LOB.SUBSTR(RESUME,5,18)	DBMS_LOB.INSTR(RESUME,'=')
Febru	40
June	36

ORACLE

Selecting `CLOB` Values by Using `DBMS_LOB`

`DBMS_LOB.SUBSTR`

Use `DBMS_LOB.SUBSTR` to display a part of a `LOB`. It is similar in functionality to the `SUBSTR` SQL function.

`DBMS_LOB.INSTR`

Use `DBMS_LOB.INSTR` to search for information within the `LOB`. This function returns the numerical position of the information.

Note: Starting with Oracle9*i*, you can also use the `SUBSTR` and `INSTR` SQL functions to perform the operations shown in the slide.

Selecting CLOB Values in PL/SQL

```
SET LINESIZE 50 SERVEROUTPUT ON FORMAT WORD_WRAP
DECLARE
  text VARCHAR2(4001);
BEGIN
 SELECT resume INTO text
 FROM emp_hiredata
 WHERE employee_id = 170;
 DBMS_OUTPUT.PUT_LINE('text is: '|| text);
END;
/
```

```
text is: Date of Birth: 1 June 1956 Resigned = 30
September 2000

PL/SQL procedure successfully completed.
```


Selecting CLOB Values in PL/SQL

The slide shows the code for accessing CLOB values that can be implicitly converted to VARCHAR2 in Oracle10*g*. When selected, the RESUME column value is implicitly converted from a CLOB into a VARCHAR2 to be stored in the TEXT variable. Prior to Oracle9*i*, you first retrieved the CLOB locator value into a CLOB variable, and then read the LOB contents specifying the amount and offset in the DBMS_LOB.READ procedure:

```
DECLARE
  rlob   CLOB;
  text   VARCHAR2(4001);
  amt    NUMBER := 4001;
  offset NUMBER := 1;
BEGIN
 SELECT resume INTO rlob FROM emp_hirdata
 WHERE employee_id = 170;
 DBMS_LOB.READ(rlob, amt, offset, text);
 DBMS_OUTPUT.PUT_LINE('text is: '|| text);
END;
/
text is: Date of Birth: 1 June 1956 Resigned = 30 September 2000
PL/SQL procedure successfully completed.
```

Removing LOBs

- Delete a row containing LOBs:

```
DELETE
FROM   emp_hiredata
WHERE  employee_id = 405;
```

- Disassociate a LOB value from a row:

```
UPDATE emp_hiredata
SET resume = EMPTY_CLOB()
WHERE employee_id = 170;
```


Removing LOBs

A LOB instance can be deleted (destroyed) using appropriate SQL DML statements. The SQL statement DELETE deletes a row and its associated internal LOB value. To preserve the row and destroy only the reference to the LOB, you must update the row by replacing the LOB column value with NULL or an empty string, or by using the EMPTY_B/CLOB() function.

Note: Replacing a column value with NULL and using EMPTY_B/CLOB are not the same. Using NULL sets the value to null; using EMPTY_B/CLOB ensures that there is nothing in the column.

A LOB is destroyed when the row containing the LOB column is deleted, when the table is dropped or truncated, or when all the LOB data is updated.

You must explicitly remove the file associated with a BFILE using OS commands.

To erase part of an internal LOB, you can use DBMS_LOB.ERASE.

Temporary LOBs

- Temporary LOBs:
  - Provide an interface to support creation of LOBs that act like local variables
  - Can be BLOBs, CLOBs, or NCLOBs
  - Are not associated with a specific table
  - Are created using the DBMS_LOB.CREATETEMPORARY procedure
  - Use DBMS_LOB routines
- The lifetime of a temporary LOB is a session.
- Temporary LOBs are useful for transforming data in permanent internal LOBs.

Temporary LOBs

Temporary LOBs provide an interface to support the creation and deletion of LOBs that act like local variables. Temporary LOBs can be BLOBs, CLOBs, or NCLOBs.

The following are the features of temporary LOBs:

- Data is stored in your temporary tablespace, not in tables.
- Temporary LOBs are faster than persistent LOBs because they do not generate any redo or rollback information.
- Temporary LOBs lookup is localized to each user's own session. Only the user who creates a temporary LOB can access it, and all temporary LOBs are deleted at the end of the session in which they were created.
- You can create a temporary LOB using DBMS_LOB.CREATETEMPORARY.

Temporary LOBs are useful when you want to perform some transformational operation on a LOB (for example, changing an image type from GIF to JPEG). A temporary LOB is empty when created and does not support the EMPTY_B/CLOB functions.

Use the DBMS_LOB package to use and manipulate temporary LOBs.

Creating a Temporary LOB

PL/SQL procedure to create and test a temporary LOB:

```
CREATE OR REPLACE PROCEDURE is_templob_open(
  lob IN OUT BLOB, retval OUT INTEGER) IS
BEGIN
  -- create a temporary LOB
  DBMS_LOB.CREATETEMPORARY (lob, TRUE);
  -- see if the LOB is open: returns 1 if open
  retval := DBMS_LOB.ISOPEN (lob);
  DBMS_OUTPUT.PUT_LINE (
    'The file returned a value...' || retval);
  -- free the temporary LOB
  DBMS_LOB.FREETEMPORARY (lob);
END;
/
```


Creating a Temporary LOB

The example in the slide shows a user-defined PL/SQL procedure, is_templob_open, which creates a temporary LOB. This procedure accepts a LOB locator as input, creates a temporary LOB, opens it, and tests whether the LOB is open.

The is_templob_open procedure uses the procedures and functions from the DBMS_LOB package as follows:

- The CREATETEMPORARY procedure is used to create the temporary LOB.
- The ISOPEN function is used to test whether a LOB is open: this function returns the value 1 if the LOB is open.
- The FREETEMPORARY procedure is used to free the temporary LOB. Memory increases incrementally as the number of temporary LOBs grows, and you can reuse temporary LOB space in your session by explicitly freeing temporary LOBs.

Summary

In this lesson, you should have learned how to:

- Identify four built-in types for large objects: `BLOB`, `CLOB`, `NCLOB`, and `BFILE`
- Describe how `LOB`s replace `LONG` and `LONG RAW`
- Describe two storage options for `LOB`s:
  - Oracle server (internal `LOB`s)
  - External host files (external `LOB`s)
- Use the `DBMS_LOB` PL/SQL package to provide routines for `LOB` management
- Use temporary `LOB`s in a session

Summary

There are four `LOB` data types:

- A `BLOB` is a binary large object.
- A `CLOB` is a character large object.
- An `NCLOB` stores multibyte national character set data.
- A `BFILE` is a large object stored in a binary file outside the database.

`LOB`s can be stored internally (in the database) or externally (in an OS file). You can manage `LOB`s by using the `DBMS_LOB` package and its procedure.

Temporary `LOB`s provide an interface to support the creation and deletion of `LOB`s that act like local variables.

Practice 9: Overview

This practice covers the following topics:

- Creating object types using the CLOB and BLOB data types
- Creating a table with LOB data types as columns
- Using the DBMS_LOB package to populate and interact with the LOB data

Practice 9: Overview

In this practice, you create a table with both BLOB and CLOB columns. Then you use the DBMS_LOB package to populate the table and manipulate the data.

Practice 9

1. Create a table called PERSONNEL by executing the script file E:\labs\PLPU\labs\lab_09_01.sql. The table contains the following attributes and data types:

Column Name	Data Type	Length
ID	NUMBER	6
last_name	VARCHAR2	35
review	CLOB	N/A
picture	BLOB	N/A

2. Insert two rows into the PERSONNEL table, one each for employee 2034 (whose last name is Allen) and for employee 2035 (whose last name is Bond). Use the empty function for the CLOB, and provide NULL as the value for the BLOB.
3. Examine and execute the E:\labs\PLPU\labs\lab_09_03.sql script. The script creates a table named REVIEW_TABLE. This table contains annual review information for each employee. The script also contains two statements to insert review details for two employees.
4. Update the PERSONNEL table.
   a. Populate the CLOB for the first row, using this subquery in an UPDATE statement:
   ```
   SELECT ann_review
   FROM   review_table
   WHERE  employee_id = 2034;
   ```
   b. Populate the CLOB for the second row, using PL/SQL and the DBMS_LOB package. Use the following SELECT statement to provide a value for the LOB locator.
   ```
   SELECT ann_review
   FROM   review_table
   WHERE  employee_id = 2035;
   ```

If you have time, complete the following exercise:

5. Create a procedure that adds a locator to a binary file into the PICTURE column of the COUNTRIES table. The binary file is a picture of the country flag. The image files are named after the country IDs. You need to load an image file locator into all rows in the Europe region (REGION_ID = 1) in the COUNTRIES table. A DIRECTORY object called COUNTRY_PIC referencing the location of the binary files has to be created for you.
   a. Add the image column to the COUNTRIES table using:
   ```
   ALTER TABLE countries ADD (picture BFILE);
   ```
   Alternatively, use the E:\labs\PLPU\labs\Lab_09_05_a.sql file.
   b. Create a PL/SQL procedure called load_country_image that uses DBMS_LOB.FILEEXISTS to test whether the country picture file exists. If the file exists, then set the BFILE locator for the file in the PICTURE column; otherwise, display a message that the file does not exist. Use the DBMS_OUTPUT package to report file size information for each image associated with the PICTURE column.
   c. Invoke the procedure by passing the name of the directory object COUNTRY_PIC as a string literal parameter value.

10

Creating Triggers

Objectives

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

- Describe the different types of triggers
- Describe database triggers and their uses
- Create database triggers
- Describe database trigger-firing rules
- Remove database triggers

Lesson Aim

In this lesson, you learn how to create and use database triggers.

Types of Triggers

A trigger:

- Is a PL/SQL block or a PL/SQL procedure associated with a table, view, schema, or database
- Executes implicitly whenever a particular event takes place
- Can be either of the following:
  - Application trigger: Fires whenever an event occurs with a particular application
  - Database trigger: Fires whenever a data event (such as DML) or system event (such as logon or shutdown) occurs on a schema or database

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).

Note: Database triggers can be defined on tables and on views. If a DML operation is issued on a view, then the `INSTEAD OF` trigger defines what actions take place. If these actions include DML operations on tables, then any triggers on the base tables are fired.

Database triggers can be system triggers on a database or a schema. For databases, triggers fire for each event for all users; for a schema, they fire for each event for that specific user.

This course explains how to create database triggers. Creating database triggers based on system events is discussed in the lesson titled "Applications for Triggers."

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.
- The excessive use of triggers can result in complex interdependencies, which may be difficult to maintain in large applications.

ORACLE

Guidelines for Designing Triggers

- Use triggers to guarantee that related actions are performed for a specific operation.
- Use database triggers 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, not 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.

Creating DML Triggers

Create DML statement or row type triggers by using:

```
CREATE [OR REPLACE] TRIGGER trigger_name
 timing
 event1 [OR event2 OR event3]
ON object_name
[[REFERENCING OLD AS old | NEW AS new]
 FOR EACH ROW
 [WHEN (condition)]]
trigger_body
```

- A statement trigger fires once for a DML statement.
- A row trigger fires once for each row affected.

Note: Trigger names must be unique with respect to other triggers in the same schema.

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;`

Types of DML Triggers

The trigger type determines whether the body executes for each row or only once for the triggering statement.

- A statement trigger:
  - Executes once for the triggering event
  - Is the default type of trigger
  - Fires once even if no rows are affected at all
- A row trigger:
  - Executes once for each row affected by the triggering event
  - Is not executed if the triggering event does not affect any rows
  - Is indicated by specifying the `FOR EACH ROW` clause

ORACLE

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.

Trigger Timing

When should the trigger fire?

- BEFORE: Execute 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.

Note: If multiple triggers are defined for the same object, then the order of firing triggers is arbitrary.

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.

Note: If multiple triggers are defined for a table, then the order in which multiple triggers of the same type fire is arbitrary. To ensure that triggers of the same type are fired in a particular order, consolidate the triggers into one trigger that calls separate procedures in the desired order.

Trigger-Firing Sequence

Use the following firing sequence for a trigger on a table when a single row is manipulated:

DML statement

```
INSERT INTO departments
   (department_id,department_name, location_id)
VALUES (400, 'CONSULTING', 2400);
```

Triggering action

→ **BEFORE statement trigger**

DEPARTMENT_ID	DEPARTMENT_NAME	LOCATION_ID
10	Administration	1700
20	Marketing	1800
30	Purchasing	1700
...		
400	CONSULTING	2400

→ **BEFORE row trigger**

→ **AFTER row trigger**

→ **AFTER statement trigger**

ORACLE

Trigger-Firing Sequence

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

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;
```

→ BEFORE statement trigger

EMPLOYEE_ID	LAST_NAME	DEPARTMENT_ID
114	Raphaely	30
115	Khoo	30
116	Baida	30
117	Tobias	30
118	Himuro	30
119	Colmenares	30

→ BEFORE row trigger
→ AFTER row trigger
...
→ BEFORE row trigger
→ AFTER row trigger
...
→ AFTER statement trigger

ORACLE

Trigger-Firing Sequence (continued)

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).

Trigger Event Types and Body

A trigger event:

- Determines which DML statement causes the trigger to execute
- Types are:
  - `INSERT`
  - `UPDATE [OF column]`
  - `DELETE`

A trigger body:

- Determines what action is performed
- Is a PL/SQL block or a `CALL` to a procedure

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 . . .
```

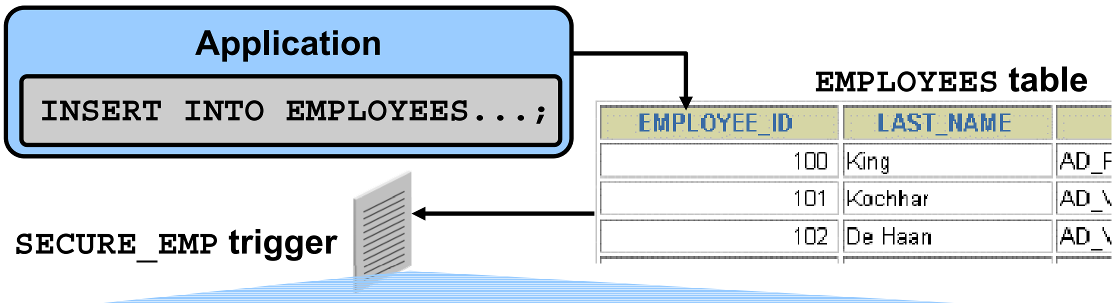
- The triggering event can contain one, two, or all three of these DML operations.

```
. . . 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 a DML Statement Trigger




```
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 '
    ||' business hours.');
  END IF;
END;
```


Creating a DML Statement Trigger

In this 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 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);
```

```
INSERT INTO employees (employee_id, last_name, first_name, email,
      *
ERROR at line 1:
ORA-20500: You may insert into EMPLOYEES table only during business hours.
ORA-06512: at "PLSQL.SECURE_EMP", line 4
ORA-04088: error during execution of trigger 'PLSQL.SECURE_EMP'
```


Testing SECURE_EMP

Insert a row into the EMPLOYEES table during nonbusiness hours. When the date and time are out of the business timings 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 business hours.');
   ELSIF INSERTING THEN RAISE_APPLICATION_ERROR(
    -20500,'You may insert into EMPLOYEES table'||
           'only during business hours.');
   ELSIF UPDATING('SALARY') THEN
    RAISE_APPLICATION_ERROR(-20503, 'You may '||
     'update SALARY only during business hours.');
   ELSE RAISE_APPLICATION_ERROR(-20504,'You may'||
     ' update EMPLOYEES table only during'||
     ' normal hours.');
   END IF;
 END IF;
END;
```

ORACLE

Combining Triggering Events

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;
/
```


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 example, a trigger is created to allow certain employees to be able to earn a salary of more than 15,000. Suppose that a user attempts to execute the following UPDATE statement:

```
UPDATE employees
SET salary = 15500
WHERE last_name = 'Russell';
```

The trigger raises the following exception:

```
UPDATE EMPLOYEES
   *
ERROR at line 1:
ORA-20202: Employee cannot earn more than $15,000.
ORA-06512: at "PLSQL.RESTRICT_SALARY", line 5
ORA-04088: error during execution of trigger
"PLSQL.RESTRICT_SALARY"
```

Using OLD and NEW Qualifiers

```
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;
/
```


Using OLD and NEW Qualifiers

Within a ROW trigger, reference the value of a column before and after the data change by prefixing it with the OLD and NEW qualifiers.

Data Operation	Old Value	New Value
INSERT	NULL	Inserted value
UPDATE	Value before update	Value after update
DELETE	Value before delete	NULL

Usage notes:

- 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.

Note: Row triggers can decrease the performance if you perform many updates on larger tables.

Using OLD and NEW Qualifiers: Example Using AUDIT_EMP

```
INSERT INTO employees
 (employee_id, last_name, job_id, salary, ...)
VALUES (999, 'Temp emp', 'SA_REP', 6000,...);

UPDATE employees
 SET salary = 7000, last_name = 'Smith'
 WHERE employee_id = 999;
```

```
SELECT user_name, timestamp, ...
FROM audit_emp;
```

USER_NAME	TIME_STAMP	ID	OLD_LAST_NAME	NEW_LAST_NAME	OLD_TITLE	NEW_TITLE	OLD_SALARY	NEW_SALARY
ORA25	31-MAR-06			Temp emp		SA_REP		6000
ORA25	31-MAR-06	999	Temp emp	Smith	SA_REP	SA_REP	6000	7000

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.

There is an additional column named COMMENTS in AUDIT_EMP that is not shown in this slide.

Restricting a Row Trigger: Example

```
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;
/
```

ORACLE

Restricting a Row Trigger: Example

To restrict the trigger action to those rows that satisfy a certain condition, provide a WHEN clause.

Create a trigger 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:
   a. Execute all `BEFORE ROW` triggers.
   b. Execute the DML statement and perform integrity constraint checking.
   c. Execute all `AFTER ROW` triggers.
3. Execute all `AFTER STATEMENT` triggers.

Note: Integrity checking can be deferred until the `COMMIT` operation is performed.

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).

Implementing an Integrity Constraint with a Trigger

```
UPDATE employees SET department_id = 999
 WHERE employee_id = 170;
-- Integrity constraint violation error
```

```
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;
/
```

```
UPDATE employees SET department_id = 999
 WHERE employee_id = 170;
-- Successful after trigger is fired
```


Implementing an Integrity Constraint with a Trigger

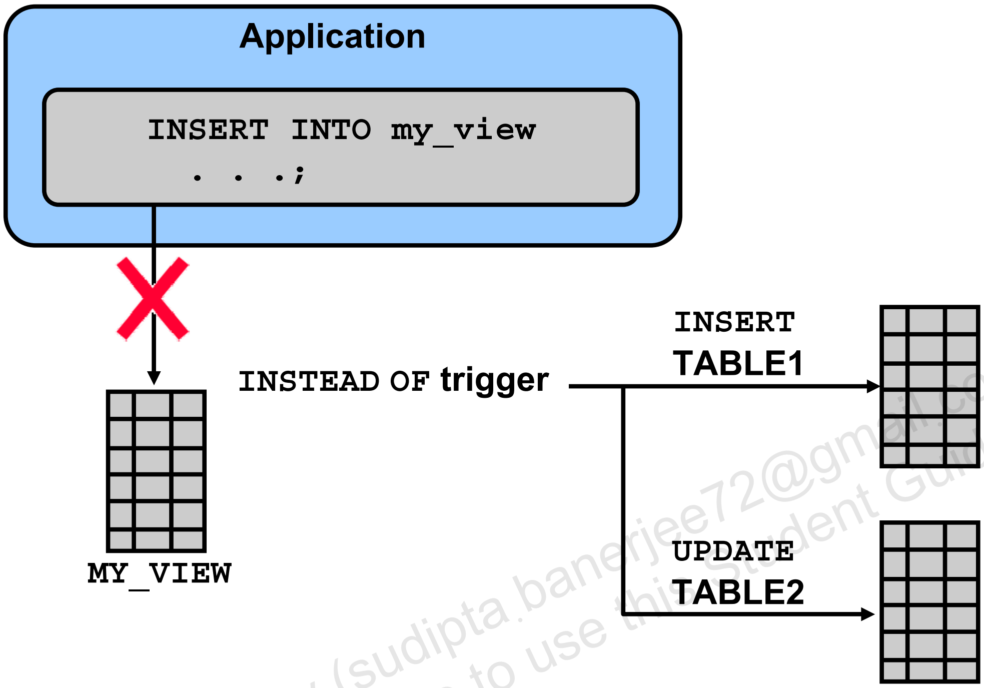
The example in the slide explains a situation in which the integrity constraint can be taken care of by using a trigger. The EMPLOYEES table has a foreign key constraint on the DEPARTMENT_ID column of the DEPARTMENTS table.

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.

Note: This example works with Oracle8*i* and later releases but produces a run-time error in releases prior to Oracle8*i*.

INSTEAD OF Triggers



INSTEAD OF Triggers

Use INSTEAD OF triggers to modify data in which the DML statement has been issued against an inherently nonupdatable 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

Perform the INSERT into EMP_DETAILS that is based on EMPLOYEES and DEPARTMENTS tables:

```
INSERT INTO emp_details
VALUES (9001,'ABBOTT',3000, 10, 'Administration');
```

1 INSTEAD OF INSERT into EMP_DETAILS

EMPLOYEE_ID	LAST_NAME	DEPARTMENT_ID
100	King	90
101	Kochhar	90
102	De Haan	90

2 INSERT into NEW_EMPS

EMPLOYEE_ID	LAST_NAME	SALARY	DEPARTMENT_ID
100	King	24000	90
101	Kochhar	17000	90
102	De Haan	17000	90
...			
9001	ABBOTT	3000	10

3 UPDATE NEW_DEPTS

DEPARTMENT_ID	DEPARTMENT_NAME	DEPT_SA
10	Administration	940
20	Marketing	1900
30	Purchasing	3012
40	Human Resources	650
...		

ORACLE

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 example illustrates an employee being inserted into 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: The code for this scenario is shown in the next few pages.

Creating an INSTEAD OF Trigger

Use INSTEAD OF 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;
```


Creating an INSTEAD OF Trigger (continued)

The example creates two new tables, NEW_EMPS and NEW_DEPTS, 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;
/
```

Comparison of Database Triggers and Stored Procedures

Triggers	Procedures
Defined with `CREATE TRIGGER`	Defined with `CREATE PROCEDURE`
Data dictionary contains source code in `USER_TRIGGERS`.	Data dictionary contains source code in `USER_SOURCE`.
Implicitly invoked by DML	Explicitly invoked
`COMMIT`, `SAVEPOINT`, and `ROLLBACK` are not allowed.	`COMMIT`, `SAVEPOINT`, and `ROLLBACK` are allowed.

Comparison of Database Triggers and Stored Procedures

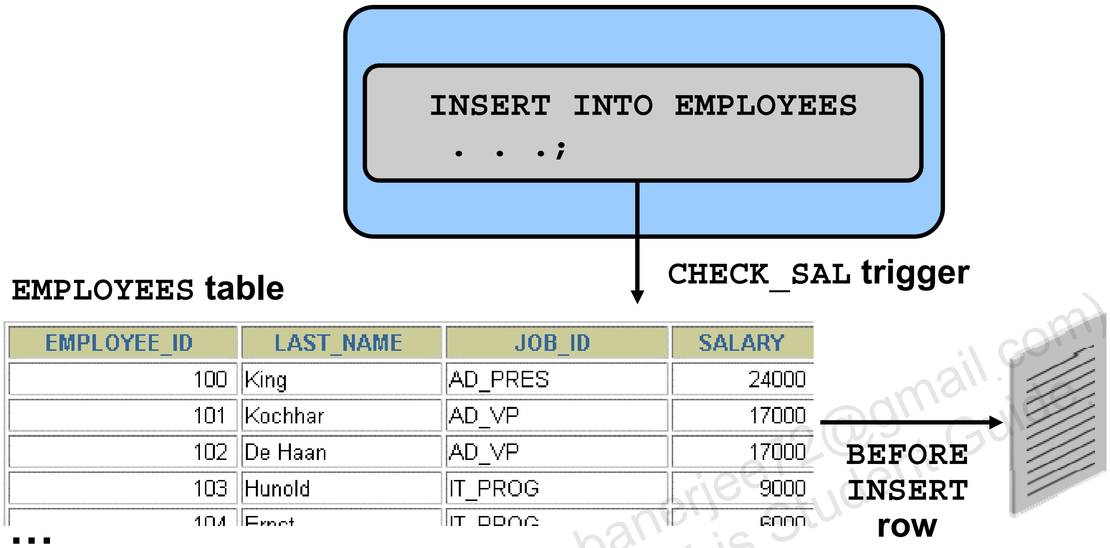
There are differences between database triggers and stored procedures:

Database Trigger	Stored Procedure
Invoked implicitly	Invoked explicitly
`COMMIT`, `ROLLBACK`, and `SAVEPOINT` statements are not allowed within the trigger body. It is possible to commit or roll back indirectly by calling a procedure, but it is not recommended because of side effects to transactions.	`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.

Comparison of Database Triggers and Oracle Forms Triggers



Comparison of Database Triggers and Oracle Forms Triggers

Database triggers are different from Forms Builder 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 action	Can be triggered by navigating from field to field, by pressing a key, or by many other actions
Is distinguished as either a statement or row trigger	Is distinguished as a statement or row trigger
Upon failure, causes the triggering statement to roll back	Upon failure, causes the cursor to freeze and may cause the entire transaction to 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

Managing Triggers

- Disable or reenable a database trigger:

```
ALTER TRIGGER trigger_name DISABLE | ENABLE
```

- Disable or reenable all triggers for a table:

```
ALTER TABLE table_name DISABLE | ENABLE
  ALL TRIGGERS
```

- Recompile a trigger for a table:

```
ALTER TRIGGER trigger_name COMPILE
```


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

- By using the ALTER TRIGGER syntax, or disable all triggers on a table by using the ALTER TABLE syntax
- To improve performance or to avoid data integrity checks when loading massive amounts of data with utilities such as SQL*Loader. Consider disabling 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

- By using the ALTER TRIGGER command to explicitly recompile a trigger that is invalid
- By issuing an ALTER TRIGGER statement with the COMPILE option, regardless of whether it is valid or invalid

Removing Triggers

To remove a trigger from the database, use the `DROP TRIGGER` statement:

```
DROP TRIGGER trigger_name;
```

Example:

```
DROP TRIGGER secure_emp;
```

Note: All triggers on a table are removed when the table is removed.

Removing Triggers

When a trigger is no longer required, use a SQL statement in *i*SQL*Plus to remove it.

Testing Triggers

- Test each triggering data operation, as well as nontriggering 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.

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.

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

ORACLE

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 10: Overview

This practice covers the following topics:

- Creating row triggers
- Creating a statement trigger
- Calling procedures from a trigger

ORACLE

Practice 10: Overview

You create statement and row triggers in this practice. You create procedures that are invoked from the triggers.

Practice 10

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. Write a procedure called CHECK_SALARY that accepts two parameters, one for an employee's job ID string and the other for the salary. The procedure uses the job ID to determine the minimum and maximum salary for the specified job. 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. The trigger must call the CHECK_SALARY procedure to carry out the business logic. 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.
   b. Test the trigger by executing the EMP_PKG.ADD_EMPLOYEE procedure with the following parameter values: first_name='Eleanor', last name='Beh', email='EBEH', job='IT_PROG', 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?

Practice 10 (continued)

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 a.m. to 6:00 p.m.
   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.

11 Applications for Triggers

Objectives

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

- Create additional database triggers
- Explain the rules governing triggers
- Implement triggers

Lesson Aim

In this lesson, you learn how to create more database triggers and learn the rules governing triggers. You also learn about the many applications of triggers.

Creating Database Triggers

- Triggering a 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

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, and 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 DDL Statements

Syntax:

```
CREATE [OR REPLACE] TRIGGER trigger_name
Timing
[ddl_event1 [OR ddl_event2 OR ...]]
ON {DATABASE|SCHEMA}
trigger_body
```


Creating Triggers on DDL Statements

DDL_Event	Possible Values
CREATE	Causes the Oracle server to fire the trigger whenever a CREATE statement adds a new database object to the dictionary
ALTER	Causes the Oracle server to fire the trigger whenever an ALTER statement modifies a database object in the data dictionary
DROP	Causes the Oracle server to fire the trigger whenever a DROP statement removes a database object in the data dictionary

The trigger body represents a complete PL/SQL block.

You can create triggers for these events on DATABASE or SCHEMA. You also specify BEFORE or AFTER for the timing of the trigger.

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 Triggers on System Events

Syntax:

```
CREATE [OR REPLACE] TRIGGER trigger_name
timing
[database_event1 [OR database_event2 OR ...]]
ON {DATABASE|SCHEMA}
trigger_body
```


Create Trigger Syntax

Database_event	Possible Values
AFTER SERVERERROR	Causes the Oracle server to fire the trigger whenever a server error message is logged
AFTER LOGON	Causes the Oracle server to fire the trigger whenever a user logs on to the database
BEFORE LOGOFF	Causes the Oracle server to fire the trigger whenever a user logs off the database
AFTER STARTUP	Causes the Oracle server to fire the trigger whenever the database is opened
BEFORE SHUTDOWN	Causes the Oracle server to fire the trigger whenever the database is shut down

You can create triggers for these events on `DATABASE` or `SCHEMA`, except `SHUTDOWN` and `STARTUP`, which apply only to `DATABASE`.

LOGON and LOGOFF Triggers: Example

```
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;
/
```


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.

CALL Statements

```
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 TRIGGER log_employee
BEFORE INSERT ON EMPLOYEES
CALL log_execution
/
```

Note: There is no semicolon at the end of the CALL statement.

CALL Statements

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.

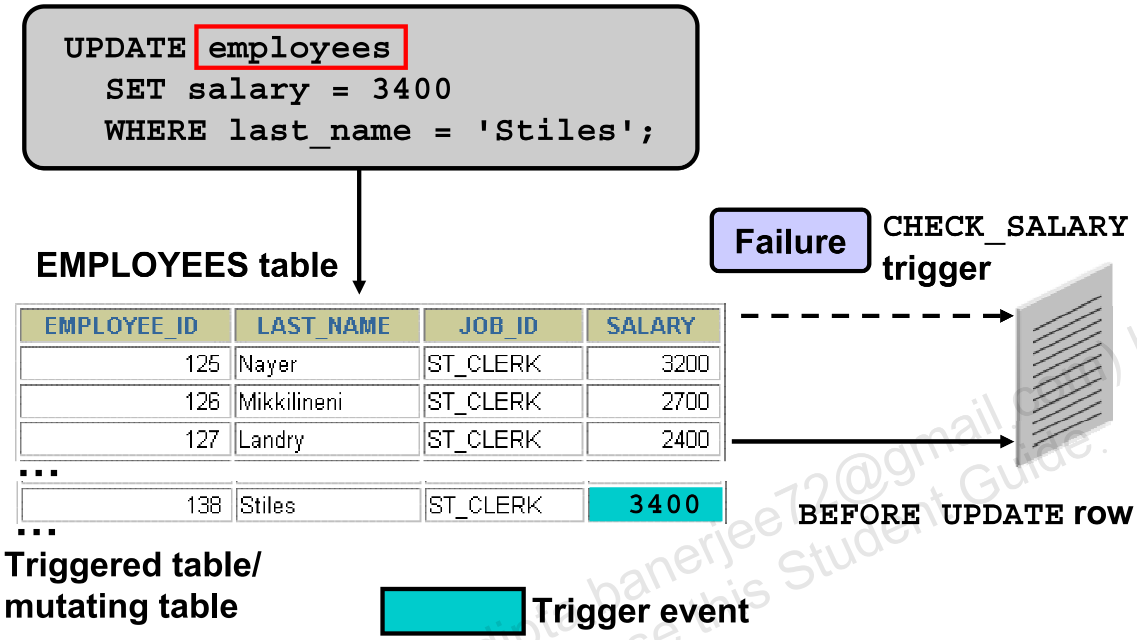
The call can reference the trigger attributes :NEW and :OLD as parameters, as in the following example:

```
CREATE 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.

Reading Data from a Mutating Table



EMPLOYEE_ID	LAST_NAME	JOB_ID	SALARY
125	Nayer	ST_CLERK	3200
126	Mikkilineni	ST_CLERK	2700
127	Landry	ST_CLERK	2400
...			
138	Stiles	ST_CLERK	3400
...			

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.

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
  minsalary employees.salary%TYPE;
  maxsalary employees.salary%TYPE;
BEGIN
  SELECT MIN(salary), MAX(salary)
   INTO  minsalary, maxsalary
   FROM  employees
   WHERE job_id = :NEW.job_id;
  IF :NEW.salary < minsalary OR
     :NEW.salary > maxsalary THEN
     RAISE_APPLICATION_ERROR(-20505,'Out of range');
  END IF;
END;
/
```


Mutating Table: Example

The CHECK_SALARY trigger in the 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';
```

```
UPDATE employees
     *
ERROR at line 1:
ORA-04091: table PLSQL.EMPLOYEES is mutating, trigger/function may not see it
ORA-06512: at "PLSQL.CHECK_SALARY", line 5
ORA-04088: error during execution of trigger 'PLSQL.CHECK_SALARY'
```

ORACLE

Mutating Table: Example (continued)

In the 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:

- 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.

Benefits of Database 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

Benefits of Database 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

Managing 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)

Note: 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.

Managing Triggers

To create a trigger in your schema, you need the CREATE TRIGGER system privilege, and you must either 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, then 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. As with 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.

To create a trigger on DATABASE, you must have the ADMINISTER DATABASE TRIGGER privilege. If this privilege is later revoked, then you can drop the trigger but you cannot alter it.

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

Note: Appendix C covers each of these examples in more detail.

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.

Feature	Enhancement
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.

Viewing Trigger Information

You can view the following trigger information:

- `USER_OBJECTS` data dictionary view: Object information
- `USER_TRIGGERS` data dictionary view: Text of the trigger
- `USER_ERRORS` data dictionary view: PL/SQL syntax errors (compilation errors) of the trigger

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

Column	Column Description
TRIGGER_NAME	Name of the trigger
TRIGGER_TYPE	The type is BEFORE, AFTER, INSTEAD OF
TRIGGERING_EVENT	The DML operation firing the trigger
TABLE_NAME	Name of the database table
REFERENCING_NAMES	Name used for :OLD and :NEW
WHEN_CLAUSE	The when_clause used
STATUS	The status of the trigger
TRIGGER_BODY	The action to take

* Abridged column list

Using USER_TRIGGERS

If the source file is unavailable, then you can use *i*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.

Listing the Code of Triggers

```
SELECT trigger_name, trigger_type, triggering_event,
        table_name, referencing_names,
        status, trigger_body
FROM   user_triggers
WHERE  trigger_name = 'RESTRICT_SALARY';
```

TRIGGER_NAME	TRIGGER_TYPE	TRIGGERING_EVENT	TABLE_NAME	REFERENCING_NAMES	WHEN_CLAUS	STATUS	TRIGGER_BODY
RESTRICT_SALARY	BEFORE EACH ROW	INSERT OR UPDATE	EMPLOYEES	REFERENCING NEW AS NEW OLD AS OLD		ENABLED	BEGIN IF NOT (:NEW.JOB_ ID IN ('AD_PRES ', 'AD_VP')) AND :NE W.SAL

Example

Use the `USER_TRIGGERS` data dictionary view to display information about the `RESTRICT_SALARY` trigger.

Summary

In this lesson, you should have learned how to:

- Use advanced database triggers
- List mutating and constraining rules for triggers
- Describe real-world applications of triggers
- Manage triggers
- View trigger information

Practice 11: 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

Practice 11: 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 lesson titled "Creating Triggers." 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 11

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 (from Practice 7) by adding a procedure called SET_SALARY that updates the employees' salaries. The procedure accepts two parameters: the job ID for those salaries that may have to be updated, and the new minimum salary for the job ID. 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, you create a JOBS_PKG to maintain in memory a copy of the rows in the JOBS table. Then the CHECK_SALARY procedure is modified to use the package data rather than issue a query on a table that is mutating to avoid the exception. However, a BEFORE INSERT OR UPDATE statement trigger must be created 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);
   ```
   b. Implement the body of the JOBS_PKG, where:
   You declare a private PL/SQL index-by table called jobs_tabtype that is indexed by a string type based on the JOBS.JOB_ID%TYPE.
   You declare a private variable called jobstab based on the jobs_tabtype.
   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. The GET_MINSALARY function uses a jobid parameter as an index to the jobstab and returns the min_salary for that element. The GET_MAXSALARY function uses a jobid parameter as an index to the jobstab and returns the max_salary for that element.

Practice 11 (continued)

The SET_MINSALARY procedure uses its jobid as an index to the jobstab to set the min_salary field of its element to the value in the min_salary parameter.
The SET_MAXSALARY procedure uses its 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 1a, 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, 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?

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, create a BEFORE INSERT OR UPDATE statement trigger called EMPLOYEE_INITJOBS_TRG on the EMPLOYEES table that calls the JOBS_PKG.INITIALIZE procedure. 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.

12

Understanding and Influencing the PL/SQL Compiler

Objectives

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

- Describe native and interpreted compilations
- List the features of native compilation
- Switch between native and interpreted compilations
- Set parameters that influence PL/SQL compilation
- Query data dictionary views on how PL/SQL code is compiled
- Use the compiler warning mechanism and the `DBMS_WARNING` package to implement compiler warnings

Lesson Aim

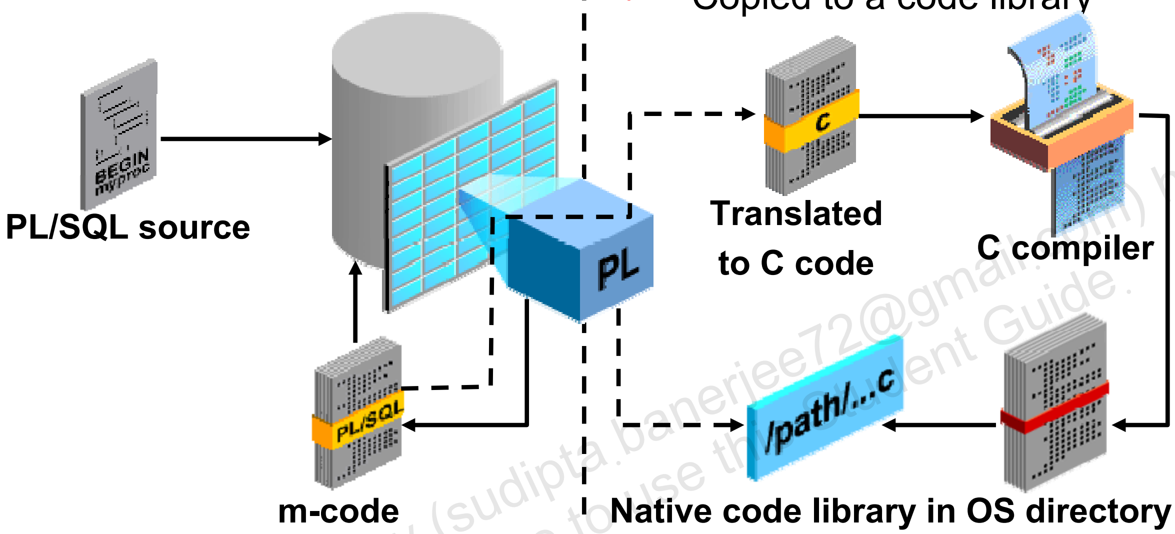
In this lesson, you learn to distinguish between native and interpreted compilation of PL/SQL code. The lesson discusses how to use native compilation, which is the default, for Oracle Database 10*g* with the benefit of having faster execution time for your PL/SQL code.

You also learn how to influence the compiler settings by setting variable session parameters, or using the programmatic interface provided by the `DBMS_WARNING` package. The lesson covers query compilation settings using the `USER_STORED_SETTINGS` and `USER_PLSQL_OBJECTS` data dictionary views.

Native and Interpreted Compilation

Interpreted code
- Compiled to m-code
- Stored in the database

Natively compiled code
- Translated C and compiled
- Copied to a code library



Native and Interpreted Compilation

As depicted in the slide, on the left of the vertical dotted line, a program unit processed as interpreted PL/SQL is compiled into machine-readable code (m-code), which is stored in the database and interpreted at run time.

On the right of the vertical dotted line, the PL/SQL source is subjected to native compilation, where the PL/SQL statements are compiled to m-code that is translated into C code. The m-code is not retained. The C code is compiled with the usual C compiler and linked to the Oracle process using native machine code library. The code library is stored in the database but copied to a specified directory path in the operating system, from which it is loaded at run time. Native code bypasses the typical run-time interpretation of code.

Note: Native compilation cannot do much to speed up SQL statements called from PL/SQL, but it is most effective for computation-intensive PL/SQL procedures that do not spend most of their time executing SQL.

You can natively compile both the supplied Oracle packages and your own PL/SQL code. Compiling all PL/SQL code in the database means that you see the speedup in your own code and all the built-in PL/SQL packages. If you decide that you will have significant performance gains in database operations using PL/SQL native compilation, Oracle recommends that you compile the whole database using the `NATIVE` setting.

Features and Benefits of Native Compilation

Native compilation:

- Uses a generic `makefile` that uses the following operating system software:
  - C compiler
  - Linker
  - Make utility
- Generates shared libraries that are copied to the file system and loaded at run time
- Provides better performance (up to 30% faster than interpreted code) for computation-intensive procedural operations

Features and Benefits of Native Compilation

The PL/SQL native compilation process makes use of a `makefile`, called `spnc_makefile.mk`, located in the `$ORACLE_HOME/plsql` directory. The `makefile` is processed by the Make utility that invokes the C compiler, which is the linker on the supported operating system, to compile and link the resulting C code into shared libraries. The shared libraries are stored inside the database and are copied to the file system. At run time, the shared libraries are loaded and run when the PL/SQL subprogram is invoked.

In accordance with Optimal Flexible Architecture (OFA) recommendations, the shared libraries should be stored near the data files. C code runs faster than PL/SQL, but it takes longer to compile than m-code. PL/SQL native compilation provides the greatest performance gains for computation-intensive procedural operations.

Examples of such operations are data warehouse applications and applications with extensive server-side transformations of data for display. In such cases, expect speed increases of up to 30%.

Considerations When Using Native Compilation

Consider the following:

- Debugging tools for PL/SQL cannot debug natively compiled code.
- Natively compiled code is slower to compile than interpreted code.
- Large amounts of natively compiled subprograms can affect performance due to operating system– imposed limitations when handling shared libraries. OS directory limitations can be managed by setting database initialization parameters:
  – `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` and
  – `PLSQL_NATIVE_LIBRARY_DIR`

Limitations of Native Compilation

As stated, the key benefit of natively compiled code is faster execution, particularly for computationally intensive PL/SQL code, as much as 30% more. Consider that:

- Debugging tools for PL/SQL do not handle procedures compiled for native execution. Therefore, use interpreted compilation in development environments, and natively compile the code in a production environment.
- The compilation time increases when using native compilation because of the requirement to translate the PL/SQL statement to its C equivalent and execute the Make utility to invoke the C compiler and linker for generating the resulting compiled code library.
- If many procedures and packages (more than 5,000) are compiled for native execution, a large number of shared objects in a single directory may affect performance. The operating system directory limitations can be managed by automatically distributing libraries across several subdirectories. To do this, perform the following tasks before natively compiling the PL/SQL code:
  - Set the `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` database initialization parameter to a large value, such as 1,000, before creating the database or compiling the PL/SQL packages or procedures.
  - Create `PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT` subdirectories in the path specified in the `PLSQL_NATIVE_LIBRARY_DIR` initialization parameter.

Parameters Influencing Compilation

System parameters are set in the `initSID.ora` file or by using the `SPFILE`:

```
PLSQL_NATIVE_LIBRARY_DIR = full-directory-path-name
PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT = count
```

System or session parameters

```
PLSQL_COMPILER_FLAGS = 'NATIVE' or 'INTERPRETED'
```


Parameters Influencing Compilation

In all circumstances, whether you intend to compile a database as NATIVE or you intend to compile individual PL/SQL units at the session level, you must set all required parameters.

The system parameters are set in the init*SID*.ora file by using the SPFILE mechanism. Two parameters that are set as system-level parameters are the following:

- The PLSQL_NATIVE_LIBRARY_DIR value, which specifies the full path and directory name used to store the shared libraries that contain natively compiled PL/SQL code
- The PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT value, which specifies the number of subdirectories in the directory specified by the PLSQL_NATIVE_LIBRARY_DIR parameter. Use a script to create directories with consistent names (for example, d0, d1, d2, and so on), and then the libraries are automatically distributed among these subdirectories by the PL/SQL compiler.

By default, PL/SQL program units are kept in one directory.

The PLSQL_COMPILER_FLAGS parameter can be set to a value of NATIVE or INTERPRETED, either as a database initialization for a systemwide default or for each session using an ALTER SESSION statement.

Switching Between Native and Interpreted Compilation

- Setting native compilation:
  - For the system:

```
ALTER SYSTEM SET plsql_compiler_flags='NATIVE';
```

  - For the session:

```
ALTER SESSION SET plsql_compiler_flags='NATIVE';
```

- Setting interpreted compilation:
  - For the system level:

```
ALTER SYSTEM
        SET plsql_compiler_flags='INTERPRETED';
```

  - For the session:

```
ALTER SESSION
        SET plsql_compiler_flags='INTERPRETED';
```


Switching Between Native and Interpreted Compilation

The PLSQL_COMPILER_FLAGS parameter determines whether PL/SQL code is natively compiled or interpreted, and determines whether debug information is included. The default setting is INTERPRETED,NON_DEBUG. To enable PL/SQL native compilation, you must set the value of PLSQL_COMPILER_FLAGS to NATIVE.

If you compile the whole database as NATIVE, then Oracle recommends that you set PLSQL_COMPILER_FLAGS at the system level.

To set compilation type at the system level (usually done by a DBA), execute the following statements:

```
ALTER SYSTEM SET plsql_compiler_flags='NATIVE'
ALTER SYSTEM SET plsql_compiler_flags='INTERPRETED'
```

To set compilation type at the session level, execute one of the following statements:

```
ALTER SESSION SET plsql_compiler_flags='NATIVE'
ALTER SESSION SET plsql_compiler_flags='INTERPRETED'
```

Viewing Compilation Information in the Data Dictionary

Query information in the following views:

- USER_STORED_SETTINGS
- USER_PLSQL_OBJECTS

Example:

```
SELECT param_value
FROM   user_stored_settings
WHERE  param_name = 'plsql_compiler_flags'
  AND  object_name = 'GET_EMPLOYEES';
```

Note: The PARAM_VALUE column has a value of NATIVE for procedures that are compiled for native execution; otherwise, it has a value of INTERPRETED.

ORACLE

Viewing Compilation Information in the Data Dictionary

To check whether an existing procedure is compiled for native execution or not, you can query the following data dictionary views:

```
[USER | ALL | DBA]_STORED_SETTINGS
[USER | ALL | DBA ]_PLSQL_OBJECTS
```

The example in the slide shows how you can check the status of the procedure called GET_EMPLOYEES. The PARAM_VALUE column has a value of NATIVE for procedures that are compiled for native execution; otherwise, it has a value of INTERPRETED.

After procedures are natively compiled and turned into shared libraries, they are automatically linked into the Oracle process. You do not need to restart the database, or move the shared libraries to a different location. You can call back and forth between stored procedures, whether they are all compiled interpreted (the default), all compiled for native execution, or a mixture of both.

Because the PLSQL_COMPILER_FLAGS setting is stored inside the library unit for each procedure, the procedures compiled for native execution are compiled the same way when the procedure is recompiled automatically after being invalidated, such as when a table that it depends on is re-created.

Using Native Compilation

To enable native compilation, perform the following steps:

1. Edit the supplied `makefile` and enter appropriate paths and other values for your system.
2. Set the `PLSQL_COMPILER_FLAGS` parameter (at system or session level) to the value `NATIVE`. The default is `INTERPRETED`.
3. Compile the procedures, functions, and packages.
4. Query the data dictionary to see that a procedure is compiled for native execution.

Using Native Compilation

To enable native compilation, perform the following steps:

1. Check and edit the compiler, linker, utility paths, and other values, if required.
2. Set the `PLSQL_COMPILER_FLAGS` to `NATIVE`.
3. Compile the procedures, functions, and packages. Compiling can be done by:
   - Using the appropriate `ALTER PROCEDURE`, `ALTER FUNCTION`, or `ALTER PACKAGE` statements with the `COMPILE` option
   - Dropping the procedure and re-creating it
   - Running one of the SQL*Plus scripts that sets up a set of Oracle-supplied packages
   - Creating a database using a preconfigured initialization file with its `PLSQL_COMPILER_FLAGS` set to `NATIVE`
4. Confirm the compilation type using the appropriate data dictionary tables.

Note: Dependencies between database objects are handled in the same manner as in previous versions. If an object on which a natively compiled PL/SQL program unit depends changes, then the PL/SQL module is invalidated. The next time the same program unit is executed, the RDBMS attempts to revalidate the module. When a module is recompiled as part of revalidation, it is compiled using the setting that was used the last time the module was compiled, and it is saved in the `*_STORED_SETTINGS` view.

Compiler Warning Infrastructure

The PL/SQL compiler in Oracle Database 10*g* has been enhanced to produce warnings for subprograms. Warning levels:

- Can be set:
  - Declaratively with the `PLSQL_WARNINGS` initialization parameter
  - Programmatically using the `DBMS_WARNINGS` package
- Are arranged in three categories: severe, performance, and informational
- Can be enabled and disabled by category or a specific message

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.

ORACLE

Compiler Warning Infrastructure

The Oracle PL/SQL compiler can issue warnings when you compile subprograms that produce ambiguous results or use inefficient constructs. You can selectively enable and disable these warnings:

- Declaratively by setting the `PLSQL_WARNINGS` initialization parameter
- Programmatically using the `DBMS_WARNINGS` package

The warning level is arranged in the following categories: severe, performance, and informational. Warnings levels can be enabled or disabled by category or by a specific warning message number.

Benefits of Compiler Warnings

Using compiler warnings can help to:

- Make your programs more robust and avoid problems at run time
- Identify potential performance problems
- Indicate 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.

Setting Compiler Warning Levels

Set the PLSQL_WARNINGS initialization parameter to enable the database to issue warning messages.

```
ALTER SESSION SET PLSQL_WARNINGS = 'ENABLE:SEVERE',
                          'DISABLE:INFORMATIONAL';
```

- The PLSQL_WARNINGS combine a qualifier value (ENABLE, DISABLE, or ERROR) with a comma-separated list of message numbers, or with one of the following modifier values:
  - ALL, SEVERE, INFORMATIONAL, or PERFORMANCE
- Warning messages use a PLW prefix.

  PLW-07203: Parameter 'IO_TBL' may benefit from use of the NOCOPY compiler hint.

Setting Compiler Warning Levels

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 PLSQL_WARNINGS parameter can be set for the system using the initialization file or the ALTER SYSTEM statement, or for the session using the ALTER SESSION statement as shown in the example in the slide. By default, the value is set to DISABLE:ALL.

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:** To enable a specific warning or a set of warnings
- **DISABLE:** To disable a specific warning or a set of warnings
- **ERROR:** To treat a specific warning or a set of warnings as errors

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. For example:

```
PLSQL_WARNINGS='ENABLE:SEVERE','DISABLE:INFORMATIONAL';
PLSQL_WARNINGS='DISABLE:ALL';
PLSQL_WARNINGS='DISABLE:5000','ENABLE:5001','ERROR:5002';
PLSQL_WARNINGS='ENABLE:(5000,5001)','DISABLE:(6000)';
```

Guidelines for Using PLSQL_WARNINGS

The PLSQL_WARNINGS setting:

- Can be set to DEFERRED at the system level
- Is stored with each compiled subprogram
- That is current for the session is used, by default, when recompiling with:
  – A CREATE OR REPLACE statement
  – An ALTER...COMPILE statement
- That is stored with the compiled subprogram is used when REUSE SETTINGS is specified when recompiling with an ALTER...COMPILE statement

Guidelines for Using PLSQL_WARNINGS

As already stated, the PLSQL_WARNINGS parameter can be set at the session level or the system level. When setting it at the system level, you can include the value DEFERRED so that it applies to future sessions but not the current one.

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.

DBMS_WARNING Package

The DBMS_WARNING package provides a way to programmatically manipulate the behavior of current system or session PL/SQL warning settings. Using DBMS_WARNING subprograms, you can:

- Query existing settings
- Modify the settings for specific requirements or restore original settings
- Delete the settings

Example: Saving and restoring warning settings for a development environment that calls your code that compiles PL/SQL subprograms, and suppresses warnings due to business requirements

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.

The DBMS_WARNINGS 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.

Here is an example: Suppose you write some code to compile PL/SQL code. You know that the compiler will issue 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_WARNINGS package, you can detect the current warning settings, change the setting to suit your business requirements, and restore the original settings when your processing has completed.

Using DBMS_WARNING Procedures

- Package procedures change PL/SQL warnings:

```
ADD_WARNING_SETTING_CAT(w_category,w_value,scope)
ADD_WARNING_SETTING_NUM(w_number,w_value,scope)
SET_WARNING_SETTING_STRING(w_value, scope)
```

  – All parameters are IN parameters and have the VARCHAR2 data type. However, the w_number parameter is a NUMBER data type.
  – Parameter string values are not case sensitive.
  – The w_value parameters values are ENABLE, DISABLE, and ERROR.
  – The w_category values are ALL, INFORMATIONAL, SEVERE, and PERFORMANCE.
  – The scope value is either SESSION or SYSTEM. Using SYSTEM requires the ALTER SYSTEM privilege.

ORACLE

Using DBMS_WARNING Procedures

The package procedures are the following:

- **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
- **SET_WARNING_SETTING_STRING:** Replaces previous settings with the new value

Using the SET_WARNING_SETTING_STRING, 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 additional settings to the initial string.

Here is an example to establish the following warning setting string in the current session:

ENABLE:INFORMATIONAL,DISABLE:PERFORMANCE,ENABLE:SEVERE

Execute the following two lines of code:

```
dbms_warning.set_warning_setting_string('ENABLE:ALL','session');
dbms_warning.add_warning_setting_cat('PERFORMANCE','disable',
                                     'session');
```

Using DBMS_WARNING Functions

- Package functions read PL/SQL warnings:

```
GET_CATEGORY(w_number) RETURN VARCHAR2
GET_WARNING_SETTING_CAT(w_category)RETURN VARCHAR2
GET_WARNING_SETTING_NUM(w_number) RETURN VARCHAR2
GET_WARNING_SETTING_STRING RETURN VARCHAR2
```

  – GET_CATEGORY returns a value of ALL, INFORMATIONAL, SEVERE, or PERFORMANCE for a given message number.
  – GET_WARNING_SETTING_CAT returns ENABLE, DISABLE, or ERROR as the current warning value for a category name, and GET_WARNING_SETTING_NUM returns the value for a specific message number.
  – GET_WARNING_SETTING_STRING returns the entire warning string for the current session.

ORACLE

Using DBMS_WARNING Functions

The following is a list of package functions:

- GET_CATEGORY returns the category name for the given message number.
- GET_WARNING_SETTING_CAT returns the current session warning setting for the specified category.
- GET_WARNING_SETTING_NUM returns the current session warning setting for the specified message number.
- GET_WARNING_SETTING_STRING returns the entire warning string for the current session.

To determine the current session warning settings, enter:

```
EXECUTE DBMS_OUTPUT.PUT_LINE( -
          DBMS_WARNING.GET_WARNING_SETTING_STRING);
```

To determine the category for warning message number PLW-07203, use:

```
EXECUTE DBMS_OUTPUT.PUT_LINE( -
          DBMS_WARNING.GET_CATEGORY(7203))
```

The result string should be PERFORMANCE.

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

Consider the following scenario:
Save current warning settings, disable warnings for the PERFORMANCE category, compile a PL/SQL package, and restore the original warning setting.

```
CREATE PROCEDURE compile(pkg_name VARCHAR2) IS
  warn_value VARCHAR2(200);
  compile_stmt VARCHAR2(200) :=
    'ALTER PACKAGE '|| pkg_name ||' COMPILE';
BEGIN
  warn_value :=   -- Save current settings
      DBMS_WARNING.GET_WARNING_SETTING_STRING;
  DBMS_WARNING.ADD_WARNING_SETTING_CAT( -- change
      'PERFORMANCE', 'DISABLE', 'SESSION');
  EXECUTE IMMEDIATE compile_stmt;
  DBMS_WARNING.SET_WARNING_SETTING_STRING(--restore
      warn_value, 'SESSION');
END;
```


Using DBMS_WARNING: Example

In the slide, the example of the compile procedure is designed to compile a named PL/SQL package. The business rules require the following:

- Warnings in the performance category are suppressed.
- The calling environment's warning settings must be restored after the compilation is performed.

The code does not know or care about what the calling environment warning settings are; it simply uses the DBMS_WARNING.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 procedure alters the current session warning level by disabling warnings for the PERFORMANCE category.

For example, the compiler will suppress warnings about PL/SQL parameters passed using OUT or IN OUT modes that do not specify the NOCOPY hint to gain better performance.

Using DBMS_WARNING: Example

To test the compile procedure, you can use the following script sequence in *i*SQL*Plus:

```
DECLARE
  PROCEDURE print(s VARCHAR2) IS
  BEGIN
    DBMS_OUTPUT.PUT_LINE(s);
  END;
BEGIN
  print('Warning settings before: '||
         DBMS_WARNING.GET_WARNING_SETTING_STRING);
  compile('my_package');
  print('Warning settings after: '||
         DBMS_WARNING.GET_WARNING_SETTING_STRING);
END;
/
SHOW ERRORS PACKAGE MY_PACKAGE
```


Using DBMS_WARNING: Example (continued)

The slide shows an anonymous block that is used to display the current warning settings for the session before compilation takes place, executes the compile procedure, and prints the current warning settings for the session again. The before and after values for the warning settings should be identical.

The last line containing the SHOW ERRORS PACKAGE MY_PACKAGE is used to verify whether the warning messages in the performance category are suppressed (that is, no performance-related warning messages are displayed).

To adequately test the compile procedure behavior, the MY_PACKAGE package should contain a subprogram with a collection (PL/SQL table) specified as an OUT or IN OUT argument without using the NOCOPY hint. Normally, with the PERFORMANCE category enabled, a compiler warning will be issued. Using the code examples shown in the last two slides, the warnings related to the NOCOPY hint are suppressed.

Summary

In this lesson, you should have learned how to:

- Switch between native and interpreted compilations
- Set parameters that influence native compilation of PL/SQL programs
- Query data dictionary views that provide information on PL/SQL compilation settings
- Use the PL/SQL compiler warning mechanism:
  - Declaratively by setting the `PLSQL_WARNINGS` parameter
  - Programmatically using the `DBMS_WARNING` package

ORACLE

Summary

The lesson covers details about how native and interpreted compilations work and how to use parameters that influence the way PL/SQL code is compiled.

The key recommendation is to enable native compilation by default, resulting in 30% faster performance (in some cases) for your PL/SQL logic. Benchmarks have shown that enabling native compilation in Oracle Database 10*g* results in twice the performance when compared to Oracle8*i* and Oracle9*i* databases, and as much as three times the performance of PL/SQL code executing in an Oracle8 database environment. For more information, refer to the Oracle white paper titled "PL/SQL Just Got Faster," by Bryn Llewellyn and Charles Wetherell, from the Oracle Technology Network (OTN) Web site at http://otn.oracle.com.

The lesson also covers the following two ways of influencing the new compiler warning system that was added to Oracle Database 10*g*:

- Setting the `PLSQL_WARNINGS` parameter
- Using the `DBMS_WARNING` package programmatic interface

Practice 12: Overview

This practice covers the following topics:

- Enabling native compilation for your session and compiling a procedure
- Creating a subprogram to compile a PL/SQL procedure, function, or a package; suppressing warnings for the `PERFORMANCE` compiler warning category; and restoring the original session warning settings
- Executing the procedure to compile a PL/SQL package containing a procedure that uses a PL/SQL table as an `IN OUT` parameter without specifying the `NOCOPY` hint

Practice 12: Overview

In this practice, you enable native compilation for your session and compile a procedure. You then create a subprogram to compile a PL/SQL procedure, function, or a package, and you suppress warnings for the `PERFORMANCE` compiler warning category. The procedure must restore the original session warning settings. You then execute the procedure to compile a PL/SQL package that you create, where the package contains a procedure with an `IN OUT` parameter without specifying the `NOCOPY` hint.

Practice 12

1. Alter the `PLSQL_COMPILER_FLAGS` parameter to enable native compilation for your session, and compile any subprogram that you have written.
   a. Execute the `ALTER SESSION` command to enable native compilation.
   b. Compile the `EMPLOYEE_REPORT` procedure. What occurs during compilation?
   c. Execute the `EMPLOYEE_REPORT` with the value `'UTL_FILE'` as the first parameter, and `'native_salrepXX.txt'` where `XX` is your student number.
   d. Switch compilation to use interpreted compilation.
2. In the `COMPILE_PKG` (from Practice 6), add an overloaded version of the procedure called `MAKE`, which will compile a named procedure, function, or package.
   a. In the specification, declare a `MAKE` procedure that accepts two string arguments, one for the name of the PL/SQL construct and the other for the type of PL/SQL program, such as `PROCEDURE`, `FUNCTION`, `PACKAGE`, or `PACKAGE BODY`.
   b. In the body, write the `MAKE` procedure to call the `DBMS_WARNINGS` package to suppress the `PERFORMANCE` category. However, save the current compiler warning settings before you alter them. Then write an `EXECUTE IMMEDIATE` statement to compile the PL/SQL object using an appropriate `ALTER...COMPILE` statement with the supplied parameter values. Finally, restore the compiler warning settings that were in place for the calling environment before the procedure is invoked.
3. Write a new PL/SQL package called `TEST_PKG` containing a procedure called `GET_EMPLOYEES` that uses an `IN OUT` argument.
   a. In the specification, declare the `GET_EMPLOYEES` procedure with two parameters: an input parameter specifying a department ID, and an `IN OUT` parameter specifying a PL/SQL table of employee rows.
      Hint: You must declare a `TYPE` in the package specification for the PL/SQL table parameter's data type.
   b. In the package body, implement the `GET_EMPLOYEES` procedure to retrieve all the employee rows for a specified department into the PL/SQL table `IN OUT` parameter.
      Hint: Use the `SELECT … BULK COLLECT INTO` syntax to simplify the code.
4. Use the `ALTER SESSION` statement to set the `PLSQL_WARNINGS` so that all compiler warning categories are enabled.
5. Recompile the `TEST_PKG` that you created two steps earlier (in Exercise 3). What compiler warnings are displayed, if any?

Practice 12 (continued)

6. Write a PL/SQL anonymous block to compile the TEST_PKG package by using the overloaded COMPILE_PKG.MAKE procedure with two parameters. The anonymous block should display the current session warning string value before and after it invokes the COMPILE_PKG.MAKE procedure. Do you see any warning messages? Confirm your observations by executing the SHOW ERRORS PACKAGE command for the TEST_PKG.

Additional Practices

Additional Practices: Overview

These additional practices are provided as a supplement to the course *Oracle Database 10g: Develop PL/SQL Program Units*. In these practices, you apply the concepts that you learned in the course.

The additional practices comprise two parts:

Part A provides supplemental exercises to create stored procedures, functions, packages, and triggers, and to use the Oracle-supplied packages with *i*SQL*Plus as the development environment. The tables used in this portion of the additional practice include `EMPLOYEES`, `JOBS`, `JOB_HISTORY`, and `DEPARTMENTS`.

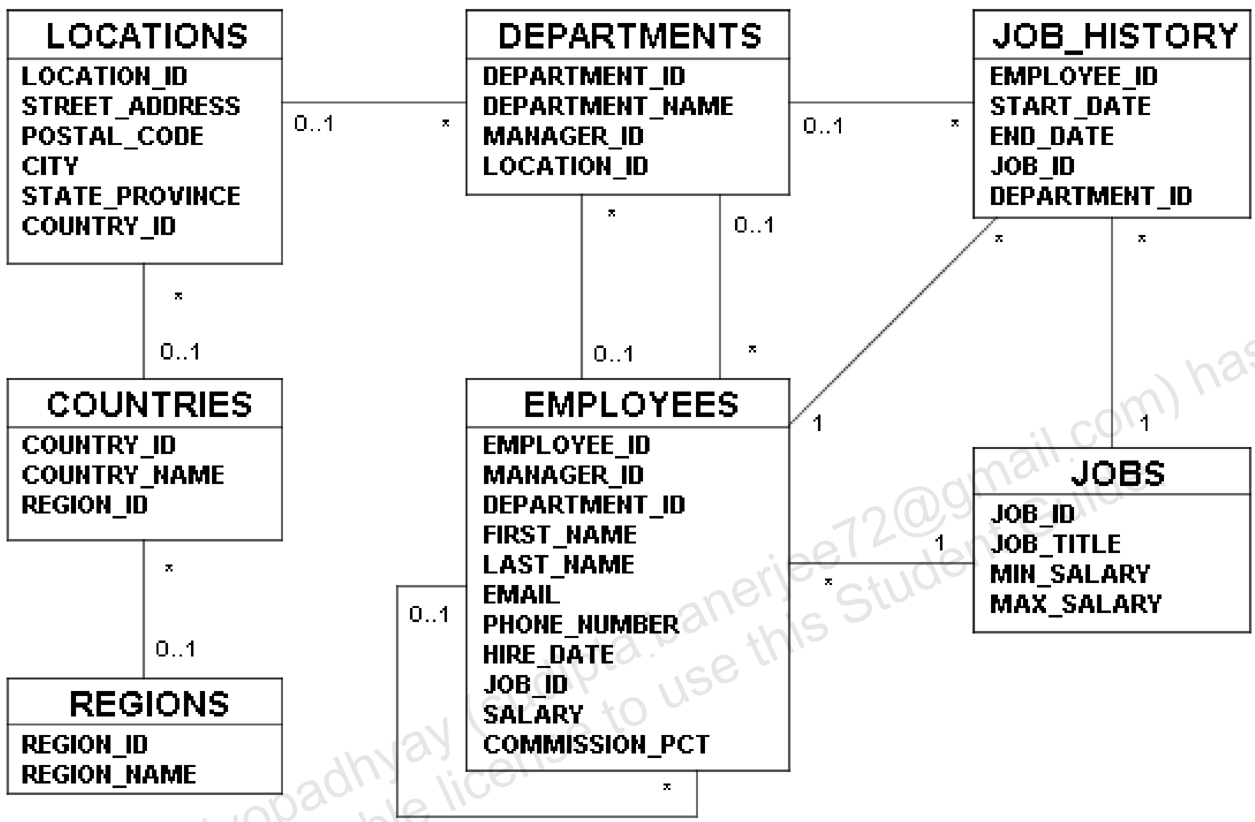
Part B is a case study that can be completed at the end of the course. This part supplements the practices for creating and managing program units. The tables used in the case study are based on a video database and contain the `TITLE`, `TITLE_COPY`, `RENTAL`, `RESERVATION`, and `MEMBER` tables.

An entity relationship diagram is provided at the start of part A and part B. Each entity relationship diagram displays the table entities and their relationships. More detailed definitions of the tables and the data contained in them is provided in the appendix titled "Additional Practices: Table Descriptions and Data."

Part A

Entity Relationship Diagram

Human Resources:



Part A (continued)

Note: These exercises can be used for extra practice when discussing how to create procedures.

1. In this exercise, create a program to add a new job into the `JOBS` table.
   a. Create a stored procedure called `NEW_JOB` to enter a new order into the `JOBS` table. The procedure should accept three parameters. The first and second parameters supply a job ID and a job title. The third parameter supplies the minimum salary. Use the maximum salary for the new job as twice the minimum salary supplied for the job ID.
   b. Invoke the procedure to add a new job with job ID `'SY_ANAL'`, job title `'System Analyst'`, and minimum salary of `6000`.
   c. Check whether a row was added and note the new job ID for use in the next exercise. Commit the changes.
2. In this exercise, create a program to add a new row to the `JOB_HISTORY` table, for an existing employee.
   a. Create a stored procedure called `ADD_JOB_HIST` to add a new row into the `JOB_HISTORY` table for an employee who is changing his job to the new job ID (`'SY_ANAL'`) that you created in exercise 1b.
      The procedure should provide two parameters, one for the employee ID who is changing the job, and the second for the new job ID. Read the employee ID from the `EMPLOYEES` table and insert it into the `JOB_HISTORY` table. Make the hire date of this employee as start date and today's date as end date for this row in the `JOB_HISTORY` table.
      Change the hire date of this employee in the `EMPLOYEES` table to today's date. Update the job ID of this employee to the job ID passed as parameter (use the `'SY_ANAL'` job ID) and salary equal to the minimum salary for that job ID + 500.
      Note: Include exception handling to handle an attempt to insert a nonexistent employee.
   b. Disable all triggers on the `EMPLOYEES`, `JOBS`, and `JOB_HISTORY` tables before invoking the `ADD_JOB_HIST` procedure.
   c. Execute the procedure with employee ID `106` and job ID `'SY_ANAL'` as parameters.
   d. Query the `JOB_HISTORY` and `EMPLOYEES` tables to view your changes for employee 106, and then commit the changes.
   e. Re-enable the triggers on the `EMPLOYEES`, `JOBS`, and `JOB_HISTORY` tables.
3. In this exercise, create a program to update the minimum and maximum salaries for a job in the `JOBS` table.
   a. Create a stored procedure called `UPD_JOBSAL` to update the minimum and maximum salaries for a specific job ID in the `JOBS` table. The procedure should provide three parameters: the job ID, a new minimum salary, and a new maximum salary. Add exception handling to account for an invalid job ID in the `JOBS` table. Raise an exception if the maximum salary supplied is less than the minimum salary, and provide a message that will be displayed if the row in the `JOBS` table is locked.
      Hint: The resource locked/busy error number is `–54`.

b. Execute the UPD_JOBSAL procedure by using a job ID of 'SY_ANAL', a minimum salary of 7000 and a maximum salary of 140.
   Note: This should generate an exception message.
c. Disable triggers on the EMPLOYEES and JOBS tables.
d. Execute the UPD_JOBSAL procedure using a job ID of 'SY_ANAL', a minimum salary of 7000, and a maximum salary of 14000.
e. Query the JOBS table to view your changes, and then commit the changes.
f. Enable the triggers on the EMPLOYEES and JOBS tables.

4. In this exercise, create a procedure to monitor whether employees have exceeded their average salaries for their job type.
   a. Disable the SECURE_EMPLOYEES trigger.
   b. In the EMPLOYEES table, add an EXCEED_AVGSAL column to store up to three characters and a default value of NO. Use a check constraint to allow the values YES or NO.
   c. Write a stored procedure called CHECK_AVGSAL which checks whether each employee's salary exceeds the average salary for the JOB_ID. The average salary for a job is calculated from the information in the JOBS table. If the employee's salary exceeds the average for their job, then update their EXCEED_AVGSAL column in the EMPLOYEES table to a value of YES; otherwise, set the value to NO. Use a cursor to select the employees rows using the FOR UPDATE option in the query. Add exception handling to account for a record being locked.
      Hint: The resource locked/busy error number is –54. Write and use a local function called GET_JOB_AVGSAL to determine the average salary for a job ID specified as a parameter.
   d. Execute the CHECK_AVGSAL procedure. Then, to view the results of your modifications, write a query to display the employee's ID, job, the average salary for the job, the employee's salary and the exceed_avgsal indicator column for employees whose salaries exceed the average for their job, and finally commit the changes.

Note: These exercises can be used for extra practice when discussing how to create functions.

5. Create a subprogram to retrieve the number of years of service for a specific employee.
   a. Create a stored function called GET_YEARS_SERVICE to retrieve the total number of years of service for a specific employee. The function should accept the employee ID as a parameter and return the number of years of service. Add error handling to account for an invalid employee ID.
   b. Invoke the GET_YEARS_SERVICE function in a call to DBMS_OUTPUT.PUT_LINE for an employee with ID 999.
   c. Display the number of years of service for employee 106 with DBMS_OUTPUT.PUT_LINE invoking the GET_YEARS_SERVICE function.
   d. Query the JOB_HISTORY and EMPLOYEES tables for the specified employee to verify that the modifications are accurate. The values represented in the results on this page may differ from those you get when you run these queries.

Part A (continued)

6. In this exercise, create a program to retrieve the number of different jobs that an employee worked on during his or her service.
   a. Create a stored function called GET_JOB_COUNT to retrieve the total number of different jobs on which an employee worked.
      The function should accept the employee ID in a parameter, and return the number of different jobs that the employee worked on until now, including the present job. Add exception handling to account for an invalid employee ID.
      Hint: Use the distinct job IDs from the JOB_HISTORY table, and exclude the current job ID, if it is one of the job IDs on which the employee has already worked. Write a UNION of two queries and count the rows retrieved into a PL/SQL table. Use a FETCH with BULK COLLECT INTO to obtain the unique jobs for the employee.
   b. Invoke the function for the employee with the ID of 176.

Note: These exercises can be used for extra practice when discussing how to create packages.

7. Create a package called EMPJOB_PKG that contains your NEW_JOB, ADD_JOB_HIST, UPD_JOBSAL procedures, as well as your GET_YEARS_SERVICE and GET_JOB_COUNT functions.
   a. Create the package specification with all the subprogram constructs as public. Move any subprogram local-defined types into the package specification.
   b. Create the package body with the subprogram implementation; remember to remove, from the subprogram implementations, any types that you moved into the package specification.
   c. Invoke your EMPJOB_PKG.NEW_JOB procedure to create a new job with the ID PR_MAN, the job title Public Relations Manager, and the salary 6,250.
   d. Invoke your EMPJOB_PKG.ADD_JOB_HIST procedure to modify the job of employee ID 110 to job ID PR_MAN.
      Note: You need to disable the UPDATE_JOB_HISTORY trigger before you execute the ADD_JOB_HIST procedure, and re-enable the trigger after you have executed the procedure.
   e. Query the JOBS, JOB_HISTORY, and EMPLOYEES tables to verify the results.

Note: These exercises can be used for extra practice when discussing how to create database triggers.

8. In this exercise, create a trigger to ensure that the minimum and maximum salaries of a job are never modified such that the salary of an existing employee with that job ID is out of the new range specified for the job.
   a. Create a trigger called CHECK_SAL_RANGE that is fired before every row that is updated in the MIN_SALARY and MAX_SALARY columns in the JOBS table. For any minimum or maximum salary value that is changed, check whether the salary of any existing employee with that job ID in the EMPLOYEES table falls within the new range of salaries specified for this job ID. Include exception handling to cover a salary range change that affects the record of any existing employee.

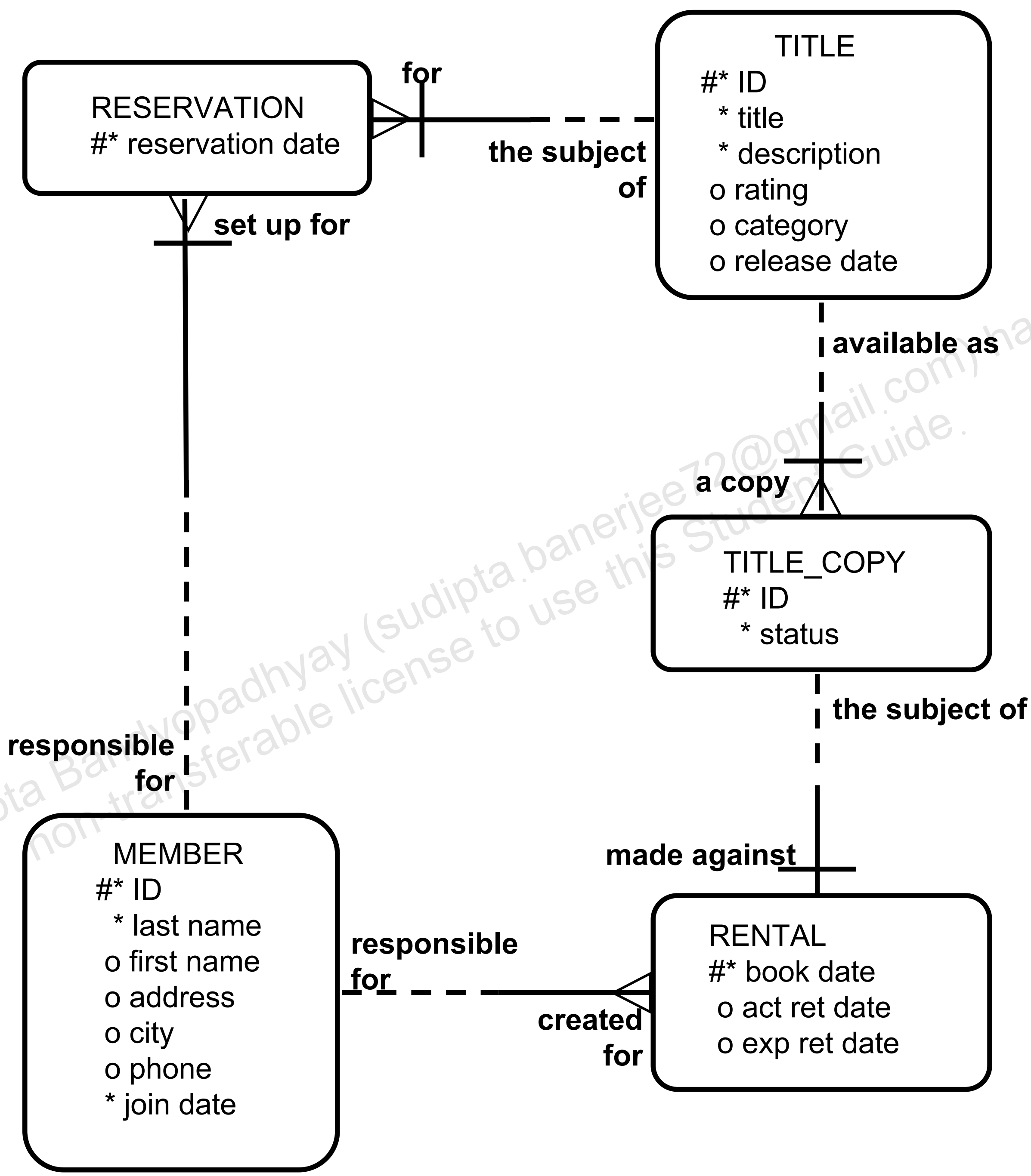
Part A (continued)

b. Test the trigger using the SY_ANAL job, setting the new minimum salary to 5,000, and the new maximum salary to 7,000. Before you make the change, write a query to display the current salary range for the SY_ANAL job ID, and another query to display the employee ID, last name, and salary for the same job ID. After the update, query the change (if any) to the JOBS table for the specified job ID.

c. Using the SY_ANAL job, set the new minimum salary to 7,000, and the new maximum salary to 18,000. Explain the results.

Part B

Entity Relationship Diagram



Part B (continued)

In this case study, you create a package named VIDEO_PKG that contains procedures and functions for a video store application. This application enables customers to become a member of the video store. Any member can rent movies, return rented movies, and reserve movies. Additionally, you create a trigger to ensure that any data in the video tables is modified only during business hours.

Create the package by using *i*SQL*Plus and use the DBMS_OUTPUT Oracle-supplied package to display messages.

The video store database contains the following tables: TITLE, TITLE_COPY, RENTAL, RESERVATION, and MEMBER. The entity relationship diagram is shown on the previous page.

Part B (continued)

1. Load and execute the `E:\labs\PLPU\labs\buildvid1.sql` script to create all the required tables and sequences that are needed for this exercise.
2. Load and execute the `E:\labs\PLPU\labs\buildvid2.sql` script to populate all the tables created through the `buildvid1.sql` script.
3. Create a package named `VIDEO_PKG` with the following procedures and functions:
   a. **`NEW_MEMBER`:** A public procedure that adds a new member to the `MEMBER` table. For the member `ID` number, use the sequence `MEMBER_ID_SEQ`; for the join date, use `SYSDATE`. Pass all other values to be inserted into a new row as parameters.
   b. **`NEW_RENTAL`:** An overloaded public function to record a new rental. Pass the title `ID` number for the video that a customer wants to rent, and either the customer's last name or his member ID number into the function. The function should return the due date for the video. Due dates are three days from the date the video is rented. If the status for a movie requested is listed as `AVAILABLE` in the `TITLE_COPY` table for one copy of this title, then update this `TITLE_COPY` table and set the status to `RENTED`. If there is no copy available, the function must return `NULL`. Then, insert a new record into the `RENTAL` table identifying the booked date as today's date, the copy `ID` number, the member `ID` number, the title `ID` number, and the expected return date. Be aware of multiple customers with the same last name. In this case, have the function return `NULL`, and display a list of the customers' names that match and their `ID` numbers.
   c. **`RETURN_MOVIE`:** A public procedure that updates the status of a video (available, rented, or damaged) and sets the return date. Pass the title `ID`, the copy `ID`, and the status to this procedure. Check whether there are reservations for that title and display a message if it is reserved. Update the `RENTAL` table and set the actual return date to today's date. Update the status in the `TITLE_COPY` table based on the status parameter passed into the procedure.
   d. **`RESERVE_MOVIE`:** A private procedure that executes only if all the video copies requested in the `NEW_RENTAL` procedure have a status of `RENTED`. Pass the member `ID` number and the title `ID` number to this procedure. Insert a new record into the `RESERVATION` table and record the reservation date, member `ID` number, and title `ID` number. Print a message indicating that a movie is reserved and its expected date of return.
   e. **`EXCEPTION_HANDLER`:** A private procedure that is called from the exception handler of the public programs. Pass the `SQLCODE` number to this procedure, and the name of the program (as a text string) where the error occurred. Use `RAISE_APPLICATION_ERROR` to raise a customized error. Start with a unique key violation (`-1`) and foreign key violation (`-2292`). Allow the exception handler to raise a generic error for any other errors.

Part B (continued)

4. Use the following scripts located in the E:\labs\PLPU\soln directory to test your routines:
   a. Add two members using sol_apb_04_a_new_members.sql.
   b. Add new video rentals using sol_apb_04_b_new_rentals.sql.
   c. Return movies using the sol_apb_04_c_return_movie.sql script.
5. The business hours for the video store are 8:00 a.m. to 10:00 p.m., Sunday through Friday, and 8:00 a.m. to 12:00 a.m. on Saturday. To ensure that the tables can be modified only during these hours, create a stored procedure that is called by triggers on the tables.
   a. Create a stored procedure called TIME_CHECK that checks the current time against business hours. If the current time is not within business hours, use the RAISE_APPLICATION_ERROR procedure to give an appropriate message.
   b. Create a trigger on each of the five tables. Fire the trigger before data is inserted, updated, and deleted from the tables. Call your TIME_CHECK procedure from each of these triggers.

Additional Practice Solutions

Additional Practice 1 and 2: Solutions

1. Evaluate each of the following declarations. Determine which of them are *not* legal and explain why.

   a.
   ```
   DECLARE
       name,dept    VARCHAR2(14);
   ```
   This is illegal because only one identifier per declaration is allowed.

   b.
   ```
   DECLARE
       test         NUMBER(5);
   ```
   This is legal.

   c.
   ```
   DECLARE
       MAXSALARY          NUMBER(7,2) = 5000;
   ```
   This is illegal because the assignment operator is wrong. It should be :=.

   d.
   ```
   DECLARE
       JOINDATE           BOOLEAN := SYSDATE;
   ```
   This is illegal because there is a mismatch in the data types. A Boolean data type cannot be assigned a date value. The data type should be date.

2. In each of the following assignments, determine the data type of the resulting expression.

   a. `email := firstname || to_char(empno);`

   Character string

   b. `confirm := to_date('20-JAN-1999', 'DD-MON-YYYY');`

   Date

   c. `sal := (1000*12) + 500`

   Number

   d. `test := FALSE;`

   Boolean

   e. `temp := temp1 < (temp2/ 3);`

   Boolean

   f. `var := sysdate;`

   Date

Additional Practice 3: Solutions

3.
```
DECLARE
    custid     NUMBER(4) := 1600;
    custname      VARCHAR2(300) := 'Women Sports Club';
    new_custid     NUMBER(3) := 500;
BEGIN
DECLARE
    custid       NUMBER(4) := 0;
    custname  VARCHAR2(300) := 'Shape up Sports Club';
    new_custid  NUMBER(3) := 300;
    new_custname VARCHAR2(300) := 'Jansports Club';
BEGIN
    custid := new_custid;
    custname := custname || ' ' ||  new_custname;
1
END;
    custid := (custid *12) / 10;
2
END;
    /
```

Evaluate the PL/SQL block given above and determine the data type and value of each of the following variables, according to the rules of scoping:

a. The value of CUSTID at position 1 is:
   300, and the data type is NUMBER

b. The value of CUSTNAME at position 1 is:
   Shape up Sports Club Jansports Club, and the data type is VARCHAR2

c. The value of NEW_CUSTID at position 2 is:
   500, and the data type is NUMBER (or INTEGER)

d. The value of NEW_CUSTNAME at position 1 is:
   Jansports Club, and the data type is VARCHAR2

e. The value of CUSTID at position 2 is:
   1920, and the data type is NUMBER

f. The value of CUSTNAME at position 2 is:
   Women Sports Club, and the data type is VARCHAR2

Additional Practice 4: Solutions

4. Write a PL/SQL block to accept a year and check whether it is a leap year. For example, if the year entered is 1990, the output should be "1990 is not a leap year."
   Hint: The year should be exactly divisible by 4 but not divisible by 100, or it should be divisible by 400.
   Test your solution with the following years:

1990	Not a leap year
2000	Leap year
1996	Leap year
1886	Not a leap year
1992	Leap year
1824	Leap year

```
SET SERVEROUTPUT ON
DECLARE
    YEAR NUMBER(4) := &P_YEAR;
    REMAINDER1 NUMBER(5,2);
    REMAINDER2 NUMBER(5,2);
    REMAINDER3 NUMBER(5,2);
BEGIN
    REMAINDER1 := MOD(YEAR,4);
    REMAINDER2 := MOD(YEAR,100);
    REMAINDER3 := MOD(YEAR,400);
    IF ((REMAINDER1 = 0 AND REMAINDER2 <> 0 )
             OR REMAINDER3 = 0) THEN
        DBMS_OUTPUT.PUT_LINE(YEAR || ' is a leap year');
    ELSE
        DBMS_OUTPUT.PUT_LINE (YEAR || ' is not a leap
year');
    END IF;
END;
/
SET SERVEROUTPUT OFF
```

Additional Practice 5: Solutions

5. a. For the exercises below, you require a temporary table to store the results. You can either create the table yourself or run the `lab_ap_05.sql` script that will create the table for you. Create a table named `TEMP` with the following three columns:

Column Name	NUM_STORE	CHAR_STORE	DATE_STORE
Key Type			
Nulls/Unique			
FK Table			
FK Column			
Data Type	Number	VARCHAR2	Date
Length	7,2	35	

```
CREATE TABLE temp
(num_store NUMBER(7,2),
char_store VARCHAR2(35),
date_store DATE);
```

b. Write a PL/SQL block that contains two variables, `MESSAGE` and `DATE_WRITTEN`. Declare `MESSAGE` as `VARCHAR2` data type with a length of 35 and `DATE_WRITTEN` as `DATE` data type. Assign the following values to the variables:

Variable	**Contents**
MESSAGE	This is my first PL/SQL program.
DATE_WRITTEN	Current date

Store the values in appropriate columns of the `TEMP` table. Verify your results by querying the `TEMP` table.

```
SET SERVEROUTPUT ON
    DECLARE
   MESSAGE VARCHAR2(35);
      DATE_WRITTEN DATE;
BEGIN
    MESSAGE := 'This is my first PLSQL Program.';
    DATE_WRITTEN := SYSDATE;
    INSERT INTO temp(CHAR_STORE,DATE_STORE)
    VALUES (MESSAGE,DATE_WRITTEN);
END;
 /
  SELECT * FROM TEMP;
```

Additional Practices 6 and 7 Solutions

6. a. Store a department number in an *i*SQL*Plus substitution variable.

```
DEFINE P_DEPTNO = 30
```

   b. Write a PL/SQL block to print the number of people working in that department.

   Hint: Enable `DBMS_OUTPUT` in *i*SQL*Plus with `SET SERVEROUTPUT ON`.

```
SET SERVEROUTPUT ON
DECLARE
    HOWMANY NUMBER(3);
    DEPTNO DEPARTMENTS.department_id%TYPE  :=
    &P_DEPTNO;
  BEGIN
    SELECT COUNT(*) INTO HOWMANY  FROM employees
    WHERE department_id = DEPTNO;
    DBMS_OUTPUT.PUT_LINE (HOWMANY || ' employee(s)
    work for department number ' ||DEPTNO);
  END;
  /
  SET SERVEROUTPUT OFF
```

7. Write a PL/SQL block to declare a variable called `sal` to store the salary of an employee. In the executable part of the program, perform the following tasks:
   a. Store an employee name in an *i*SQL*Plus substitution variable:

```
SET SERVEROUTPUT ON
    DEFINE P_LASTNAME = Pataballa
```

   b. Store his or her salary in the `sal` variable.
   c. If the salary is less than 3,000, give the employee a raise of 500 and display the message "<*Employee Name*>'s salary updated" in the window.
   d. If the salary is more than 3,000, print the employee's salary in the format, "<*Employee Name*> earns …...………"
   e. Test the PL/SQL block for the last names.

LAST_NAME	SALARY
Pataballa	4800
Greenberg	12000
Ernst	6000

Note: Undefine the variable that stores the employee's name at the end of the script.

Additional Practices 7 and 8: Solutions

```
DECLARE
       SAL NUMBER(7,2);
       LASTNAME EMPLOYEES.LAST_NAME%TYPE;
BEGIN
       SELECT salary INTO SAL
       FROM employees
       WHERE last_name = INITCAP('&&P_LASTNAME') FOR
  UPDATE of salary;

       LASTNAME := INITCAP('&P_LASTNAME');
       IF SAL < 3000 THEN
            UPDATE employees SET salary = salary + 500
            WHERE last_name =  INITCAP('&P_LASTNAME') ;
            DBMS_OUTPUT.PUT_LINE (LASTNAME || '''s salary
            updated');
       ELSE
            DBMS_OUTPUT.PUT_LINE (LASTNAME || ' earns '
  ||
            TO_CHAR(SAL));
       END IF;
END;
/
SET SERVEROUTPUT OFF
UNDEFINE P_LASTNAME
```

8. Write a PL/SQL block to store the salary of an employee in an *i*SQL*Plus substitution variable. In the executable part of the program, perform the following:
   - Calculate the annual salary as salary * 12.
   - Calculate the bonus as indicated below:

Annual Salary	Bonus
>= 20,000	2,000
19,999 - 10,000	1,000
<= 9,999	500

   - Display the amount of the bonus in the window in the following format: "The bonus is $……………….."
   - Test the PL/SQL for the following test cases:

SALARY	BONUS
5000	2000
1000	1000
15000	2000

```
SET SERVEROUTPUT ON
   DEFINE P_SALARY = 5000
   DECLARE
     SAL  NUMBER(7,2) := &P_SALARY;
     BONUS   NUMBER(7,2);
     ANN_SALARY NUMBER(15,2);
BEGIN
   ANN_SALARY := SAL * 12;
   IF ANN_SALARY >= 20000 THEN
      BONUS := 2000;
   ELSIF ANN_SALARY <= 19999 AND ANN_SALARY >=10000 THEN
      BONUS := 1000;
   ELSE
      BONUS := 500;
   END IF;
   DBMS_OUTPUT.PUT_LINE ('The Bonus is $  ' ||
   TO_CHAR(BONUS));
 END;
 /
 SET SERVEROUTPUT OFF
```

9. a. Execute the `lab_ap_09_a.sql` script to create a temporary table called `emp`. Write a PL/SQL block to store an employee number, the new department number, and the percentage increase in the salary in *i*SQL*Plus substitution variables.

```
SET SERVEROUTPUT ON
DEFINE P_EMPNO = 100
DEFINE P_NEW_DEPTNO = 10
DEFINE P_PER_INCREASE = 2
```

   b. Update the department ID of the employee with the new department number, and update the salary with the new salary. Use the `emp` table for the updates. After the update is complete, display the message "Update complete" in the window. If no matching records are found, display the message "No Data Found." Test the PL/SQL block for the following test cases.

EMPLOYEE_ID	NEW_DEPARTMENT_ID	% INCREASE	MESSAGE
100	20	2	Update Complete
10	30	5	No Data found
126	40	3	Update Complete

```
DECLARE
    EMPNO emp.EMPLOYEE_ID%TYPE := &P_EMPNO;
    NEW_DEPTNO emp.DEPARTMENT_ID%TYPE :=
   &P_NEW_DEPTNO;
    PER_INCREASE NUMBER(7,2) := & P_PER_INCREASE;
 BEGIN
     UPDATE emp
     SET department_id = NEW_DEPTNO,
      salary  = salary + (salary * PER_INCREASE/100)
     WHERE employee_id = EMPNO;
     IF SQL%ROWCOUNT = 0 THEN
       DBMS_OUTPUT.PUT_LINE ('No Data Found');
      ELSE
       DBMS_OUTPUT.PUT_LINE ('Update Complete');
     END IF;
 END;
 /
 SET SERVEROUTPUT OFF
```

10. Create a PL/SQL block to declare an `EMP_CUR` cursor to select the employee name, salary, and hire date from the `employees` table. Process each row from the cursor, and if the salary is greater than 15,000 and the hire date is greater than 01-FEB-1988, display the employee name, salary, and hire date in the window.

```
SET SERVEROUTPUT ON
DECLARE
    CURSOR EMP_CUR IS
    SELECT  last_name,salary,hire_date FROM EMPLOYEES;
    ENAME VARCHAR2(25);
    SAL   NUMBER(7,2);
    HIREDATE DATE;
BEGIN
   OPEN EMP_CUR;
   FETCH EMP_CUR INTO ENAME,SAL,HIREDATE;
   WHILE EMP_CUR%FOUND
   LOOP
   IF SAL > 15000 AND HIREDATE >=  TO_DATE('01-FEB-
   1988','DD-MON-
        YYYY') THEN
   DBMS_OUTPUT.PUT_LINE (ENAME ||  ' earns ' ||
   TO_CHAR(SAL)||
    ' and joined the organization on ' ||
   TO_DATE(HIREDATE,'DD-
        Mon-YYYY'));
   END IF;
```

```
FETCH EMP_CUR INTO ENAME,SAL,HIREDATE;
   END LOOP;
CLOSE EMP_CUR;
END;
/
SET SERVEROUTPUT OFF
```

11. Create a PL/SQL block to retrieve the last name and department ID of each employee from the `employees` table for those employees whose `EMPLOYEE_ID` is less than 114. From the values retrieved from the `employees` table, populate two PL/SQL tables, one to store the records of the employee last names and the other to store the records of their department IDs. Using a loop, retrieve the employee name information and the salary information from the PL/SQL tables and display them in the window, using `DBMS_OUTPUT.PUT_LINE`. Display these details for the first 15 employees in the PL/SQL tables.

```
SET SERVEROUTPUT ON
DECLARE
   TYPE Table_Ename is table of
   employees.last_name%TYPE
   INDEX  BY BINARY_INTEGER;
   TYPE Table_dept  is table of
   employees.department_id%TYPE
   INDEX  BY BINARY_INTEGER;
   Tename  Table_Ename;
   Tdept  Table_dept;
   i  BINARY_INTEGER :=0;
   CURSOR Namedept IS SELECT last_name,department_id
   from employees WHERE employee_id < 115;
    TRACK  NUMBER := 15;
BEGIN
   FOR emprec in Namedept
   LOOP
      i := i +1;
      Tename(i)  := emprec.last_name;
       Tdept(i)  := emprec.department_id;
   END LOOP;
```

```
    FOR i IN 1..TRACK
      LOOP
         DBMS_OUTPUT.PUT_LINE ('Employee Name: ' ||
       Tename(i) || ' Department_id: ' || Tdept(i));
       END LOOP;
  END;
  /
  SET SERVEROUTPUT OFF
```

12. a. Create a PL/SQL block that declares a cursor called `DATE_CUR`. Pass a parameter of the `DATE` data type to the cursor and print the details about all the employees who have joined after that date.

```
SET SERVEROUTPUT ON
    DEFINE P_HIREDATE = 08-MAR-00
```

b. Test the PL/SQL block for the following hire dates: `08-MAR-00`, `25-JUN-97`, `28-SEP-98`, `07-FEB-99`.

```
DECLARE
   CURSOR DATE_CURSOR(JOIN_DATE DATE) IS
   SELECT employee_id,last_name,hire_date FROM
  employees
   WHERE HIRE_DATE >JOIN_DATE ;
   EMPNO   employees.employee_id%TYPE;
   ENAME   employees.last_name%TYPE;
    HIREDATE employees.hire_date%TYPE;
   HDATE employees.hire_date%TYPE :=   '&P_HIREDATE';
BEGIN
   OPEN DATE_CURSOR(HDATE);
   LOOP
     FETCH DATE_CURSOR INTO EMPNO,ENAME,HIREDATE;
      EXIT WHEN DATE_CURSOR%NOTFOUND;
     DBMS_OUTPUT.PUT_LINE (EMPNO || ' ' || ENAME || '
  ' ||
         HIREDATE);
      END LOOP;
 END;
/
SET SERVEROUTPUT OFF;
```

Additional Practice 13: Solutions

13. Execute the `lab_ap_09_a.sql` script to re-create the `emp` table. Create a PL/SQL block to promote clerks who earn more than 3,000 to SR CLERK and increase their salaries by 10%. Use the `emp` table for this practice. Verify the results by querying on the `emp` table.
    Hint: Use a cursor with `FOR UPDATE` and `CURRENT OF` syntax.

```
DECLARE
   CURSOR Senior_Clerk IS
   SELECT employee_id,job_id FROM emp
   WHERE job_id = 'ST_CLERK' AND salary > 3000
   FOR UPDATE OF job_id;
BEGIN
   FOR Emrec IN Senior_Clerk
   LOOP
    UPDATE emp
    SET job_id = 'SR_CLERK',
    salary = 1.1 * salary
    WHERE CURRENT OF Senior_Clerk;
   END LOOP;
   COMMIT;
END;
/
SELECT * FROM emp;
```

Additional Practice 14: Solutions

14. a. For the following exercise, you require a table to store the results. You can create the `analysis` table yourself or run the `lab_ap_14_a.sql` script that creates the table for you. Create a table called `analysis` with the following three columns:

Column Name	ENAME	YEARS	SAL
Key Type			
Nulls/Unique			
FK Table			
FK Column			
Data Type	VARCHAR2	Number	Number
Length	20	2	8,2

```
CREATE TABLE analysis
 (ename Varchar2(20),
 years Number(2),
 sal Number(8,2));
```

b. Create a PL/SQL block to populate the `analysis` table with the information from the `employees` table. Use an *i*SQL*Plus substitution variable to store an employee's last name.

```
SET SERVEROUTPUT ON
DEFINE P_ENAME = Austin
```

c. Query the `employees` table to find if the number of years that the employee has been with the organization is greater than five, and if the salary is less than 3,500, raise an exception. Handle the exception with an appropriate exception handler that inserts the following values into the `analysis` table: employee last name, number of years of service, and the current salary. Otherwise, display `Not due for a raise` in the window. Verify the results by querying the `analysis` table. Use the following test cases to test the PL/SQL block.

LAST_NAME	MESSAGE
Austin	Not due for a raise
Nayer	Not due for a raise
Fripp	Not due for a raise
Khoo	Due for a raise

Additional Practice 14: Solutions (continued)

```
DECLARE
    DUE_FOR_RAISE EXCEPTION;
    HIREDATE EMPLOYEES.HIRE_DATE%TYPE;
    ENAME EMPLOYEES.LAST_NAME%TYPE :=  INITCAP(
'&P_ENAME');
    SAL EMPLOYEES.SALARY%TYPE;
    YEARS NUMBER(2);
BEGIN
    SELECT LAST_NAME,SALARY,HIRE_DATE
    INTO  ENAME,SAL,HIREDATE
    FROM employees WHERE last_name =  ENAME;
    YEARS := MONTHS_BETWEEN(SYSDATE,HIREDATE)/12;
    IF SAL < 3500 AND YEARS > 5  THEN
         RAISE DUE_FOR_RAISE;
    ELSE
         DBMS_OUTPUT.PUT_LINE ('Not due for a raise');
    END IF;
EXCEPTION
    WHEN DUE_FOR_RAISE THEN
    INSERT INTO ANALYSIS(ENAME,YEARS,SAL)
    VALUES (ENAME, YEARS, SAL);
END;
/
```

Additional Practices: Table Descriptions and Data

Part A

The tables and data used in part A are the same as those in Appendix B, “Table Descriptions and Data.”

Part B: Tables Used

TNAME	TABTYPE	CLUSTERID
MEMBER	TABLE	
RENTAL	TABLE	
RESERVATION	TABLE	
TITLE	TABLE	
TITLE_COPY	TABLE	

Part B: MEMBER Table

```
DESCRIBE member
```

Name	Null?	Type
MEMBER_ID	NOT NULL	NUMBER(10)
LAST_NAME	NOT NULL	VARCHAR2(25)
FIRST_NAME		VARCHAR2(25)
ADDRESS		VARCHAR2(100)
CITY		VARCHAR2(30)
PHONE		VARCHAR2(25)
JOIN_DATE	NOT NULL	DATE

```
SELECT * FROM member;
```

MEMBER_ID	LAST_NAME	FIRST_NAME	ADDRESS	CITY	PHONE	JOIN_DATE
101	Velasquez	Carmen	283 King Street	Seattle	587-99-6666	03-MAR-90
102	Ngao	LaDoris	5 Modrany	Bratislava	586-355-8882	08-MAR-90
103	Nagayama	Midori	68 Via Centrale	Sao Paolo	254-852-5764	17-JUN-91
104	Quick-To-See	Mark	6921 King Way	Lagos	63-559-777	07-APR-90
105	Ropeburn	Audry	86 Chu Street	Hong Kong	41-559-87	04-MAR-90
106	Urguhart	Molly	3035 Laurier Blvd.	Quebec	418-542-9988	18-JAN-91
107	Menchu	Roberta	Boulevard de Waterloo 41	Brussels	322-504-2228	14-MAY-90
108	Biri	Ben	398 High St.	Columbus	614-455-9863	07-APR-90
109	Catchpole	Antoinette	88 Alfred St.	Brisbane	616-399-1411	09-FEB-92

9 rows selected.

Part B: RENTAL Table

```
DESCRIBE rental
```

Name	Null?	Type
BOOK_DATE	NOT NULL	DATE
COPY_ID	NOT NULL	NUMBER(10)
MEMBER_ID	NOT NULL	NUMBER(10)
TITLE_ID	NOT NULL	NUMBER(10)
ACT_RET_DATE		DATE
EXP_RET_DATE		DATE

```
SELECT * FROM rental;
```

BOOK_DATE	COPY_ID	MEMBER_ID	TITLE_ID	ACT_RET_D	EXP_RET_D
02-OCT-01	2	101	93		04-OCT-01
01-OCT-01	3	102	95		03-OCT-01
30-SEP-01	1	101	98		02-OCT-01
29-SEP-01	1	106	97	01-OCT-01	01-OCT-01
30-SEP-01	1	101	92	01-OCT-01	02-OCT-01

Part B: RESERVATION Table

```
DESCRIBE reservation
```

Name	Null?	Type
RES_DATE	NOT NULL	DATE
MEMBER_ID	NOT NULL	NUMBER(10)
TITLE_ID	NOT NULL	NUMBER(10)

```
SELECT * FROM reservation;
```

RES_DATE	MEMBER_ID	TITLE_ID
02-OCT-01	101	93
01-OCT-01	106	102

Part B: `TITLE` Table

```
DESCRIBE title
```

Name	Null?	Type
TITLE_ID	NOT NULL	NUMBER(10)
TITLE	NOT NULL	VARCHAR2(60)
DESCRIPTION	NOT NULL	VARCHAR2(400)
RATING		VARCHAR2(4)
CATEGORY		VARCHAR2(20)
RELEASE_DATE		DATE

```
SELECT * FROM title;
```

TITLE_ID	TITLE	DESCRIPTION	RATI	CATEGORY	RELEASE_D
92	Willie and Christmas Too	All of Willie's friends made a Christmas list for Santa, but Willie has yet to create his own wish list.	G	CHILD	05-OCT-95
93	Alien Again	Another installment of science fiction history. Can the heroine save the planet from the alien life form?	R	SCIFI	19-MAY-95
94	The Glob	A meteor crashes near a small American town and unleashes carivorous goo in this classic.	NR	SCIFI	12-AUG-95
95	My Day Off	With a little luck and a lot of ingenuity, a teenager skips school for a day in New York.	PG	COMEDY	12-JUL-95
96	Miracles on Ice	A six-year-old has doubts about Santa Claus. But she discovers that miracles really do exist.	PG	DRAMA	12-SEP-95
97	Soda Gang	After discovering a cached of drugs, a young couple find themselves pitted against a vicious gang.	NR	ACTION	01-JUN-95
98	Interstellar Wars	Futuristic interstellar action movie. Can the rebels save the humans from the evil Empire?	PG	SCIFI	07-JUL-77

7 rows selected.

Part B: TITLE_COPY Table

```
DESCRIBE title_copy
```

Name	Null?	Type
COPY_ID	NOT NULL	NUMBER(10)
TITLE_ID	NOT NULL	NUMBER(10)
STATUS	NOT NULL	VARCHAR2(15)

```
SELECT * FROM title_copy;
```

COPY_ID	TITLE_ID	STATUS
1	92	AVAILABLE
1	93	AVAILABLE
2	93	RENTED
1	94	AVAILABLE
1	95	AVAILABLE
2	95	AVAILABLE
3	95	RENTED
1	96	AVAILABLE
1	97	AVAILABLE
1	98	RENTED
2	98	AVAILABLE

11 rows selected.