PL/SQL (Procedural Language Extension to SQL)

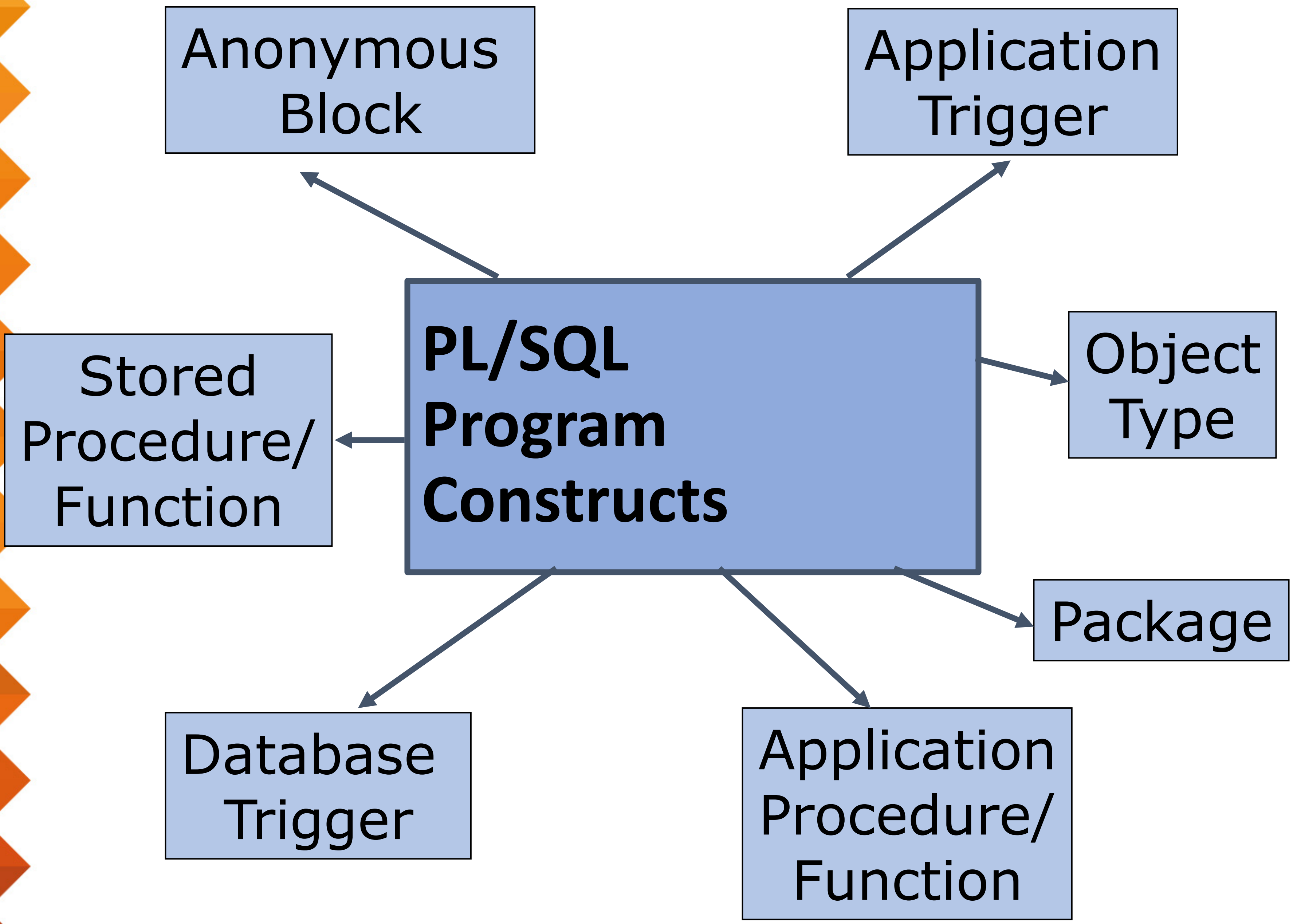
INFS602 Physical Database Design

Learning Outcomes

- Be able to:
  - write a simple PL/SQL program
  - write simple stored procedures and stored functions
- Understand the difference between implicit and explicit cursors
  - Be able to manipulate an explicit cursor in a PL/SQL program
- Be able to define PL/SQL Exceptions

PL/SQL

- PL/SQL is an extension to SQL with design features of programming languages
- PL/SQL program units are compiled by the Oracle Database server and stored inside the database.
- Data manipulation (DML) and query statements of SQL are included within procedural units of code
- PL/SQL automatically inherits the robustness, security, and portability of the Oracle Database.

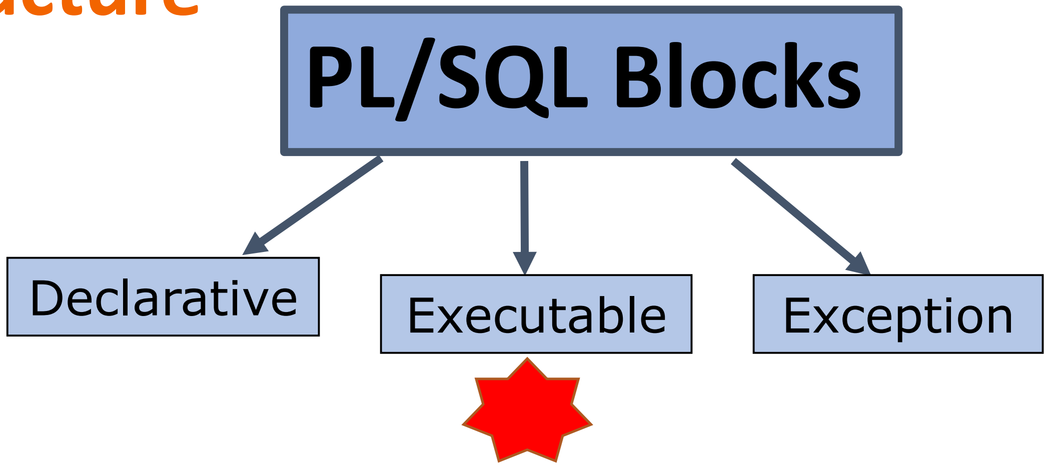

PL/SQL Program Constructs
Anonymous Block
Application Trigger
Object Type
Package
Application Procedure/ Function
Database Trigger
Stored Procedure/ Function

PL/SQL Blocks

- PL/SQL code is built of Blocks, with a unique structure.
- There are two types of blocks in PL/SQL:

1. **Anonymous Blocks:** have no name (like scripts)
   - can be written and executed immediately in SQL*PLUS
   - can be used in a trigger
2. **Named Blocks:**
   - Procedures
   - Functions

PL/SQL Block Structure



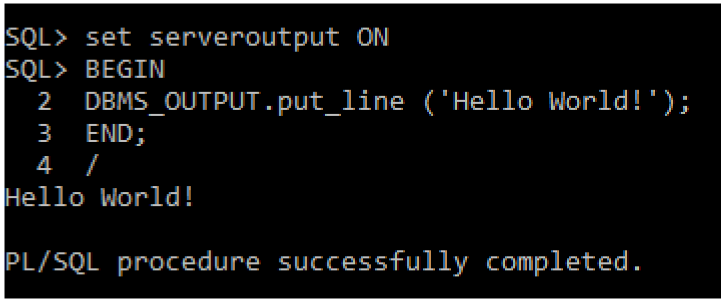
1. Anonymous Blocks

- DECLARE – Optional
    - Variable, cursors, constants
- BEGIN – Mandatory
    - SQL statements
    - PL/SQL statements
- EXCEPTION – Optional
    - Actions to perform when errors occur
- END; – Mandatory

Example

- Without Declaration

```
BEGIN
DBMS_OUTPUT.put_line ('Hello World!');
END;
```

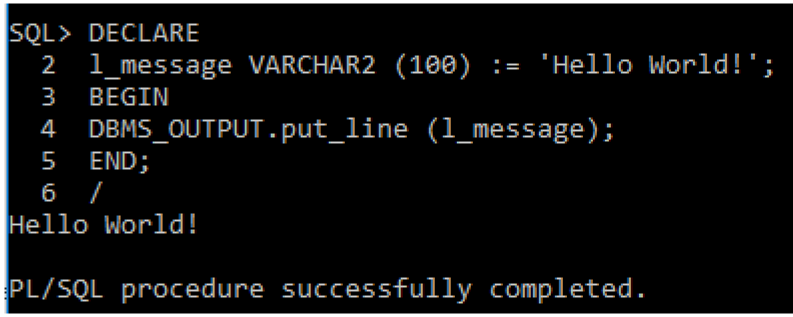


```
SQL> set serveroutput ON
SQL> BEGIN
  2  DBMS_OUTPUT.put_line ('Hello World!');
  3  END;
  4  /
Hello World!

PL/SQL procedure successfully completed.
```

- With Declaration

```
DECLARE
l_message VARCHAR2 (100) := 'Hello World!';
BEGIN
DBMS_OUTPUT.put_line (l_message);
END;
```



```
SQL> DECLARE
  2  l_message VARCHAR2 (100) := 'Hello World!';
  3  BEGIN
  4  DBMS_OUTPUT.put_line (l_message);
  5  END;
  6  /
Hello World!

PL/SQL procedure successfully completed.
```

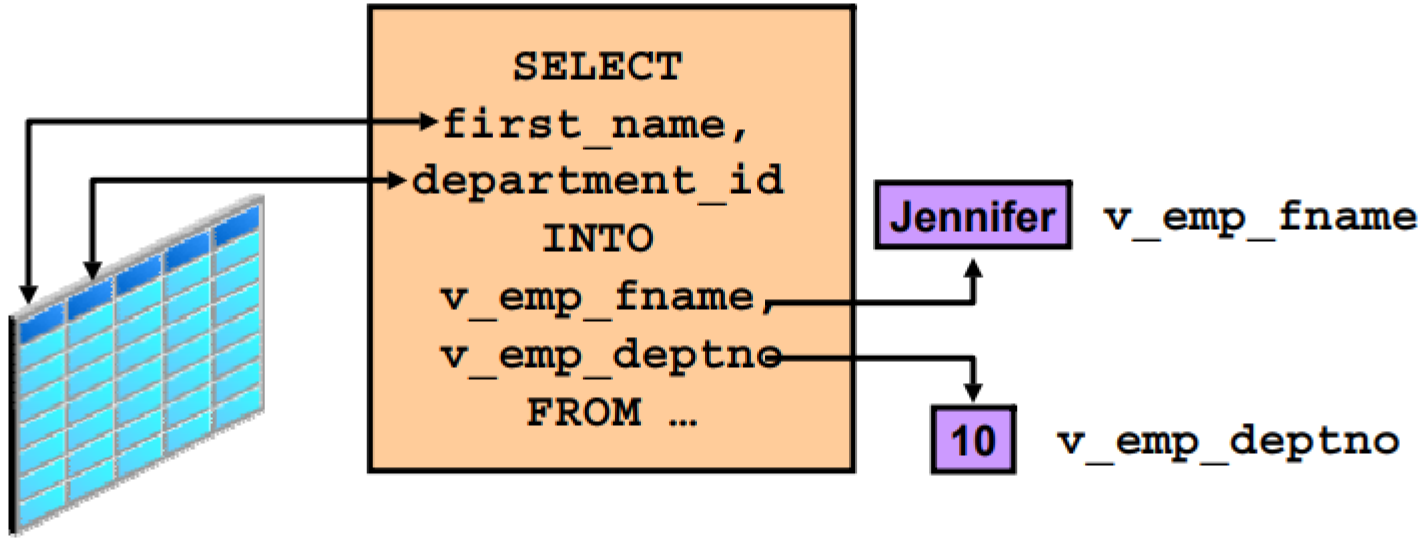
NOTE the INTO clause this is mandatory and must occur Between the SELECT and FROM clauses

```
DECLARE

  qty_on_hand NUMBER(5);
BEGIN
  SELECT quantity INTO qty_on_hand
  FROM inventory
  WHERE product = 'TENNIS RACKET'
  FOR UPDATE OF quantity;
  IF qty_on_hand > 0 THEN -- check quantity
UPDATE inventory SET quantity = quantity - 1
WHERE product = 'TENNIS RACKET';
      INSERT INTO purchase_record VALUES ('Tennis
      racket purchased', SYSDATE);
  ELSE INSERT INTO purchase_record
      VALUES ('Out of tennis rackets', SYSDATE);
  END IF;
  COMMIT;
END;
```

Using Variables in PL/SQL

- Information is transmitted between a PL/SQL program and the database through *variables*.
- Variables can be used for:
  - Temporary storage of data
  - Manipulation of stored values
  - Reusability



Declaring PL/SQL Variables

- Syntax

```
Identifier [CONSTANT] datatype [NOT
 NULL] {:= | DEFAULT expr];
```

NOTE: assign values to variables

- Examples

```
Declare
    v_hiredate DATE;
    v_deptno   NUMBER(2) NOT NULL := 10;
    v_location VARCHAR2(13) :=
      'Auckland';
    c_comm CONSTANT NUMBER := 1400;
```

PL/SQL Datatypes

- VARCHAR2 (maximum_length)
- NUMBER [(precision, scale)] - most commonly used generic type
- DATE
- CHAR [(maximum_length)]
- LONG/LONG RAW
- LOB Types - CLOB, BLOB (large objects)
- BOOLEAN
- BINARY_INTEGER
- PLS_INTEGER (identical to binary integer)

Reference variables - %Type Attribute

- Declare a variable based on a database column or another previously declared variable (very useful)
- The **%TYPE** attribute is particularly useful when declaring variables that refer to **database columns**.

- Prefix %type with the database table and column or the previously declared variable name.

- Examples

```
v_ename             emp.ename%TYPE;
v_balance           NUMBER(7,2);
v_min_balance       v_balance%TYPE := 10;
```

Stored Procedures

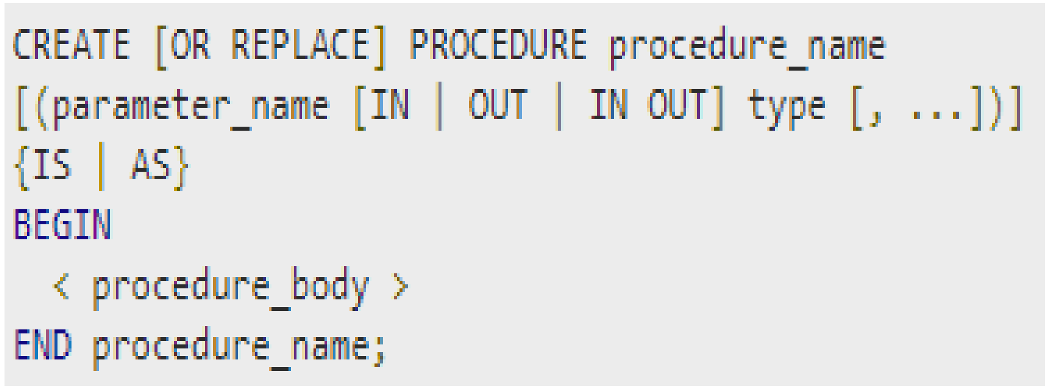
- A procedure is a named PL/SQL block that performs an action (a set of related tasks)
- A procedure can be stored in the database, as a database object, for repeated execution
    - A procedure can be invoked repeatedly (called by name from an application).
- Procedures can serve as building blocks for an application

PL/SQL Block Structure for Stored Procedures

2. Named Blocks (stored procedures)

```
Header
IS
      Declaration section
BEGIN
      Executable section
EXCEPTION
      Exception section
END;
```

Procedure Syntax



```
CREATE [OR REPLACE] PROCEDURE procedure_name
[(parameter_name [IN | OUT | IN OUT] type [, ...])]
{IS | AS}
BEGIN
  < procedure_body >
END procedure_name;
```

- *procedure-name* specifies the name of the procedure.
- [OR REPLACE] option allows the modification of an existing procedure.
- **IN** parameter lets you pass a value to the subprogram. **It is a read-only parameter**.
- **OUT** parameter returns a value to the calling program. Inside the subprogram, an OUT parameter acts like a variable.
- *procedure-body* contains the executable part.
- The AS keyword is used instead of the IS keyword for creating a standalone procedure.

SQL*Plus: Named Block example

```
SQL> ed test       --opens Notepad
SQL> create or replace procedure test
  2  is
  3  begin
  4  dbms_output.put_line ('Hello World');
  5  End test;
  6  /
Procedure created.
SQL> show errors
No errors.
SQL> set serveroutput on
SQL> execute test;
Hello World
PL/SQL procedure successfully completed.
```

NOTE: marks the beginning of the body of the procedure and is similar to DECLARE

Note

Printing in PL/SQL –

Using DBMS_OUTPUT.PUT_LINE

```
SQL> set serveroutput on
```

- You can then use the following in procedures to print:

  DBMS_OUTPUT.PUT_LINE (‘Literals’);

  DBMS_OUTPUT.PUT_LINE (variables);
- Or a combination of literals & variables using the concatenation operator

Substitution Variables

```
SQL>    CREATE OR REPLACE PROCEDURE Test3
               IS
                      v_num NUMBER(2);
                      v_double NUMBER(2);
               BEGIN
                      v_num := & in_num;
                      v_double := v_num * 2;
                      DBMS_OUTPUT.PUT_LINE ('DOUBLE OF  '||
  TO_CHAR(v_num) || ' IS ' ||   TO_CHAR(v_double));
               END;
               /
SQL> SET serveroutput ON
SQL> execute test3
Enter value for in_num: 7
old   4:    v_num := &in_num;
new  4:    v_num := 7;
DOUBLE OF 7 IS 14
PL/SQL procedure successfully completed.
```

NOTE: Concatenation Operator

PL/SQL Decision Control Structures

- Use IF/THEN structure to execute code if condition is true
  - IF *condition* THEN

    commands that execute if condition is TRUE;

    END IF;
- If condition evaluates to NULL it is considered false

PL/SQL Decision Control Structures

- Use IF/THEN/ELSE to execute code if condition is true or false
  - IF *condition* THEN

        commands that execute if condition is TRUE;

    ELSE

        commands that execute if condition is FALSE;

    END IF;
- Can be nested – be sure to end nested statements

Control Structures
IF Statement

- Use IF/ELSIF to evaluate many conditions:
- Syntax (similar to Case statement in other languages)

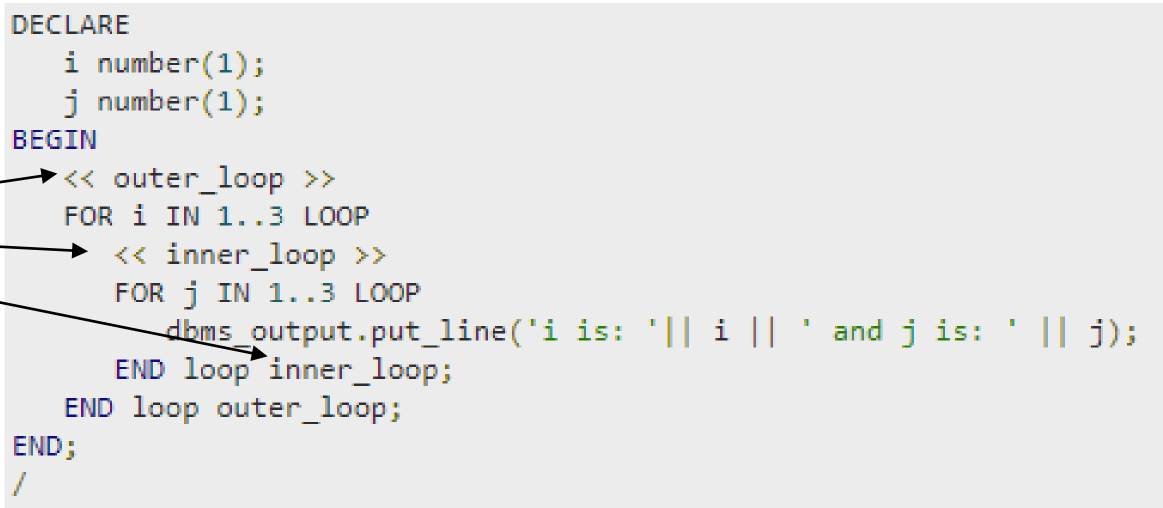
```
IF condition THEN
   Statements;
[ELSIF condition THEN
   Statements;]
[ELSE
   Statements;]
END IF;
```

Iterative Control Basic/Simple LOOP

- Syntax

```
LOOP
   Statement1;
   …
   EXIT [WHEN condition];
END LOOP;
```

Loop Label



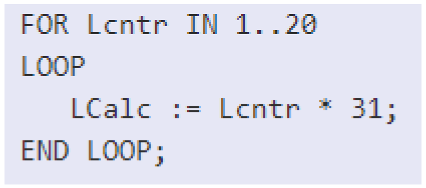
```
DECLARE
   i number(1);
   j number(1);
BEGIN
   << outer_loop >>
   FOR i IN 1..3 LOOP
      << inner_loop >>
      FOR j IN 1..3 LOOP
         dbms_output.put_line('i is: '|| i || ' and j is: ' || j);
      END loop inner_loop;
   END loop outer_loop;
END;
/
```

The Numeric FOR Loop

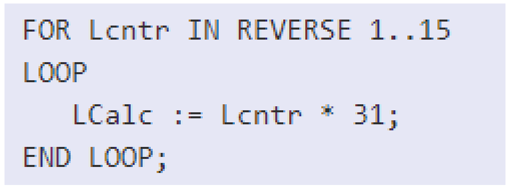
- Syntax

```
FOR counter in [REVERSE]
   Lower_bound..upper_bound LOOP
Statement1;
Statement2;
…
END LOOP;
```

Example



```
FOR Lcntr IN 1..20
LOOP
   LCalc := Lcntr * 31;
END LOOP;
```



```
FOR Lcntr IN REVERSE 1..15
LOOP
   LCalc := Lcntr * 31;
END LOOP;
```

NOTE: use a FOR LOOP when you want to execute the loop body a fixed number of times.

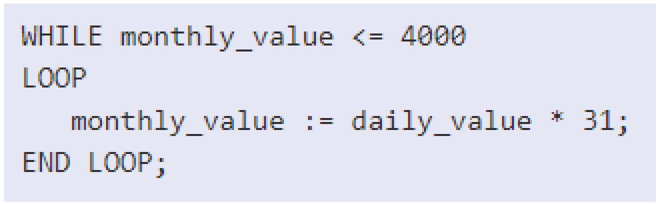
Iterative Control
WHILE Loop

- We use a WHILE LOOP when we are not sure how many times we will execute the loop body and the loop body may not execute even once.

- Syntax

```
WHILE condition LOOP
   Statement1;
   Statement2;
   …
END LOOP;
```

Example



```
WHILE monthly_value <= 4000
LOOP
   monthly_value := daily_value * 31;
END LOOP;
```

Named Block example using Parameters and IF Statement

```
CREATE OR REPLACE PROCEDURE debit_account (acct_id
  INTEGER, amount NUMBER)
IS
v_old_balance NUMBER;
v_new_balance NUMBER;
BEGIN
  SELECT bal INTO v_old_balance FROM accts
       WHERE acct_no = acct_id;
  v_new_balance := v_old_balance - amount;
  IF v_new_balance < 0 THEN
       DBMS_OUTPUT.PUT_LINE ('Account is Out of
  Funds');
  ELSE
       UPDATE accts SET bal = v_new_balance
       WHERE acct_no = acct_id;
       Commit;
   END IF;
END debit_account;
```

NOTE the INTO clause this is mandatory and must occur Between the SELECT and FROM clauses

Subprogram Parameters

- Transfer values to and from the subprogram through parameters
- Subprogram parameters have three modes
  - IN, (the default) passes values to a subprogram
  - OUT, must be specified, returns values to the caller
  - IN OUT, must be specified, passes values to a subprogram and returns updated values to the caller

Parameter Examples

- IN Parameter Example
- An IN parameter lets you pass a value to the subprogram. **It is a read-only parameter**.

- OUT Parameter Example
- An OUT parameter returns a value to the calling program. Inside the subprogram, an OUT parameter acts like a variable.

- IN OUT Parameter Example
- An **IN OUT** parameter passes an initial value to a subprogram and returns an updated value to the caller. It can be assigned a value and the value can be read.

Exercise

- Given a product table description

```
SQL> desc prod
 Name                Null?    Type
 ------------------- -------- -------------
 ProdID              NOT NULL NUMBER(6)
 Description                  VARCHAR2(30)
```

- Create a procedure called DEL_PROD to delete a product, passing ProdID as a parameter. Include the necessary exception handling

Exercise

- Given a Employee table description

```
SQL> desc emp
 Name                                      Null?    Type
 ----------------------------------------- -------- ------------
 EMPNO                                     NOT NULL NUMBER(4)
 ENAME                                              VARCHAR2(10)
 JOB                                                VARCHAR2(9)
 MGR                                                NUMBER(4)
 HIREDATE                                           DATE
 SAL                                                NUMBER(7,2)
 COMM                                               NUMBER(7,2)
 DEPTNO                                             NUMBER(2)
```

- Create a procedure called Qemp to query the EMP table and print the sal and job for an employee, passing EmpID as a parameter.

Invoking a Procedure From a Stored Procedure

```
CREATE OR REPLACE PROCEDURE process_emps
IS
  CURSOR emp_cursor IS
  SELECT empno
  FROM emp;
BEGIN
  FOR emp_rec IN emp_cursor LOOP
      raise_salary(emp_rec.empno);
  END LOOP;
COMMIT;
END process_emps;
/
```

Stored Functions

3. Named Blocks (stored functions)

- A function is a named PL/SQL block that returns a value.
- A function can be stored in the database, as a database object, for repeated execution.
- A function can be called as part of an expression.

Stored Function Example

```
CREATE OR REPLACE FUNCTION get_sal
  (v_id IN emp.empno%TYPE)
RETURN NUMBER
IS
  v_salary emp.sal%TYPE :=0;
BEGIN
  SELECT sal
  INTO v_salary
  FROM emp
  WHERE empno = v_id;
  RETURN (v_salary);
END get_sal;
/
```

Executing Functions

- We can use a host variable to quickly execute and test the function

```
SQL> VARIABLE g_salary NUMBER
SQL> EXECUTE :g_salary := get_sal(7934)

SQL> PRINT g_salary
```

- User-defined function can be called from any SQL expression wherever a built-in function can be called

Exercise

- Create a function called Q_PROD to return a product description when passed a ProdID as a parameter.

```
SQL> desc prod
 Name                Null?     Type
 -------------       --------  ----
 PRODID              NOT NULL  NUMBER(6)
 DESCRIP                       VARCHAR2(30)
```

- Create a function ANNUAL_COMP to return the annual salary when passed an employee’s monthly salary and annual commission.

Stored Function Restrictions

- A user-defined function must be a ROW function not a GROUP function.
- A user-defined function only takes IN parameters.
- When called from a SELECT statement the function cannot modify any database tables.
- When called from an INSERT, UPDATE, or DELETE statement, the function cannot query or modify any database tables modified by that statement.

Comparing Procedures and Functions

Procedure	Function
Execute as a PL/SQL statement	Invoke as part of an expression
No RETURN datatype	Must contain a RETURN datatype
Can return one or more values	Must return a value

Programming Guidelines

- Document code with comments
- Develop a case convention for the code
- Develop naming convention for identifiers and other objects
- Enhance readability by indenting

Cursors

- Pointer to a memory location that the DBMS uses to process a SQL query

- Used to retrieve and manipulate database data

SQL Statements in PL/SQL

- Extract a row of data from the database by using the SELECT command. Only a single set of values can be returned (Implicit Cursor).
- Make changes to rows in the database by using DML (Data Manipulation Language) commands
- Control transactions with the COMMIT, ROLLBACK, or SAVEPOINT command.

SELECT Statements in PL/SQL

```
DECLARE
   V_deptno NUMBER(2);
   V_loc         VARCHAR2(15);
BEGIN
   SELECT deptno, loc INTO v_deptno, v_loc
   FROM dept
   WHERE dname = ‘SALES’
…
END;
```

SQL Cursor

- A cursor is an SQL work area
- Two type of cursors
  - Implicit cursors
  - Explicit cursors
- PL/SQL implicitly declares a cursor for all SQL data manipulation statements and queries that return only one row.
- For queries that return more than one row the programmer must explicitly declare a cursor! IMPORTANT!

SQL Implicit Cursor Attributes

SQL%ROWCOUNT	Number of rows affected by the most recent SQL statement
SQL%FOUND	Boolean attribute that evaluates to TRUE if the most recent SQL statement affects one or more rows
SQL%NOTFOUND	Boolean attribute that evaluate to TRUE if the most recent SQL does not affect any rows
SQL%ISOPEN	Always evaluates to FALSE because PL/SQL closes implicit cursors immediately after they are executed

PL/SQL Records

- Similar in structure to records in a 3GL
- Convenient for fetching a row of data from a table for processing.

```
…
TYPE emp_record_type IS RECORD
    (ename          VARCHAR2(10),
     Job            VARCHAR2(9),
     Sal            NUMBER(7,2));
emp_record         emp_record_type;
…
```

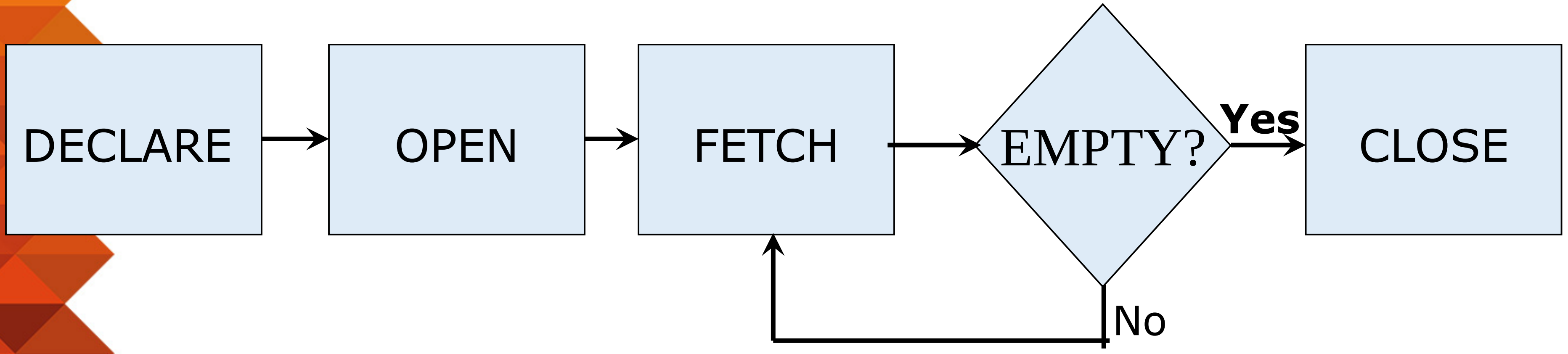
The %ROWTYPE Attribute

- Declare a variable according to a collection of columns in a database table or view.
- Prefix %ROWTYPE with the database table.
- Fields in the record take their name and datatypes from the columns of the table or view.

```
DECLARE
   Emp_record          emp%ROWTYPE;
```

Explicit Cursors

- Explicit cursors are named SQL work areas to manipulate queries returning more than one row.
- Use DECLARE, OPEN, FETCH and CLOSE to control explicit cursors.



Declaring the Cursor

- Syntax

```
CURSOR cursor_name IS
     SELECT_statement;
v_empno          emp.empno%Type
v_eName          emp.ename%Type
v_deptRec  dept%RowType
```

- Examples

```
CURSOR emp_cursor IS
   SELECT empno, ename
   FROM emp;
CURSOR dept_cursor IS
   SELECT *
   FROM dept;
```

Opening the Cursor

- Syntax

```
OPEN cursor_name;
```

- Example

```
OPEN emp_cursor;
```

- Open the cursor to execute the query and identify the active set.
- The cursor now points to the first row in the active set

Fetching Data From the Cursor

- Syntax

```
FETCH cursor_name INTO [variable1,
variable2, …]|record_name];
```

- Example

```
FETCH emp_cursor INTO v_empNo, v_eName;
FETCH dept_cursor INTO v_deptRec;
```

- Retrieve the current row values into variable(s) or record.
- Include the same number of variables.

Closing the Cursor

- Syntax

```
CLOSE cursor_name;
```

- Close the cursor after completing the processing of the rows

SQL Explicit Cursor Attributes

%ROWCOUNT	Evaluate to the total number of rows returned so far
%FOUND	Boolean attribute that evaluates to TRUE if the most recent fetch returns a row
%NOTFOUND	Boolean attribute that evaluate to TRUE if the most recent fetch does not return a row
%ISOPEN	Evaluates to TRUE if the cursor is open

Controlling Multiple Fetches

- Process several rows from an explicit cursor using a loop
- Fetch a row with each iteration
- Use the %NOTFOUND attribute to write a test for an unsuccessful fetch

Example Cursor

```
DECLARE
   V_empno          emp.empno%TYPE;
   V_ename          emp.ename%TYPE;
   CURSOR emp_cursor IS
      SELECT empno, ename FROM emp;
BEGIN
   OPEN emp_cursor;
   LOOP
      FETCH emp_cursor INTO v_empno, v_ename;
      EXIT WHEN emp_cursor%NOTFOUND;
      … do something with the cursor row
   END LOOP;
   CLOSE emp_cursor;
END;
```

Cursor FOR Loops

- Syntax

```
FOR record_name IN cursor_name
 LOOP
   Statement1;
   Statement2;
   …
END LOOP;
```

- *Implicit (automatic) open, fetch and close occur.*
- *The record is implicitly declared.*

Example Cursor For Loop

- DECLARE
  - CURSOR emp_cursor IS
    - SELECT empno, ename
    - FROM emp;
- BEGIN
  - FOR emp_record IN emp_cursor LOOP
    - … do required processing with emp_record
  - END LOOP;
- END;

Exceptions

- Errors are known as exceptions. An exception occurs when an unwanted situation arises during the execution of a program.
- Can result from a system error, a user error, or an application error.
- When an exception occurs, control of the current program block shifts to another section of the program, known as the exception handler.

Handling Exceptions

- Three types of exception
  - Predefined Oracle Server
  - Non-predefined Oracle Server
  - User Defined

Predefined Exceptions

- Sample predefined exception
  - NO_DATA_FOUND
  - TOO_MANY_ROWS
  - INVALID_CURSOR
  - ZERO_DIVIDE
  - DUP_VAL_ON_INDEX

  - Complete list is available in the PL/SQL User’s Guide and Reference, “Error Handling”

Handling Exceptions…

- Syntax

```
EXCEPTION
    WHEN exception1 [OR exception2 …] THEN
        Statement1;
        Statement2;
        …
    WHEN OTHERS THEN
        Statement1;
        Statement2;
        …
```

Some Examples

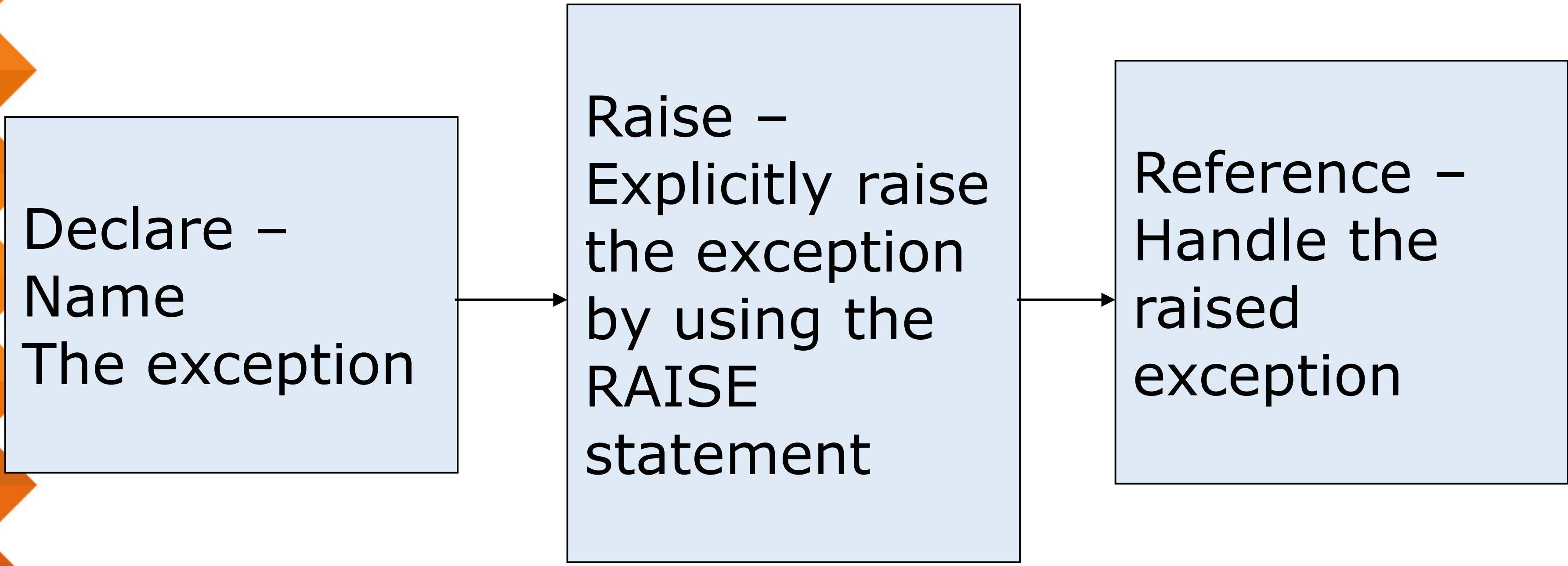
- You can write handlers for predefined exceptions using their names

```
EXCEPTION
   WHEN NO_DATA_FOUND THEN
     dbms_output.put_line('No data!');
   WHEN TOO_MANY_ROWS THEN
     dbms_output.put_line('Too many!');
   WHEN OTHERS THEN
     dbms_output.put_line('Error,
                          closing program now');
END;
```

Non-predefined Exceptions

- Non-predefined exception has an attached Oracle error code, but it is not named by Oracle.
- Such exceptions can be trapped with a WHEN OTHERS clause, or by **declaring them** with names.

User-Defined Exceptions


Declare – Name The exception
Raise – Explicitly raise the exception by using the RAISE statement
Reference – Handle the raised exception

User-defined Exception Example

```
DECLARE
    E_invalid_product EXCEPTION;
BEGIN
    UPDATE product
        SET descrip = ‘&product_description’
        WHERE prodid = &product_number;
    IF SQL%NOTFOUND THEN
            RAISE e_invalid_product;
    END IF;
    COMMIT;
EXCEPTION
    WHEN e_invalid_product THEN
            DBMS_OUTPUT.PUT_LINE (‘Invalid product number.’);
END;
```

Defining Your Own Error Messages

- Procedure RAISE_APPLICATION_ERROR
  - An application can call raise_application_error only from an executing stored subprogram
  - When called, raise_application_error ends the subprogram and returns a user-defined error number and message to the application
  - error_numbers should be a negative integer in the range -20000 .. -20999 and message is a character string up to 2048 bytes long
  - The error number and message can be trapped like any Oracle error

Procedure RAISE_APPLICATION_ERROR

- To call RAISE_APPLICATION_ERROR, use the syntax

  raise_application_error(error_number, message);

- For example:

```
…
          IF SaleQty > v_QOH THEN
                    Raise_application_error(-20501,'Not enough

          stock on Hand');
          END IF;
```

Exercise

- Change the Debit_Account Procedure discussed earlier (slide 23) to include Exception Handling for an error of your choice.

Reference

- Oracle 11g PL/SQL User's Guide and Reference
- http://plsql-tutorial.com/plsql-variables.htm
- https://www.tutorialspoint.com/plsql/plsql_variable_types.htm