Database Programming with PL/SQL

Creating DML Triggers: Part II

Objectives

This lesson covers the following objectives:

- Create a DML trigger that uses conditional predicates
- Create a row-level trigger
- Create a row-level trigger that uses `OLD` and `NEW` qualifiers
- Create an `INSTEAD OF` trigger
- Create a Compound Trigger

Purpose

There might be times when you want a trigger to fire under a specific condition. Or, you might want a trigger to impact just a row of data. These are examples of the DML trigger features covered in this lesson.

Using Conditional Predicates

In the previous lesson, you saw a trigger that prevents INSERTs into EMPLOYEES during the weekend:

```
CREATE OR REPLACE TRIGGER secure_emp
BEFORE INSERT ON employees BEGIN
  IF TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN') THEN
    RAISE_APPLICATION_ERROR(-20500,
         'You may insert into EMPLOYEES'
       ||' table only during business hours');
  END IF;
END;
```

Using Conditional Predicates (cont.)

```
CREATE OR REPLACE TRIGGER secure_emp
BEFORE INSERT ON employees BEGIN
  IF TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN') THEN
    RAISE_APPLICATION_ERROR(-20500,
         'You may insert into EMPLOYEES'
       ||' table only during business hours');
  END IF;
END;
```

Suppose you wanted to prevent any DML operation on `EMPLOYEES` during the weekend, with different error messages for `INSERT`, `UPDATE`, and `DELETE`. You could create three separate triggers; however, you can also do this with a single trigger. The next slide shows how.

Using Conditional Predicates (cont.)

```
CREATE OR REPLACE TRIGGER secure_emp
BEFORE INSERT OR UPDATE OR DELETE ON employees
BEGIN
  IF TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN') THEN
    IF DELETING THEN RAISE_APPLICATION_ERROR
      (-20501,'You may delete from EMPLOYEES'
            ||' table only during business hours');
    ELSIF INSERTING THEN RAISE_APPLICATION_ERROR
      (-20502,'You may insert into EMPLOYEES'
            ||' table only during business hours');
    ELSIF UPDATING THEN RAISE_APPLICATION_ERROR
      (-20503,'You may update EMPLOYEES'
            ||' table only during business hours');
    END IF;
  END IF;
END;
```

Using Conditional Predicates (cont.)

You can use conditional predicates to test for `UPDATE` on a specific column:

```
CREATE OR REPLACE TRIGGER secure_emp
BEFORE UPDATE ON employees
BEGIN
  IF UPDATING('SALARY') THEN
    IF TO_CHAR(SYSDATE,'DY') IN ('SAT','SUN')
      THEN RAISE_APPLICATION_ERROR
        (-20501,'You may update SALARY'
              ||' only during business hours');
    END IF;
  ELSIF UPDATING('JOB_ID') THEN
    IF TO_CHAR(SYSDATE,'DY') = 'SUN'
      THEN RAISE_APPLICATION_ERROR
        (-20502,'You may not update JOB_ID on Sunday');
    END IF;
  END IF;
END;
```

Understanding Row Triggers

Remember that a statement trigger executes only once for each triggering DML statement:

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees BEGIN
  INSERT INTO log_emp_table (who, when)
    VALUES (USER, SYSDATE);
END;
```

This trigger inserts exactly one row into the log table, regardless of whether the triggering statement updates one employee, several employees, or no employees at all.

Understanding Row Triggers (cont.)

Suppose you want to insert one row into the log table for each updated employee. For example, if four employees were updated, insert four rows into the log table. You need a *row trigger*.

Row Trigger Firing Sequence

A row trigger fires (executes) once for each row affected by the triggering DML statement, either just `BEFORE` the row is processed or just `AFTER`. If five employees are in department 50, the row trigger executes five times:

```
UPDATE employees
  SET salary = salary * 1.1
  WHERE department_id = 50;
```

EMPLOYEE_ID	LAST_NAME	DEPARTMENT_ID
124	Mourgos	50
141	Rajs	50
142	Davies	50
143	Matos	50
144	Vargas	50

→ `BEFORE` row trigger
→ `AFTER` row trigger
...
→ `BEFORE` row trigger
→ `AFTER` row trigger
...

Creating a Row Trigger

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table (who, when)
    VALUES (USER, SYSDATE);
END;
```

You specify a row trigger using `FOR EACH ROW`. The `UPDATE` statement in the previous slide now inserts five rows into the log table, one for each `EMPLOYEE` row updated.

Creating a Row Trigger (cont.)

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table (who, when)
    VALUES (USER, SYSDATE);
END;
```

However, all five rows in the log table are identical to each other. And the log table does not show which employees were updated, or what changes were made to their salaries.

Using :OLD and :NEW Qualifiers

Only within a row trigger, can you reference and use both old and new column values in the EMPLOYEES row currently being updated.

You code **:OLD.column_name** to reference the pre-update value, and **:NEW.column_name** to reference the post-update value.

Using :OLD and :NEW Qualifiers (cont.)

For example, if the UPDATE statement is changing an employee's salary from 10000 to 11000, then **:OLD.salary** has a value of 10000, and **:NEW.salary** has a value of 11000. Now you can insert the data you need into the logging table. The next slide shows how.

Using :OLD and :NEW Qualifiers (cont.)

To log the employee_id, does it matter whether you code **:OLD.employee_id** or **:NEW.employee_id**? Is there a difference?

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table
   (who, when, which_employee, old_salary, new_salary)
    VALUES (USER, SYSDATE, :OLD.employee_id,
            :OLD.salary, :NEW.salary);
END;
```

A Second Example of Row Triggers

```
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;
```

A Second Example: Testing the `audit_emp_values` Trigger

```
INSERT INTO employees
  (employee_id, last_name, job_id, salary, ...)
  VALUES (999, 'Temp emp', 'SA_REP', 1000,...);

UPDATE employees
  SET salary = 2000, last_name = 'Smith'
  WHERE employee_id = 999;
```

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

USER_NAME	TIME_STAMP	ID	OLD_LAST_NAME	NEW_LAST_NAME	OLD_TITLE	NEW_TITLE	OLD_SALARY	NEW_SALARY
APEX_PUBLIC_USER	04-DEC-2006	999	Temp emp	Smith	SA_REP	SA_REP	1000	2000
APEX_PUBLIC_USER	04-DEC-2006	-	-	Temp emp	-	SA_REP	-	1000

A Third Example of Row Triggers

Suppose you need to prevent employees who are not a President or Vice-President from having a salary of more than $15000.

```
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;
```

Testing the `restrict_salary` Trigger:

```
UPDATE employees SET salary = 15500
  WHERE last_name IN ('King','Davies');
```

King is a (Vice-)President, but Davies is not. This `UPDATE` statement produces the following error:

```
ORA-20202:  Employee cannot earn more than $15,000.
ORA-06512:  at "USVA_TEST_SQL01_T01.RESTRICT_SALARY", line 4
ORA-04088:  error during execution of trigger
'USVA_TEST_SQL01_T01.RESTRICT_SALARY'
2.   WHERE last_name IN ('King', 'Davies');
```

Neither `EMPLOYEES` row is updated, because the `UPDATE` statement must either succeed completely or not at all.

A Fourth Example: Implementing an Integrity Constraint With a Trigger

The EMPLOYEES table has a foreign key constraint on the DEPARTMENT_ID column of the DEPARTMENTS table. DEPARTMENT_ID 999 does not exist, so this DML statement violates the constraint and the employee row is not updated:

```
UPDATE employees SET department_id = 999
  WHERE employee_id = 124;
```

You can use a trigger to create the new department automatically. The next slide shows how.

A Fourth Example: Creating the Trigger:

```
CREATE OR REPLACE TRIGGER employee_dept_fk_trg
BEFORE UPDATE OF department_id ON employees
FOR EACH ROW
DECLARE
  v_dept_id    departments.department_id%TYPE;
BEGIN
  SELECT department_id INTO v_dept_id FROM departments
    WHERE department_id = :NEW.department_id;
EXCEPTION
  WHEN NO_DATA_FOUND THEN
    INSERT INTO departments VALUES(:NEW.department_id,
      'Dept '||:NEW.department_id, NULL, NULL);
END;
```

Let's test it:

```
UPDATE employees SET department_id = 999
  WHERE employee_id = 124;
-- Successful after trigger is fired
```

Using the REFERENCING Clause

Look again at the first example of a row trigger:

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table
   (who, when, which_employee, old_salary, new_salary)
    VALUES (USER, SYSDATE, :OLD.employee_id,
            :OLD.salary, :NEW.salary);
END;
```

What if the EMPLOYEES table had a different name? What if it was called OLD instead? OLD is not a good name, but is possible. What would our code look like now?

Using the REFERENCING Clause (cont.)

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON old
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table
   (who, when, which_employee, old_salary, new_salary)
    VALUES (USER, SYSDATE, :OLD.employee_id,
            :OLD.salary, :NEW.salary);
END;
```

The word OLD now means two things: it is a value qualifier (like :NEW) and also a table name. The code will work, but is confusing to read. We don't have to use :OLD and :NEW. We can use different qualifiers by including a REFERENCING clause.

Using the REFERENCING Clause (cont.)

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON old
REFERENCING OLD AS former NEW AS latter
FOR EACH ROW
BEGIN
  INSERT INTO log_emp_table
   (who, when, which_employee, old_salary, new_salary)
    VALUES (USER, SYSDATE, :former.employee_id,
            :former.salary, :latter.salary);
END;
```

FORMER and LATTER are called correlation-names. They are aliases for OLD and NEW. We can choose any correlation names we like (for example TOM and MARY) as long as they are not reserved words. The REFERENCING clause can be used only in row triggers.

Using the WHEN clause

Look at this trigger code. It logs salary changes only if the new salary is greater than the old salary.

```
CREATE OR REPLACE TRIGGER restrict_salary
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  IF :NEW.salary > :OLD.salary THEN
    INSERT INTO log_emp_table
    (who, when, which_employee, old_salary, new_salary)
    VALUES (USER, SYSDATE, :OLD.employee_id,
            :OLD.salary, :NEW.salary);
  END IF;
END;
```

The whole trigger body is a single `IF` statement. In real life, this could be many lines of code, including `CASE` statements, loops and many other constructs. This would be difficult to read.

Using the WHEN clause (cont.)

We can code our `IF` condition in the trigger header, just before the `BEGIN` clause.

```
CREATE OR REPLACE TRIGGER restrict_salary
AFTER UPDATE OF salary ON employees
FOR EACH ROW
WHEN (NEW.salary > OLD.salary)
BEGIN
  INSERT INTO log_emp_table
  (who, when, which_employee, old_salary, new_salary)
  VALUES (USER, SYSDATE, :OLD.employee_id,
          :OLD.salary, :NEW.salary);
END;
```

This code is easier to read, especially if the trigger body is long and complex. The `WHEN` clause can be used only with row triggers.

INSTEAD OF Triggers

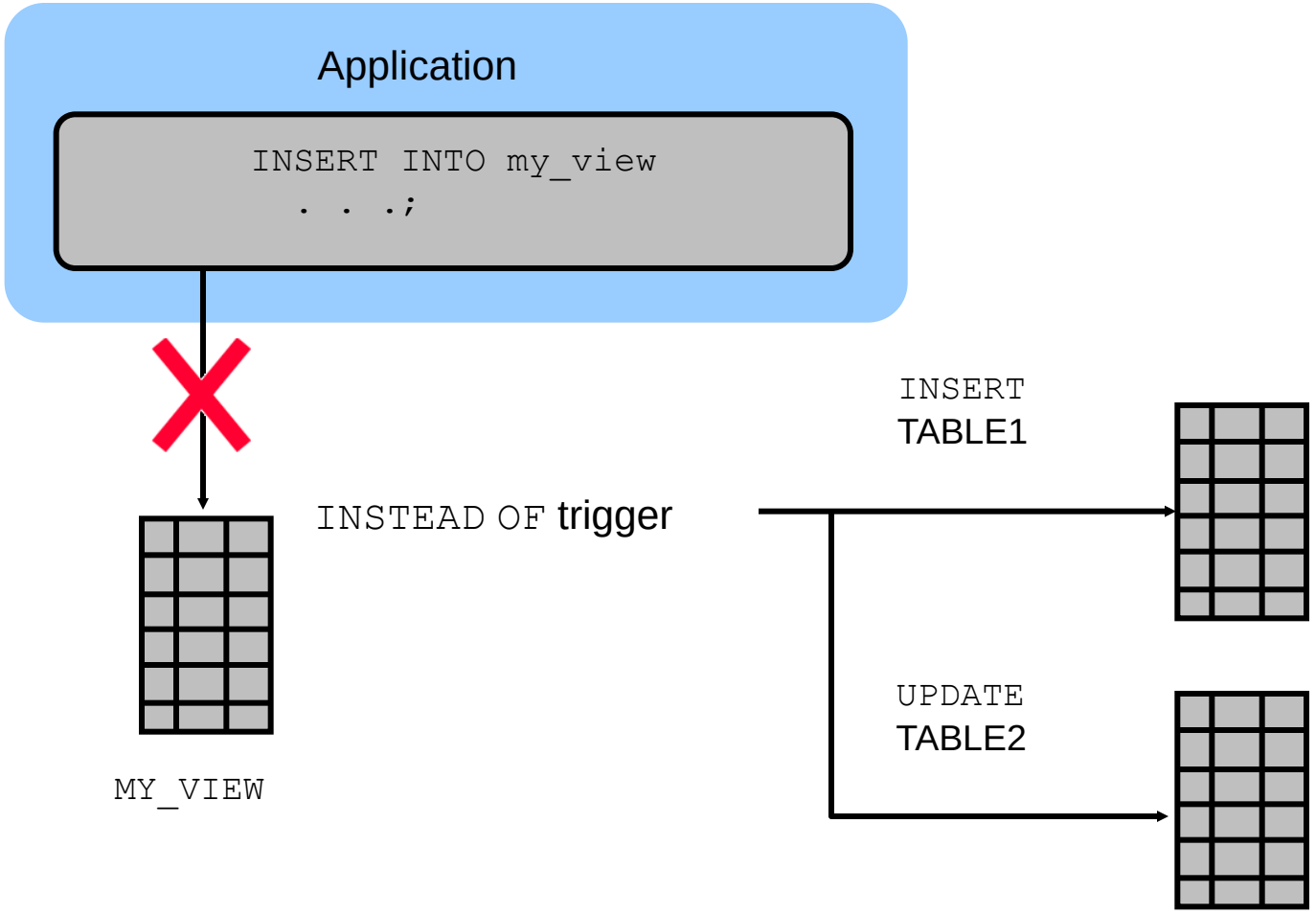
A Complex View (for example a view based on a join) cannot be updated. Suppose the EMP_DETAILS view is a complex view based on a join of EMPLOYEES and DEPARTMENTS. The following SQL statement fails:

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

You can overcome this by creating a trigger that updates the two base tables directly *instead of* trying (and failing) to update the view.

INSTEAD OF triggers are always row triggers.

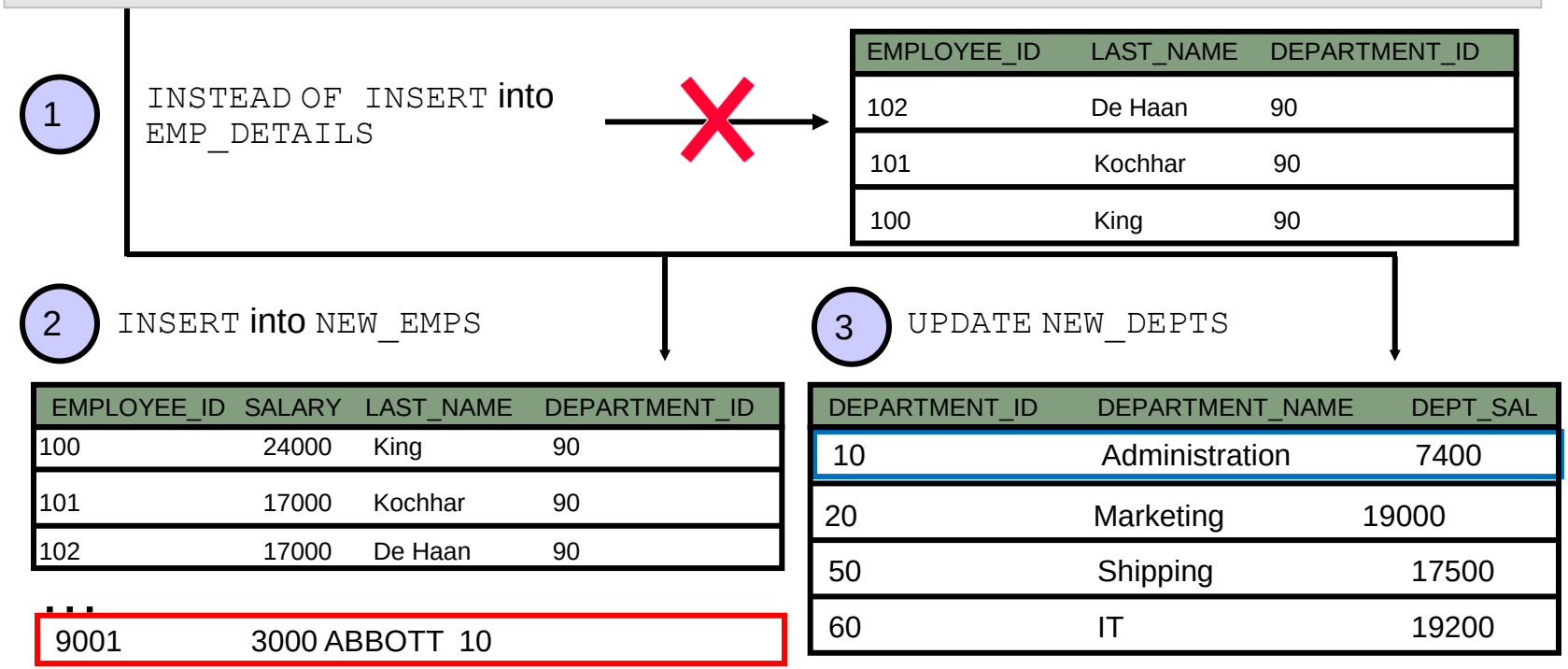
INSTEAD OF Triggers (cont.)



An Example of an INSTEAD OF Trigger

Perform the INSERT into the EMP_DETAILS view that is based on the NEW_EMPS and NEW_DEPTS tables:

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



Creating an INSTEAD OF Trigger

Step 1: Create the tables and the complex view:

```
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
    GROUP BY d.department_id,d.department_name;

CREATE VIEW emp_details AS
  SELECT e.employee_id, e.last_name, e.salary,
         e.department_id, d.department_name
    FROM new_emps e, new_depts d
    WHERE e.department_id = d.department_id;
```

Creating an INSTEAD OF Trigger (cont.)

Step 2: Create the INSTEAD OF Trigger:

```
CREATE OR REPLACE TRIGGER new_emp_dept
INSTEAD OF INSERT ON emp_details
BEGIN
  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;
END;
```

Row Triggers Revisited

Look at this row trigger, which logs employees' salary changes:

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
BEGIN
  INSERT INTO log_table
   (employee_id, change_date, salary)
    VALUES (:OLD.employee_id, SYSDATE, :NEW.salary);
END;
```

Row Triggers Revisited (cont.)

What if there are one million employees, and you give every employee a 5% salary increase:

```
UPDATE employees SET salary = salary * 1.05;
```

The row trigger will automatically execute one million times, `INSERT`ing one row each time. This will be very slow.

Row Triggers Revisited (cont.)

Earlier in the course you learned how to use Bulk Binding (FORALL) to speed up DML. Can we use FORALL in our trigger?

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
DECLARE
  TYPE t_log_emp IS TABLE OF log_table%ROWTYPE
                    INDEX BY BINARY_INTEGER;
  log_emp_tab    t_log_emp;
BEGIN
  ... Populate log_emp_tab with employees' change data
  FORALL i IN log_emp_tab.FIRST..log_emp_tab.LAST
    INSERT INTO log_table VALUES log_emp_tab(i);
END;
```

Row Triggers Revisited (cont.)

This will not work. Why not? Hint: remember that this is a *row* trigger, and think about the scope of the `LOG_EMP_TAB` collection variable.

```
CREATE OR REPLACE TRIGGER log_emps
AFTER UPDATE OF salary ON employees
FOR EACH ROW
DECLARE
  TYPE t_log_emp IS TABLE OF log_table%ROWTYPE
                    INDEX BY BINARY_INTEGER;
  log_emp_tab    t_log_emp;
BEGIN
  ... Populate log_emp_tab with employees' change data
  FORALL i IN log_emp_tab.FIRST..log_emp_tab.LAST
    INSERT INTO log_table VALUES log_emp_tab(i);
END;
```

Row Triggers Revisited (cont.)

Trigger variables lose scope at the end of each execution of the trigger. So each time the row trigger is fired, all the data already collected in `LOG_EMP_TAB` is lost.

To avoid losing this data, we need a trigger that fires only once – a statement trigger. But to reference column values from each row (using `:OLD` and `:NEW`) we need a row trigger.

Row Triggers Revisited (cont.)

But a single trigger cannot be both a row trigger and a statement trigger at the same time. Right?

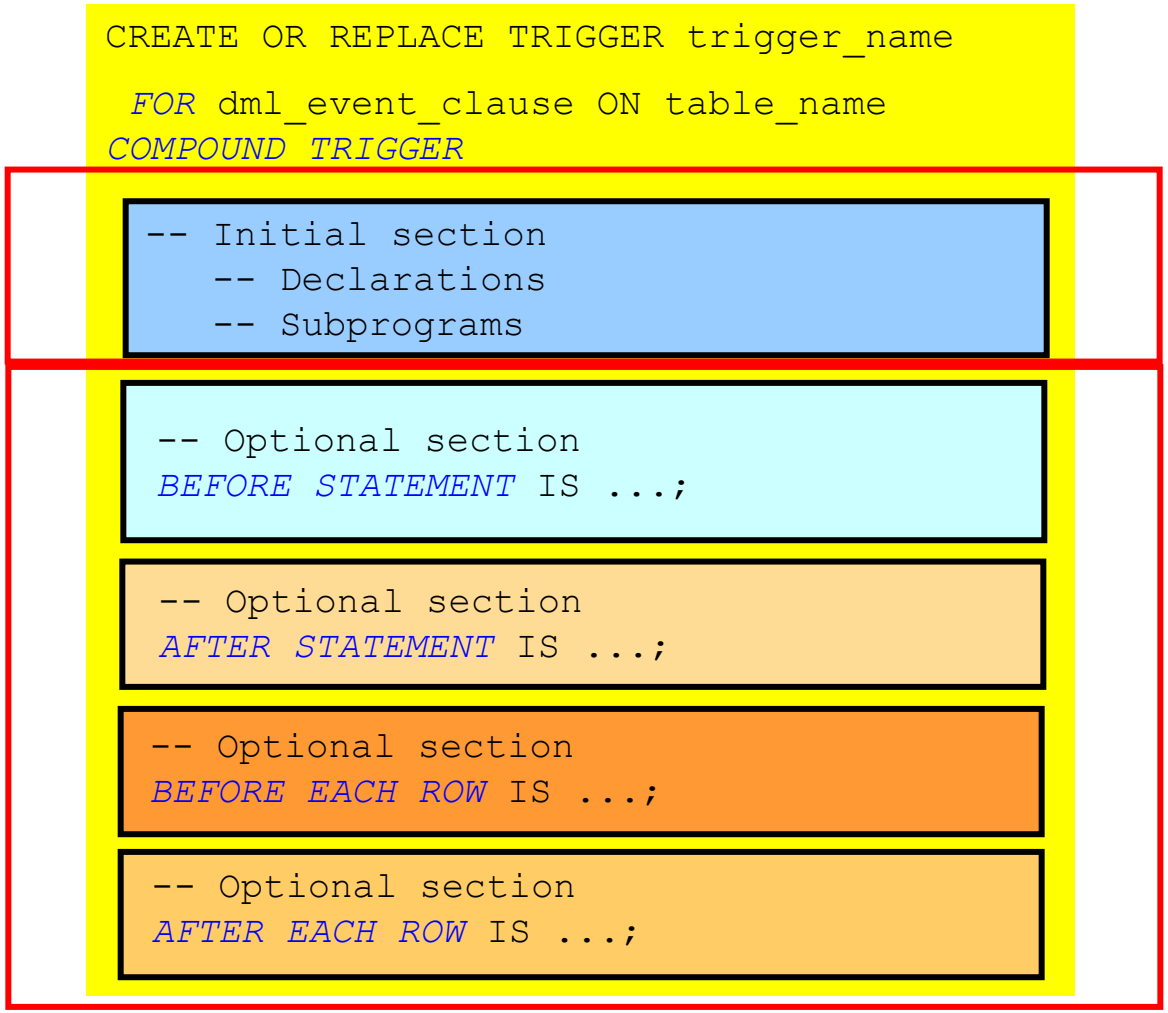
Wrong! We create a *Compound Trigger*.

What is a Compound Trigger?

A single trigger that can include actions for each of the four possible timing points: before the triggering statement, before each row, after each row, and after the triggering statement.

A compound trigger has a declaration section, and a section for each of its timing points. You do not have to include all the timing points, just the ones you need. The scope of compound trigger variables is the whole trigger, so they retain their scope throughout the whole execution.

Compound Trigger Structure



Compound Triggers: an Example:

This example has a declaration section and two of the four possible timing point sections.

```
CREATE OR REPLACE TRIGGER log_emps
FOR UPDATE OF salary ON employees
COMPOUND TRIGGER
DECLARE
  TYPE t_log_emp IS TABLE OF log_table%ROWTYPE
                    INDEX BY BINARY_INTEGER;
  log_emp_tab    t_log_emp;
AFTER EACH ROW IS
BEGIN
  ... Populate log_emp_tab with employees' change data
END AFTER EACH ROW;
AFTER STATEMENT IS
BEGIN
  FORALL ...
END AFTER STATEMENT;
END log_emps;
```

Compound Triggers Example: The Full Code

```
CREATE OR REPLACE TRIGGER log_emps
FOR UPDATE OF salary ON employees
COMPOUND TRIGGER
DECLARE
  TYPE t_log_emp IS TABLE OF log_table%ROWTYPE
                    INDEX BY BINARY_INTEGER;
  log_emp_tab    t_log_emp;
  v_index        BINARY_INTEGER := 0;
AFTER EACH ROW IS BEGIN
  v_index := v_index + 1;
  log_emp_tab(v_index).employee_id := :OLD.employee_id;
  log_emp_tab(v_index).change_date := SYSDATE;
  log_emp_tab(v_index).salary      := :NEW.salary;
END AFTER EACH ROW;
AFTER STATEMENT IS BEGIN
  FORALL I IN log_emp_tab.FIRST..log_emp_tab.LAST
    INSERT INTO log_table VALUES log_emp_tab(i);
END AFTER STATEMENT;
END log_emps;
```

Terminology

Key terms used in this lesson included:

- Conditional predicate
- Compound trigger
- DML row trigger
- `INSTEAD OF` trigger
- `:OLD` and `:NEW` qualifiers

Summary

In this lesson, you should have learned how to:

- Create a DML trigger that uses conditional predicates
- Create a row-level trigger
- Create a row-level trigger that uses `OLD` and `NEW` qualifiers
- Create an `INSTEAD OF` trigger
- Create a Compound Trigger