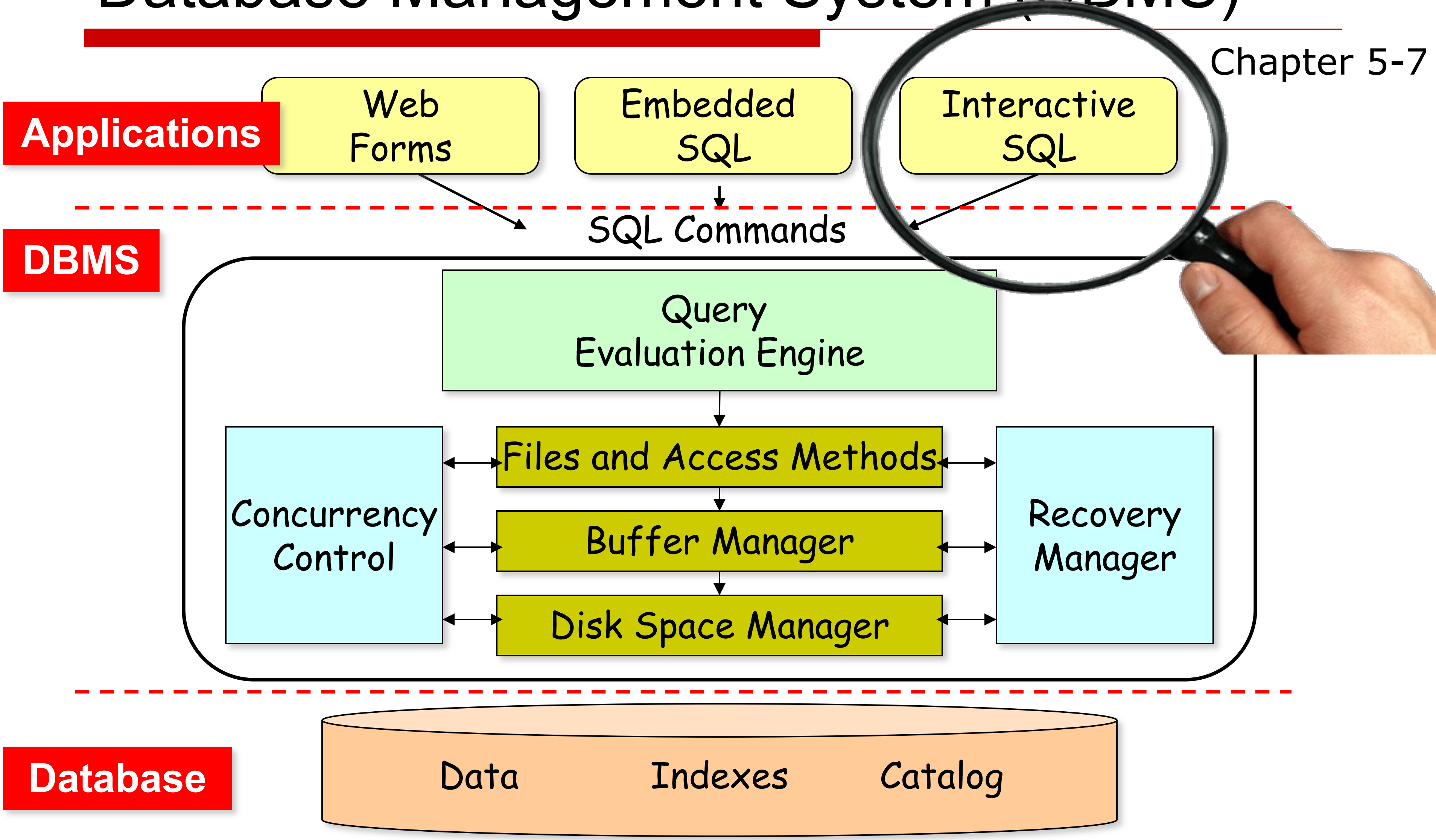
Database Management System (DBMS)

Chapter 5-7



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Relational Database Management Systems

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  - SQL Queries
  - Views
  - Integrity Constraints
  - Complex Integrity Constraints

Complex Integrity Constraints

- A constraint is expressed as a **Predicate**
  - A condition similar to the one in the `WHERE`-clause of an SQL query

- Three DDL constructs
  - Checks
  - Assertions
  - Triggers

Queries and Transactions

- Queries: requests to the DBMS to retrieve data from the database
- Updates: requests to the DMBS to insert, delete or modify existing data
- Transactions: logical grouping of query and update requests to perform a task
  - Logical unit of work (like a function/subroutine)

ACID Properties

A tomicity

C onsistency

I solation

D urability

ACID Properties

- **Atomicity**

  Either all the operations associated with a transaction happen or none of them happens

- **Consistency**

  It satisfies the integrity constraints on the database at the transaction's boundaries

- **Isolation**

  The result of the execution of concurrent transactions is the same as if transactions were executed serially

- **Durability**

  The effects of completed transactions become permanent surviving any subsequent failures

SQL Transactions

- Basic transaction statements:
  - SET TRANSACTION READ WRITE NAME <name>;
    (DECLARE TRANSACTION READ WRITE;)
  - SET TRANSACTION READ ONLY NAME <name>;
    (DECLARE TRANSACTION READ ONLY;)
  - COMMIT ;
  - ROLLBACK;

Transaction Consistency

T$_1$: `UPDATE` Accounts `SET` balance= balance - 100 `WHERE` client=7

- □ **Consistency:** It satisfies the integrity constraints on the database at the transaction's boundaries
  - □ E.g., balance is not allowed to be negative
- □ Mechanism: **Integrity Constraints (ICs)**
  - □ *Checks, Assertions, Triggers, etc.*

Transaction Atomicity

- What do we expect with Atomicity?
  - "All or nothing"

- Consider a transaction:

```
set transaction read write name 'test';
  insert into Student values (23, 'John', 'CS');
  insert into Dept values ('CS', 'ITEE');
Commit;
```

- What happens if the first insert fails, e.g., due to a referential constraint violation?
  - Is the new tuple inserted into Department? No?

Modes of Constraints Enforcement

- **NON DEFERRABLE** or **IMMEDIATE**
  - Evaluation is performed at input time
  - By default constraints are created as NON DEFERRABLE
  - It *cannot* be changed during execution
- **DEFERRED**
  - Constraints are not evaluated until commit time
- **DEFERRABLE**
  - It can be changed within a transaction to be DEFERRED using SET CONSTRAINT
- Modes can be specified when a table is created
  - INITIALLY IMMEDIATE: constraint validation happen immediately
  - INITIALLY DEFERRED: constraint validation defer until commit

Specifying Initial Evaluation Mode in Tables

```
CREATE TABLE SECTION
( SectNo sectno_dom,
  Name section_dom,
  HeadSSN ssn_dom,
  Budget budget_dom,


);
```

Specifying Initial Evaluation Mode in Tables

```
CREATE TABLE SECTION
( SectNo sectno_dom,
  Name section_dom,
  HeadSSN ssn_dom,
  Budget budget_dom,
 CONSTRAINT section_PK
   PRIMARY KEY (SectNo) DEFERRABLE,
 CONSTRAINT section_FK
   FOREIGN KEY (HeadSSN) REFERENCES LIBRARIAN(SSN)
   INITIALLY DEFERRED DEFERRABLE,
 CONSTRAINT section_name_UN UNIQUE (Name)
   DEFERRABLE INITIALLY IMMEDIATE
);
```

Changing Constraint Evaluation Mode

- It is permitted only for deferrable constraints

- Setting the constraint validation mode within a transaction
  - Set mode of all deferrable constraints

    ```
    SET CONSTRAINT ALL IMMEDIATE;
    SET CONSTRAINT ALL DEFERRED;
    ```

  - Set mode of specific deferrable constraints (list)

    ```
    SET CONSTRAINT section_budget_IC IMMEDIATE;
    SET CONSTRAINT section_budget_IC DEFERRED;
    ```

Specifying Transaction Atomicity 1

- Errors at commit time: only when **deferred constraints** are violated
  - Constraints can be deferred if specified as **deferrable** in the table schema, and
  - Deferred in the scope of the transaction
- E.g. 1, *assume the constraints are deferrable*

```
set transaction read write name ’test’;
set constraints all deferred;
insert into Student values (23, 'John', 'CS');
insert into Dept values ('CS', 'ITEE');
Commit;
```

- No constraint violation of the first insert is detected at *commit time* → the whole transaction is committed

Specifying Transaction Atomicity 2

- Errors at commit time: only when **deferred constraints** are violated
  - E.g. 2, *assume the constraints are deferrable and assume SID 23 exists in that Database*

```
set transaction read write name ’test’;
set constraints all deferred;
insert into Student values (23, 'John', 'CS');
insert into Dept values ('CS', 'ITEE');
Commit;
```

- The constraint violation of the first insert is detected at *commit time* → the whole transaction is rollback

Specifying Transaction Atomicity 3

- Errors at commit time: only when **deferred constraints** are violated
  - E.g. 3, *assume the primary key constraints are non-deferrable but the foreign key constraints are deferrable and assume SID 23 exists in that Database*

```
set transaction read write name ’test’;
set constraints all deferred;
insert into Student values (23, 'John', 'CS');
insert into Dept values ('CS', 'ITEE');
Commit;
```

- What would happen?

Complex Integrity Constraints

- Three DDL constructs
  - Checks
  - Assertions
  - Triggers

Example Schema

SID	*Name*	*Age*	*GPA*	*Major*
546007	Peter	18	3.8	IT
546100	Bob	19	6.65	Cinema
546500	Peter	20	4.7	History

Example Schema

```
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major CHAR(10),

    PRIMARY KEY (Sid));
```

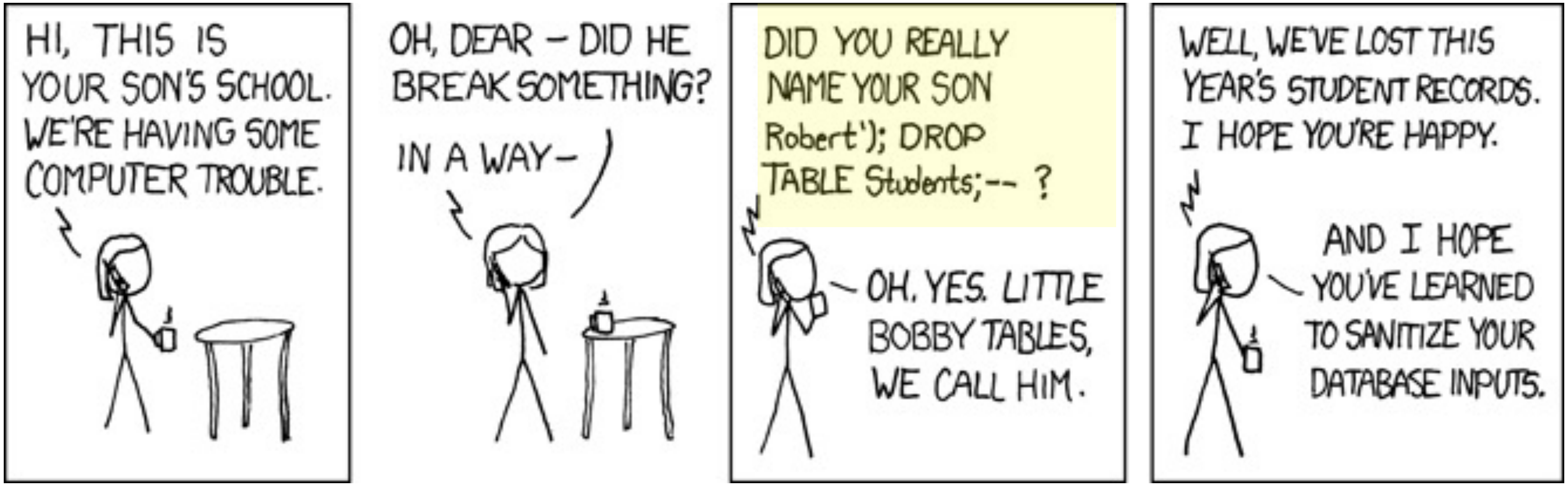
CHECK Constraint 1

```
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
        CHECK (GPA>=0.0 AND GPA <= 7.0);
    Major CHAR(10),

    PRIMARY KEY (Sid));
```

CHECK Constraint 2

```
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major CHAR(10),
        CHECK (Major IN (‘IT’, ‘Cinema’, ‘History’));

    PRIMARY KEY (Sid));
```

Be Careful with Your Database Inputs ☺


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

CHECK Constraint and DOMAIN

```
CREATE DOMAIN M_Code AS CHAR(10)
CHECK (M_Code IN (‘IT’, ‘Cinema’, ‘History’));


CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major M_Code,
    PRIMARY KEY (Sid));
```

CHECK: Attribute- vs. Tuple-based

- CHECK prohibits an operation on a table that would violate a constraint
- CHECK clause restricts acceptable attribute values according to some definition
  - **Attribute-based**
- CHECK is also used as a **tuple-based** constraint:
  - Apply to each tuple individually
  - Checked whenever a tuple is inserted or modified
  - See next example…

Example

```
CREATE DOMAIN M_Code AS CHAR(10)
CHECK (M_Code IN (‘IT’ ,‘Cinema’, ‘History’));
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major M_Code,
    Minor …, what constraints are needed for Minor?
    PRIMARY KEY (Sid));
```

IC1: Minor IN …

IC2: Minor ≠ Major

Example: Attribute-based

```
CREATE DOMAIN M_Code AS CHAR(10)
CHECK (M_Code IN (‘IT’, ‘Cinema’, ‘History’));
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major M_Code,
    Minor M_Code,
    PRIMARY KEY (Sid));
```

IC1: attribute-based

Example: Attribute- and Tuple-based

```
CREATE DOMAIN M_Code AS CHAR(10)
CHECK (M_Code IN ('IT', 'Cinema', 'History'));
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major M_Code,
    Minor M_Code, CHECK (Major != Minor);
    PRIMARY KEY (Sid));
```

IC1: attribute-based

IC2: tuple-based

Naming Constraints

- A constraint may be given a name using the keyword **`CONSTRAINT`**
  - E.g., **`CONSTRAINT`** Major_Minor

- Advantages of naming a constraint:
  - Facilitates editing
  - Identifies a particular constraint
    1. For reporting
    2. For constraint management

Naming Constraints

```
CREATE DOMAIN M_Code AS CHAR(10)
CHECK (M_Code IN (‘IT’, ‘Cinema’, ‘History’));
CREATE TABLE Student (
    Sid INTEGER,
    Name CHAR(20),
    Age INTEGER,
    GPA REAL,
    Major M_Code,
    Minor M_Code,
    CONSTRAINT Major_Minor
        CHECK (Major != Minor););
```

Constraint Management

```
ALTER TABLE Student DROP CONSTRAINT Major_Minor;
```

```
ALTER TABLE Student ADD CONSTRAINT Major_Minor
      CHECK (Major != Minor);
```

- To modify a constraint:
  - Drop it first and then add a new one

Assertions

- Similar to `CHECK` but they are **global** constraints

```
CREATE ASSERTION <assertion_name>
CHECK <condition>;
```

  - Global: schema-based
  - <condition> must be TRUE for each database state
- Examples:
  - # of IT stduents cannot exceed 1800
  - # of students in a prac cannot exceed lab capacity
  - …

Assertions

```
CREATE ASSERTION <assertion_name>
CHECK NOT EXISTS (vquery);
```

1. Specify a query <*vquery*> such that:
   vquery selects any tuple that **violates** *<condition>*

2. Include vquery inside a **`NOT EXISTS`** clause

Assertions

```
CREATE ASSERTION <assertion_name>
CHECK NOT EXISTS (vquery);
```

Result of *vquery*	**NOT EXISTS (*vquery*)**	**CHECK**
Empty (no tuples violate the condition)	TRUE	Satisfied
Not Empty (some tuples violate the condition)	FALSE	Violated

Example Schema

SID	*Name*	*Age*	*GPA*	*Major_Code*
546007	Peter	18	3.8	0
546100	Bob	19	3.65	50
546500	Peter	20	3.7	1

Major_Code	*Major_name*
0	IT
1	History
…	
50	Cinema

Example

- Number of students in any major cannot exceed 1800

```
CREATE ASSERTION Major_Limit
CHECK  NOT EXISTS (
                 SELECT Major_Code, COUNT(*)
                 FROM Student
                 GROUP BY Major_Code
                 HAVING COUNT(*) > 1800 );
```

Example

- The Number of students cannot exceed 1800 in each of the IT or Cinema majors

```
CREATE ASSERTION Major_Limit
CHECK NOT EXISTS (
      SELECT Major_Code, COUNT(*)
      FROM Student AS S , Major AS M
      WHERE S.major_code = M.major_code
      AND (M.major_name=“IT” OR M.major_name=“Cinema”)
      GROUP BY Major_Code
      HAVING COUNT(*) > 1800 );
```

Triggers

- A trigger consists of 3 parts:
  1. Event(s),
  2. Condition, and
  3. Action

  - E.g., notify the Dean whenever the number of students in any major exceeds 1800

Triggers vs. Assertions

- Assertion
  - Condition must be true for each database state
  - DBMS rejects operations that violate such condition
- Trigger
  - DBMS takes a certain **action** when condition is true
  - Action could be: stored procedure, SQL statements, Rollback, etc.

Example

- Notify the Dean when the # of students in any major exceeds 1800

`CREATE TRIGGER` Major_Limit

Event(s)

Condition

Action

Example

- Notify the Dean when the # of students in any major exceeds 1800

CREATE TRIGGER Major_Limit

Event(s)

```
WHEN( EXISTS (
                 SELECT Major_Code, COUNT(*)
                 FROM Student
                 GROUP BY Major_Code
                 HAVING COUNT(*)  > 1800 ))
```

Action

Example

- Notify the Dean when the # of students in any major exceeds 1800

```
CREATE TRIGGER Major_Limit
```

Event(s)

```
WHEN( EXISTS (
                SELECT Major_Code, COUNT(*)
                FROM Student
                GROUP BY Major_Code
                HAVING COUNT(*)  > 1800 ))
```

```
CALL email_dean(Major_code);
```

Example

- Notify the Dean when the # of students in any major exceeds 1800

```
CREATE TRIGGER Major_Limit
```

```
AFTER INSERT OR UPDATE OF Major_Code
ON Student
```

```
WHEN( EXISTS (
                 SELECT Major_Code, COUNT(*)
                 FROM Student
                 GROUP BY Major_Code
                 HAVING COUNT(*)  > 1800 ))
```

```
CALL email_dean(Major_code);
```

Triggers (SQL99)

```
CREATE or REPLACE TRIGGER <trigger-name>
     <time events> ON <list-of-tables>
     REFERENCING { NEW | OLD} AS  <user-name>
  [FOR EACH { ROW | STATEMENT} ]
    [WHEN (<Predicate>)]
  <action>
```

- time: **before** or **after**
- events: **Insert, Delete, Update [of <list of attributes>]**
- **NEW & OLD** refer to new & old (existing) tuples/table respectively
- The REFERENCING clause assigns aliases to NEW and OLD
- action: Stored procedure or

  `BEGIN ATOMIC {<SQL procedural statements>} END`

Oracle Example: Statement Trigger

- Statement-level trigger fires **once** by the triggering statement

- No WHEN-clause in the definition of statement trigger

-
```
CREATE OR REPLACE TRIGGER Audit_Updater
   AFTER
   INSERT OR DELETE OR UPDATE
   ON STUDENTS
BEGIN
     INSERT INTO AUDIT_Table VALUES (`STUDENT’, sysdate);
END;
/
```

- The end slash (“/”) installs and activates the trigger

Oracle Example: Row-Level Trigger

- Row- or tuple-level trigger fires once **for each row** affected by the triggering statement

-
  ```
  CREATE OR REPLACE TRIGGER trigger_deans_list
     AFTER INSERT ON STUDENTS
     REFERENCING NEW AS newRow
  FOR EACH ROW
      WHEN (newRow.GPA > 6.0)
  BEGIN
       INSERT INTO DL VALUES ( :newRow.SID, :newRow.GPA );
  END;
  /
  ```

- Scope Rules: In the trigger body, NEW and OLD must be preceded by a colon (":"), but in the WHEN clause (triggering condition), they do not have a preceding colon!