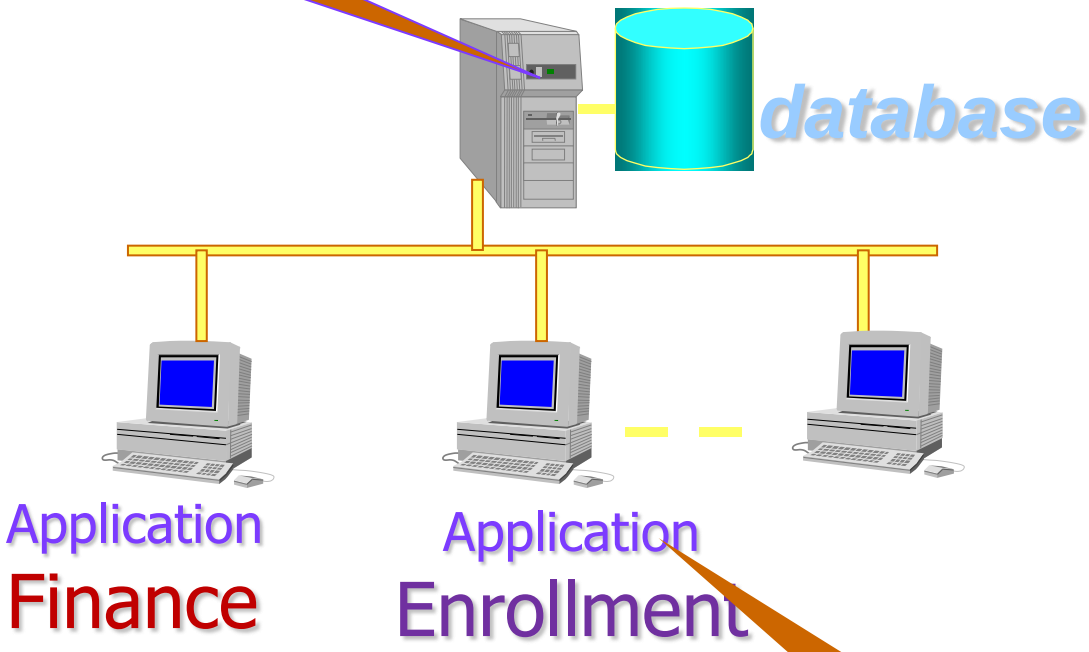
Stored Procedures & Triggers

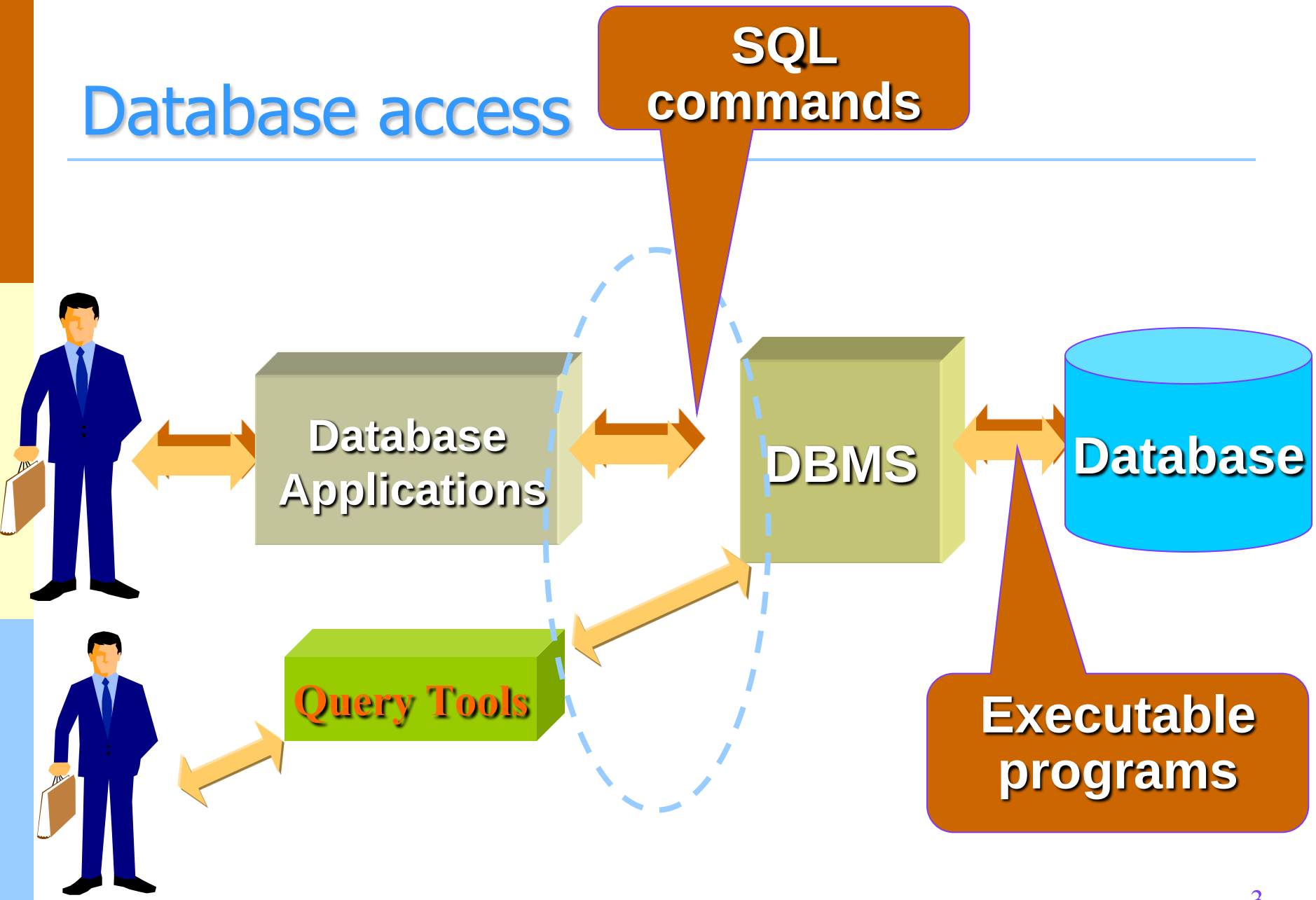
DBMS



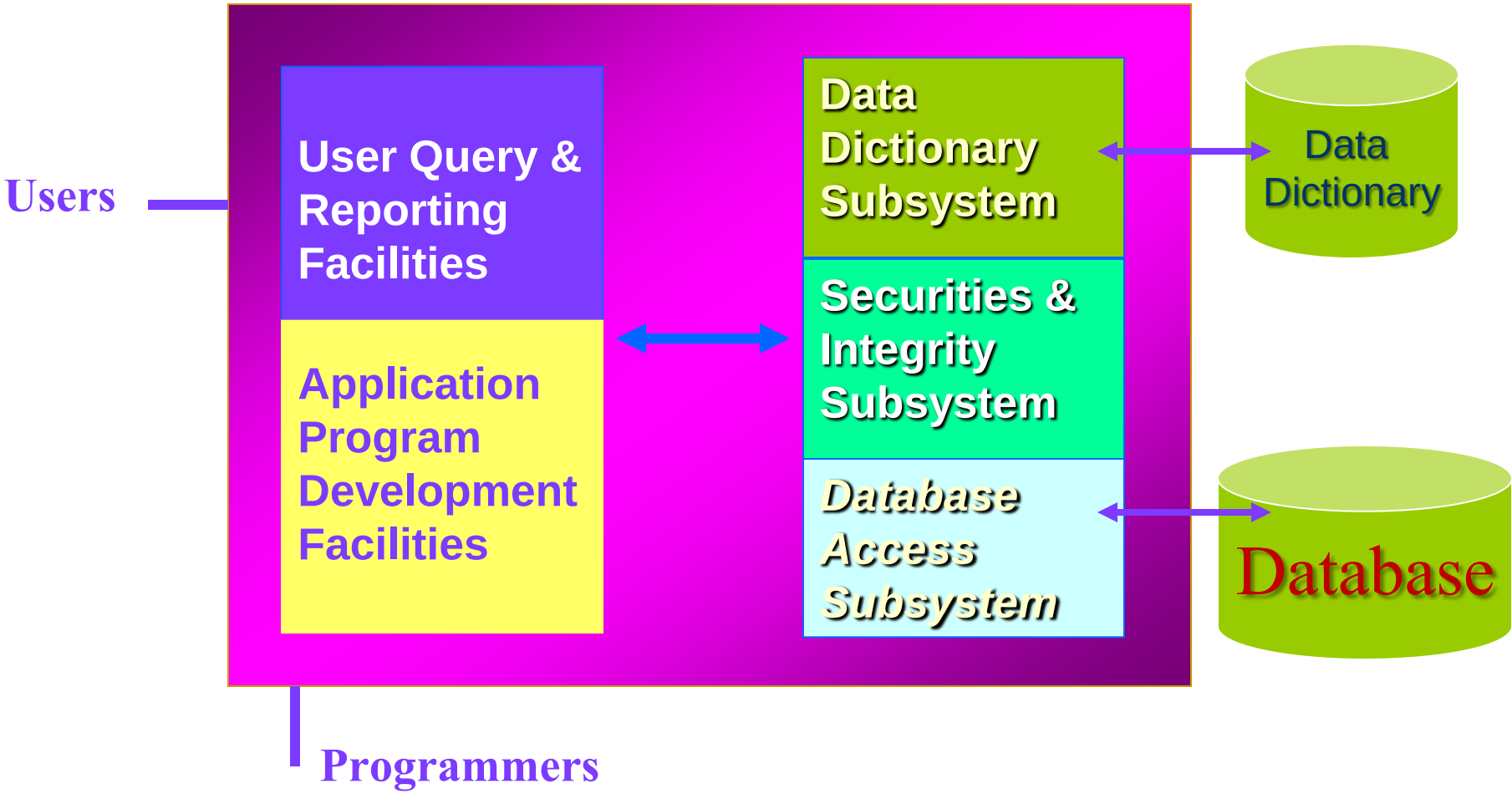
- ***Multiple programs***
- ***Many types of users***

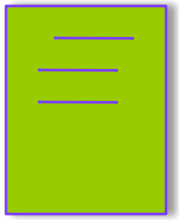
สร้างโดย Application development tools

Database access



DBMS

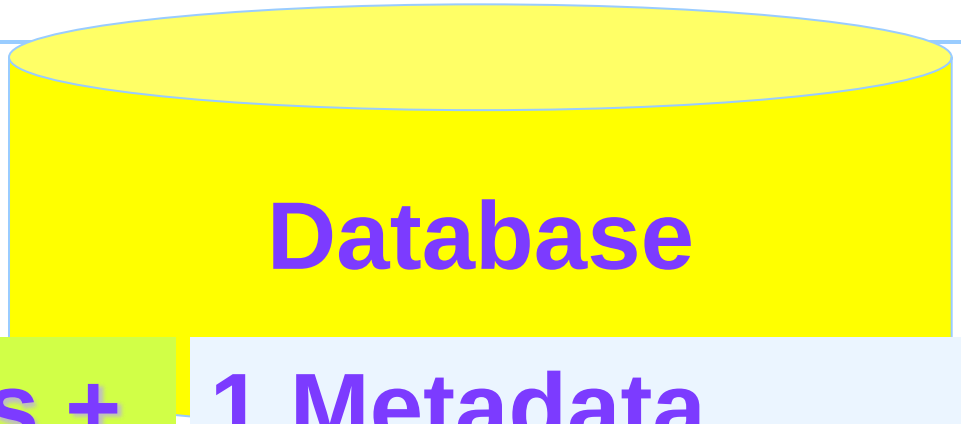

Users
User Query & Reporting Facilities
Application Program Development Facilities
Data Dictionary Subsystem
Securities & Integrity Subsystem
Database Access Subsystem
Data Dictionary
Database
Programmers

Bits } bytes } fields } records } files 

Bits } bytes } fields } records } files +

Metadata,
Indices,
Application Metadata

} Database



files +

1.Metadata,

2.Indices,

3.Application Metadata

a program/ function to be used and shared by many applications

Outline

- *Database programming language background*
- *Stored **procedures***
- *Triggers*

Motivation for Database Programming Languages

- Customization
- Batch processing
- Complex operations
- Efficiency and portability
  - Compatibilities of applications with many types of servers and browsers

Database Programming Languages

- A procedural language with an interface to one or more DBMSs.
- Interface allows a program to combine
  - *procedural statements* with
  - *nonprocedural* database access (SQL).

SQL Results Processing

- กรณีมีผลลัพธ์ SELECT statements มีเพียง 1 แถว
  - result values can be stored in program variables

Select INTO variables

DECLARE

- deptid employees.department_id%TYPE;
- jobid employees.job_id%TYPE;

SELECT department_id, job_id

- **INTO** deptid, jobid
- FROM employees
- WHERE employee_id = 140;

SQL Results Processing

- กรณีผลลัพธ์ SELECT statements > 1 แถว
  - Cursor for multiple row results
  - Cursor is similar to a dynamic array
    - array size = size of the query result
- Interface provides statements to
  - declare,
  - open,
  - close,
  - iterate (position), and
  - retrieve values

Overview of PL/SQL

- Proprietary database programming language for Oracle
- Widely used language
- Java style syntax with a statement level interface
- Use PL/SQL for writing stored procedures and triggers

User Identifiers in PL/SQL

- Variables and Constants
- Names: not case sensitive
- Restrictions
  - At most 30 characters
  - Must begin with a letter
  - Must be unique
  - Allowable characters are letters, numbers, _, #, and $

PL/SQL Constants

- Numeric constants: whole numbers, fixed decimal numbers, and scientific notation
- String constants: use single quotes; case sensitive
- Boolean constants: TRUE, FALSE
- NULL: *constant for every data type*
- No date constants: use the To_Date function to create string constants

PL/SQL Data Types

- String: CHAR(L), VARCHAR2(L)
- Numeric: INTEGER, DECIMAL(W,D), FLOAT(P). SMALLINT
- Logical: BOOLEAN
- DATE: stores both date and time

Variable Declaration Examples

```
DECLARE
  aFixedLengthString      CHAR(6) DEFAULT 'ABCDEF';
  aVariableLengthString   VARCHAR2(30);
  anIntegerVariable       INTEGER := 0;
  aFixedPrecisionVariable DECIMAL(10,2);
-- Uses the SysDate function for the default value
  aDateVariable           DATE DEFAULT SysDate;
```

Variable Declaration Examples

```
DECLARE
-- Anchored declarations  %TYPE
 anOffTerm          Offering.OffTerm%TYPE;
 anOffYear          Offering.OffYear%TYPE;
 aCrsUnits          Course.CrsUnits%TYPE;
 aSalary1           DECIMAL(10,2);
 aSalary2           aSalary1%TYPE;
```

ชนิดข้อมูลตรงกับ Attributes ในฐานข้อมูล

Assignment Examples

```
aFixedLengthString := 'XYZABC';
anIntegerVariable  := anAge + 1;

aFixedPrecisionVar := aSalary*0.10;
```

String concatenation function (| |)

```
aVarLengthString := aFixedLengthString || 'ABCDEF';

-- To_Date is the date conversion function

aDateVariable          DATE;
aDateVariable := To_Date('30-Jun-2006');
```

IF Statement Format

IF-THEN Statement:

```
IF condition THEN
   sequence of statements
END IF;
```

IF-THEN-ELSE Statement:

```
IF condition THEN
   sequence of statements 1
ELSE
   sequence of statements 2
END IF;
```

CASE Statement Format

CASE Statement (Oracle 9i/10g only):

```
CASE selector
 WHEN expression1 THEN sequence of statements 1
 WHEN expression2 THEN sequence of statements 2
 WHEN expressionN THEN sequence of statements N
 [ ELSE sequence of statements N+1 ]
END CASE;
```

Formats of Iteration Statements

FOR LOOP Statement:

```
FOR variable IN BeginExpr .. EndExpr LOOP
   sequence of statements
END LOOP;
```

WHILE LOOP Statement:

```
WHILE condition LOOP
   sequence of statements
END LOOP;
```

LOOP Statement:

```
LOOP
   sequence of statements containing an EXIT statement
END LOOP;
```

Common SQL *Plus Commands

- CONNECT: login to a database
- DESCRIBE: list table details
- EXECUTE: execute statements
- HELP: lists column details
- SET: assigns values to SQL *Plus environment variables
- SHOW: displays error details
- SPOOL: send output to a file

Note: By Oracle

PL/SQL Blocks

- Anonymous blocks to test procedures and triggers
- Named blocks for stored procedures

Block Structure:

```
[ DECLARE
    sequence of declarations ]
BEGIN
    sequence of statements
[ EXCEPTION
    sequence of statements to respond to exceptions ]
END;
```

Anonymous Block Example

```
SET SERVEROUTPUT ON; -- SQL Plus command
-- Anonymous block คือไม่ตั้งชื่อโปรแกรม
DECLARE
 TmpSum     INTEGER;
 TmpProd    INTEGER;
 Idx        INTEGER;
BEGIN
 TmpSum := 0;
 TmpProd := 1;
 -- Use a loop to compute the sum and product
 FOR Idx IN 1..10 LOOP
    TmpSum := TmpSum + Idx;
    TmpProd := TmpProd * Idx;
 END LOOP;
 Dbms_Output.Put_Line('Sum is ' || To_Char(TmpSum));
 Dbms_Output.Put_Line('Product is ' || To_Char(TmpProd));
END;
/
```

Format of PL/SQL Procedures

```
CREATE [OR REPLACE] PROCEDURE ProcedureName
   [ (Parameter1, …, ParameterN) ]
IS
   [  sequence of declarations  ]
BEGIN
   sequence of statements
[  EXCEPTION
   sequence of statements to respond to exceptions  ]
END;
```

Simple Procedure Example

```
CREATE OR REPLACE PROCEDURE pr_InsertRegistration
(aRegNo IN Registration.RegNo%TYPE,
 aStdSSN IN Registration.StdSSN%TYPE,
 aRegStatus IN Registration.RegStatus%TYPE,
 aRegDate IN Registration.RegDate%TYPE,
 aRegTerm IN Registration.RegTerm%TYPE,
 aRegYear IN Registration.RegYear%TYPE) IS
-- Create a new registration
BEGIN
   INSERT INTO Registration
    (RegNo, StdSSN, RegStatus, RegDate, RegTerm, RegYear)
   VALUES
    (aRegNo, aStdSSN, aRegStatus, aRegDate, aRegTerm,
     aRegYear);
   dbms_output.put_line('Added a row to the table');
END;
/
```

Registration.RegNo%TYPE

%TYPE indicates the same type
as
Registration.RegNo type

Exception Example

```
CREATE OR REPLACE PROCEDURE pr_InsertRegistration
(aRegNo IN Registration.RegNo%TYPE,
 aStdSSN IN Registration.StdSSN%TYPE,
 aRegStatus IN Registration.RegStatus%TYPE,
 aRegDate IN Registration.RegDate%TYPE,
 aRegTerm IN Registration.RegTerm%TYPE,
 aRegYear IN Registration.RegYear%TYPE,
 aResult OUT BOOLEAN ) IS
-- aResult is TRUE if successful, false otherwise.
BEGIN
        aResult := TRUE;
        INSERT INTO Registration
        (RegNo, StdSSN, RegStatus, RegDate, RegTerm, RegYear)
        VALUES
        (aRegNo, aStdSSN, aRegStatus, aRegDate, aRegTerm,
        aRegYear);
EXCEPTION
    WHEN OTHERS THEN aResult := FALSE;
END;
```

OTHERS exception catches a variety of errors

- such as
  - a violation of a primary key constraint or
  - a foreign key constraint

Common Predefined Exceptions

- Cursor_Already_Open
- Dup_Val_On_Index
- Invalid_Cursor
- No_Data_Found
- Rowtype_Mismatch
- Timeout_On_Resource
- Too_Many_Rows

Format of PL/SQL *Functions*

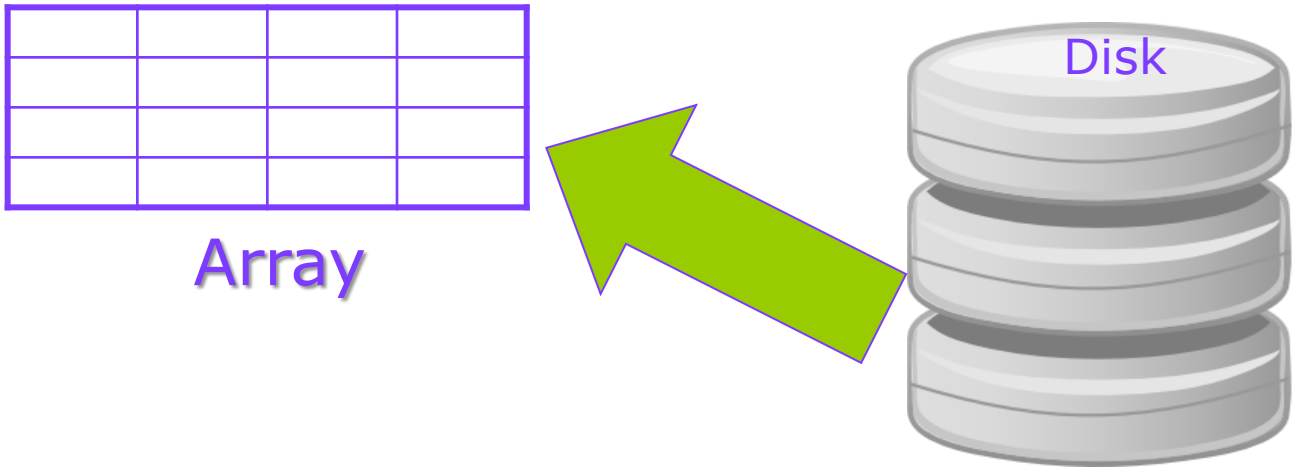
```
CREATE [OR REPLACE] FUNCTION FunctionName
   [ (Parameter1, …, ParameterN) ]
RETURN DataType
IS
   [ sequence of declarations ]
BEGIN
   sequence of statements including a RETURN statement
   [ EXCEPTION
   sequence of statements to respond to exceptions ]
END;
```

Simple Function Example

```
CREATE OR REPLACE FUNCTION fn_RetrieveStdName
(aStdSSN IN Student.StdSSN%type) RETURN VARCHAR2 IS
aFirstName Student.StdFirstName%type;
aLastName Student.StdLastName%type;
BEGIN
      SELECT StdFirstName, StdLastName
      INTO aFirstName, aLastName
      FROM Student
      WHERE StdSSN = aStdSSN;
      RETURN(aLastName || ', ' || aFirstName);
EXCEPTION
      WHEN No_Data_Found THEN
      RETURN(NULL);
      WHEN OTHERS THEN
      raise_application_error(-20001,'Database error');
END;
```

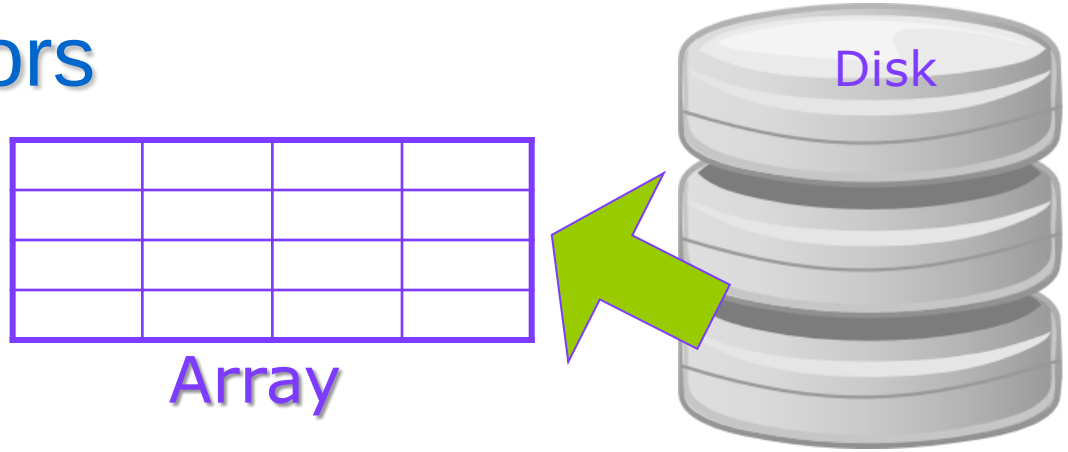

COFFEE
BREAK

PL/SQL Cursors



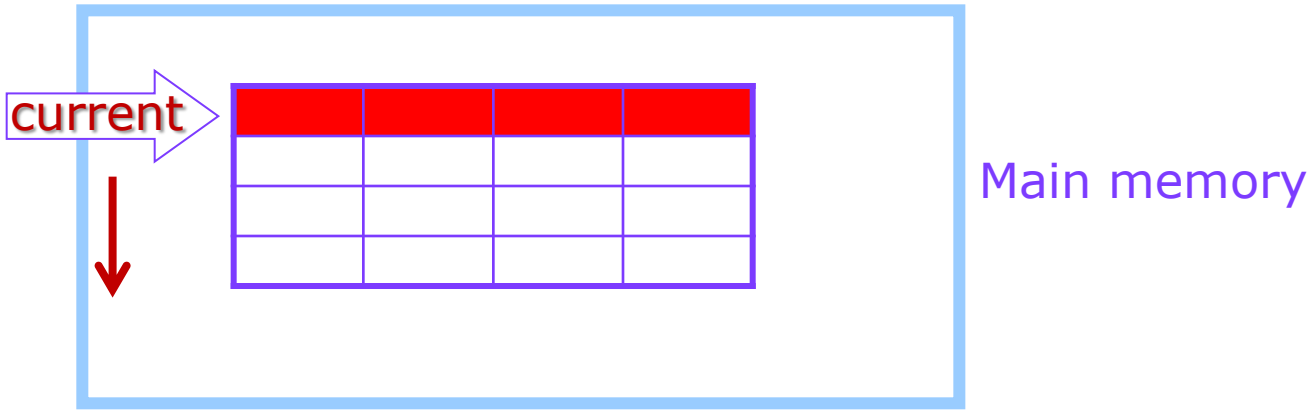
PL/SQL Cursors

- Supports usage of SQL statements that *return a collection of rows*
- Declaration statements
- ***Specialized FOR*** statement
- Cursor attributes *(indicate the status of cursor operations)*
- Actions on cursors



What are Cursors?

- A cursor is a temporary work area created in the system memory when a SQL statement is executed.
  - store the data retrieved from the database *(array with a pointer)*



Classification of Cursors

- Implicit: ไม่ต้องประกาศ /เปิดใช้
  - Cursor created by Data Manipulation Language :
    - INSERT, UPDATE, DELETE, SELECT
      - Return a single row
- Explicit: ต้องประกาศ/ เปิดใช้เอง
  - Cursor defined and manipulated by users
  - declared with the CURSOR statement in the DECLARE section

Classification of Cursors

- Statement binding:
  - Static: SQL statement specified at compile-time
  - Dynamic: SQL statement specified at execution

Common Cursor Attributes

Cursor states:

- %ISOpen:
  - true if cursor is open
- %Found:
  - true if cursor is not empty following a **FETCH** statement
- %NotFound:
  - true if cursor is empty following a **FETCH** statement
- %RowCount:
  - number of rows fetched

Returning an implicit cursor into a record ***

```
declare
        r_emp   employee%ROWTYPE;
begin
   Select * into r_emp from employee
   Where id = '01';
      DBMS_OUTPUT.put_line(r_emp.first_Name);
end;
```

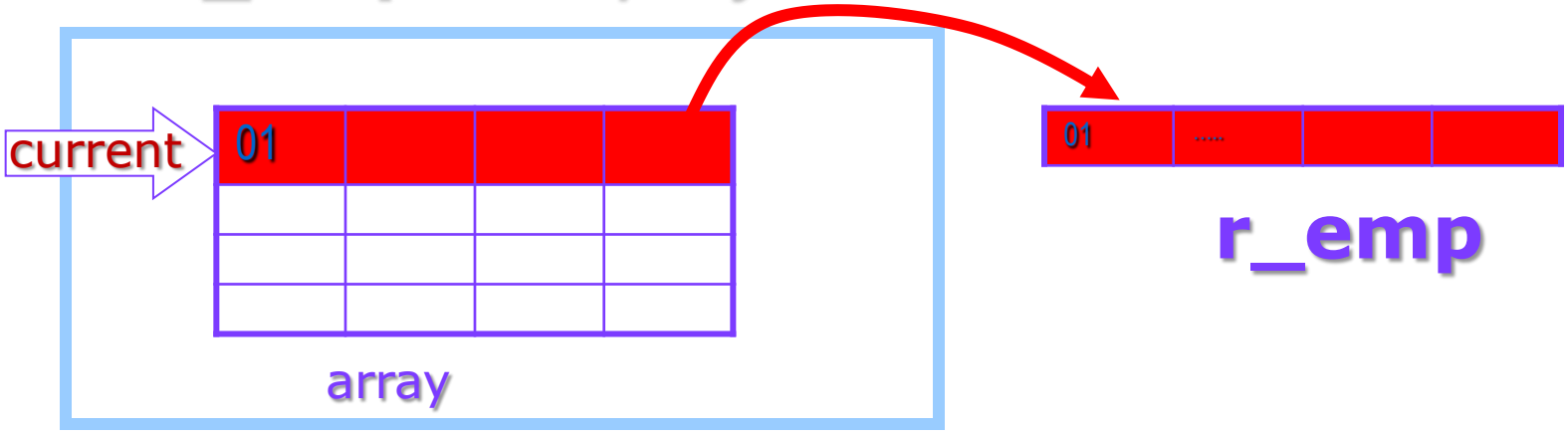
****if use select statement, avoid implicit cursor***

นี่แค่ตัวอย่าง ไม่ควรทำแบบนี้

Returning an implicit cursor into a record

- **declare**

r_emp employee%ROWTYPE;




```
select * into r_emp from employee
    where id = '01';
```

Creating an explicit cursor

- *Syntax*

```
CURSOR  cursor_name  IS
    select_statement;
```

  - *cursor_name – A suitable name for the cursor.*
  - *select_statement – A select query which returns multiple rows.*

How to use Explicit Cursor?

There are 4steps in using an Explicit Cursor.

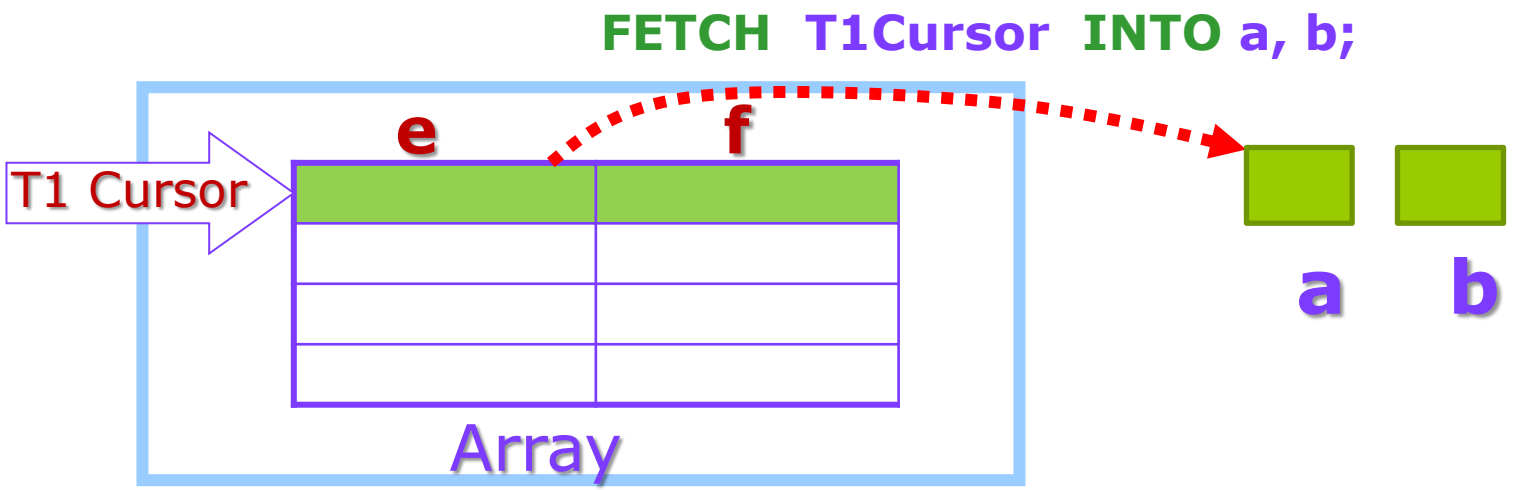
1. DECLARE the cursor in the declaration section.
2. OPEN the cursor in the Execution Section.
3. **FETCH** the data from cursor into PL/SQL variables or records in the Execution Section.
4. CLOSE the cursor in the Execution Section before you end the PL/SQL Block.

เพื่ออ่านข้อมูล

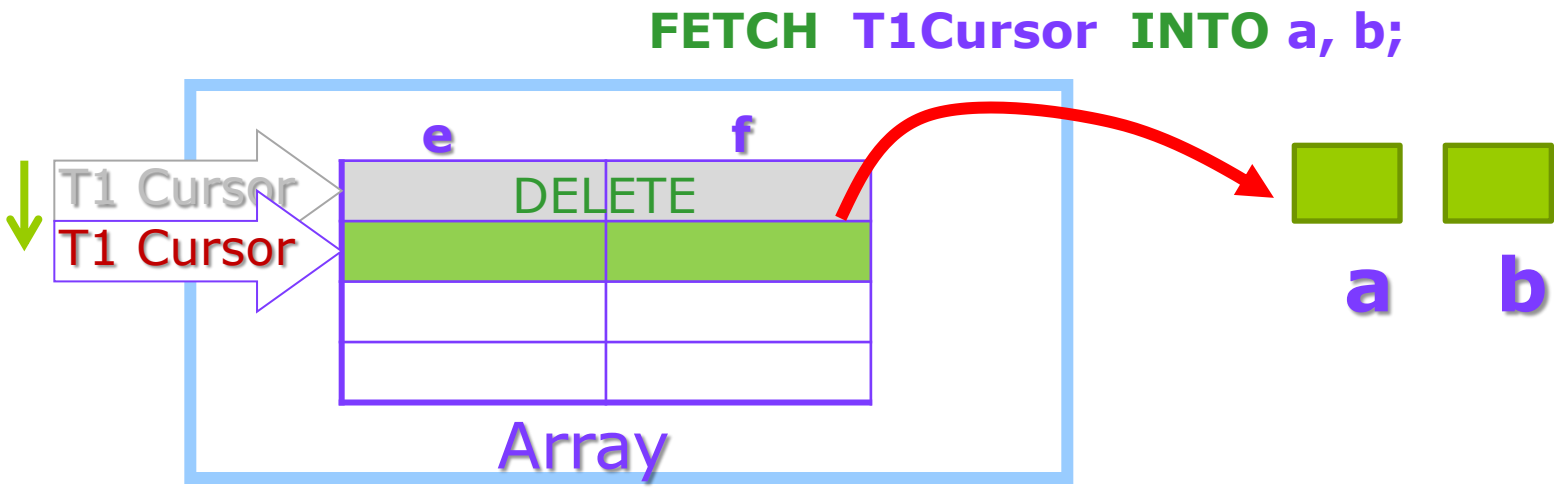
```
DECLARE
1  CURSOR  c1  IS  SELECT * FROM employees;
   emp_rec    employees%ROWTYPE;
BEGIN
2  OPEN c1;
   LOOP  FETCH c1 INTO emp_rec;   3
         EXIT WHEN c1%NOTFOUND;
         DBMS_OUTPUT.PUT_LINE (emp_rec.first_name);
   END LOOP;
4  CLOSE c1;
END;
```

เพื่อแก้ไขข้อมูล

```
DECLARE
   a  T1.e%TYPE;
   b  T1.f%TYPE;
   CURSOR  T1Cursor  IS
      SELECT e, f
      FROM T1
      WHERE e < f
   FOR UPDATE;
```



Next FETCH




```
LOOP
   FETCH T1Cursor INTO a, b;
   EXIT WHEN T1Cursor%NOTFOUND;
   DELETE FROM T1 WHERE CURRENT OF T1Cursor;
END LOOP;
```

Cursor FOR Loops (PL/SQL)

- Need not use the DECLARE, OPEN, FETCH, and CLOSE statements
- Implicit Cursor

```
DECLARE ...
BEGIN
    FOR emprec IN (SELECT empno, salary, comm FROM employee) LOOP
          IF emprec.comm / emprec.sal > 0.25  THEN ... ……..
    END LOOP;
END;
```

Binding

- Association of access plan with an SQL statement
- Static binding: association at compile time
- Dynamic binding: association at run time

Binding options

- Statement-level interface
  - Static
  - Dynamic
- Call-level interface (Dynamic)
  - e.g. **executeQuery("*SQL query statement*")**
- Static: allow reuse of access plans for repetitively executed statements in a program

Statement-level interface

- **Nothing Known at Compile Time**
- Host language อนุญาตให้เขียนแบบ **Dynamic**
- …"SELECT * FROM %s WHERE COUNT(*) = 1", table);
  - table – *host var;*
  - *even the table is known only at run time!*

Trigger

Trigger Overview

Triggers are rules managed by a DBMS.

- Triggers are executed by the rule system of the DBMS
- not by explicit calls as for procedures and functions.
- Ex.
  - execute procedure P1
  - Rule: after inserting a record in the student table

Trigger Overview

- *Event-Condition-Action (ECA)* rules
- Writing the action part or trigger body is similar to writing a procedure or a function
  - except that a trigger has **no parameters.**

Typical Usage of Triggers

- Complex integrity constraints
- Transition constraints
  - *compare the values before and after an update occurs*
- Update propagation *(in related tables)*
- Exception reporting
- Audit trail
  - *create a historical record of a transaction such as a history of automated teller usage*

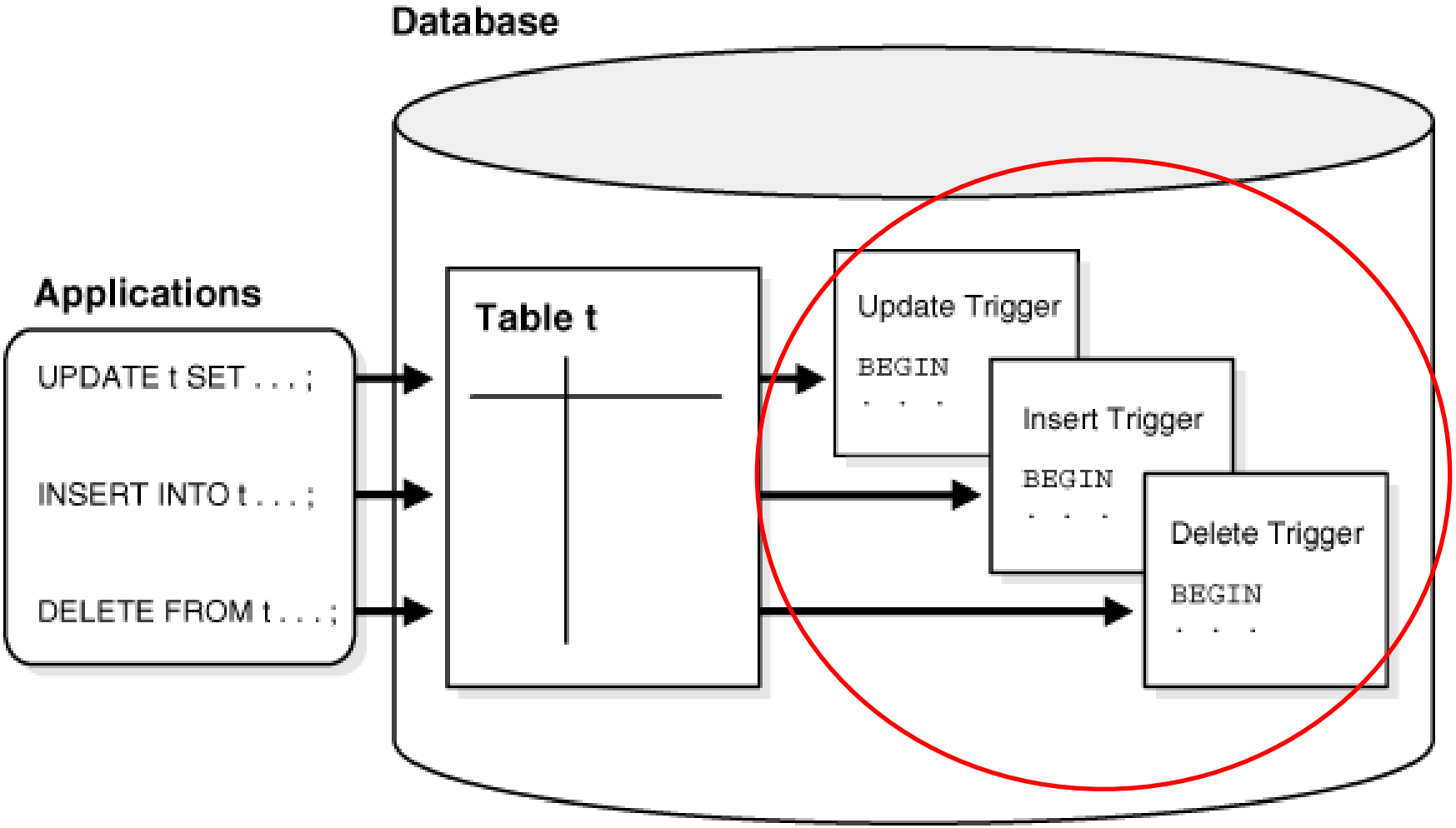
Classification of Triggers

- Granularity
  - Row: fire for each modified row
  - Statement: fire once per SQL statement
- Timing: before or after
- Event
  - Manipulation statements
  - Update event with a list of columns

Format of Oracle Triggers

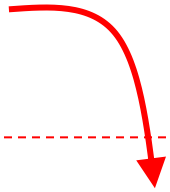
CREATE [OR REPLACE] TRIGGER TriggerName
TriggerTiming **TriggerEvent**
[Referencing clause]
[FOR EACH ROW]
[WHEN (Condition)]
[DECLARE sequence of declarative statements]
BEGIN sequence of statements
[EXCEPTION exception handling statements]
END;

Triggers


Database
Applications
UPDATE t SET . . . ;
INSERT INTO t . . . ;
DELETE FROM t . . . ;
Table t
Update Trigger
BEGIN
. . .
Insert Trigger
BEGIN
. . .
Delete Trigger
BEGIN
. . .

AFTER ROW Trigger Example

```
CREATE OR REPLACE TRIGGER tr_Enrollment_IA
AFTER INSERT ON Enrollment
  FOR EACH ROW
  BEGIN
   UPDATE Offering
    SET OffNumEnrolled = OffNumEnrolled + 1
    WHERE OfferNo = :NEW.OfferNo;
  EXCEPTION
  WHEN OTHERS THEN
    RAISE_Application_Error(-20001,'Database
                                  error');
END;
```



:NEW refers to a new record

Guide to Trigger Examples

- BEFORE ROW:
  - Complex integrity constraints
  - Transition constraints
  - Standardization of data
- AFTER ROW
  - Update propagation
  - Audit trail
  - Exception reporting *เช่น บันทึกเรียบร้อยแล้ว*

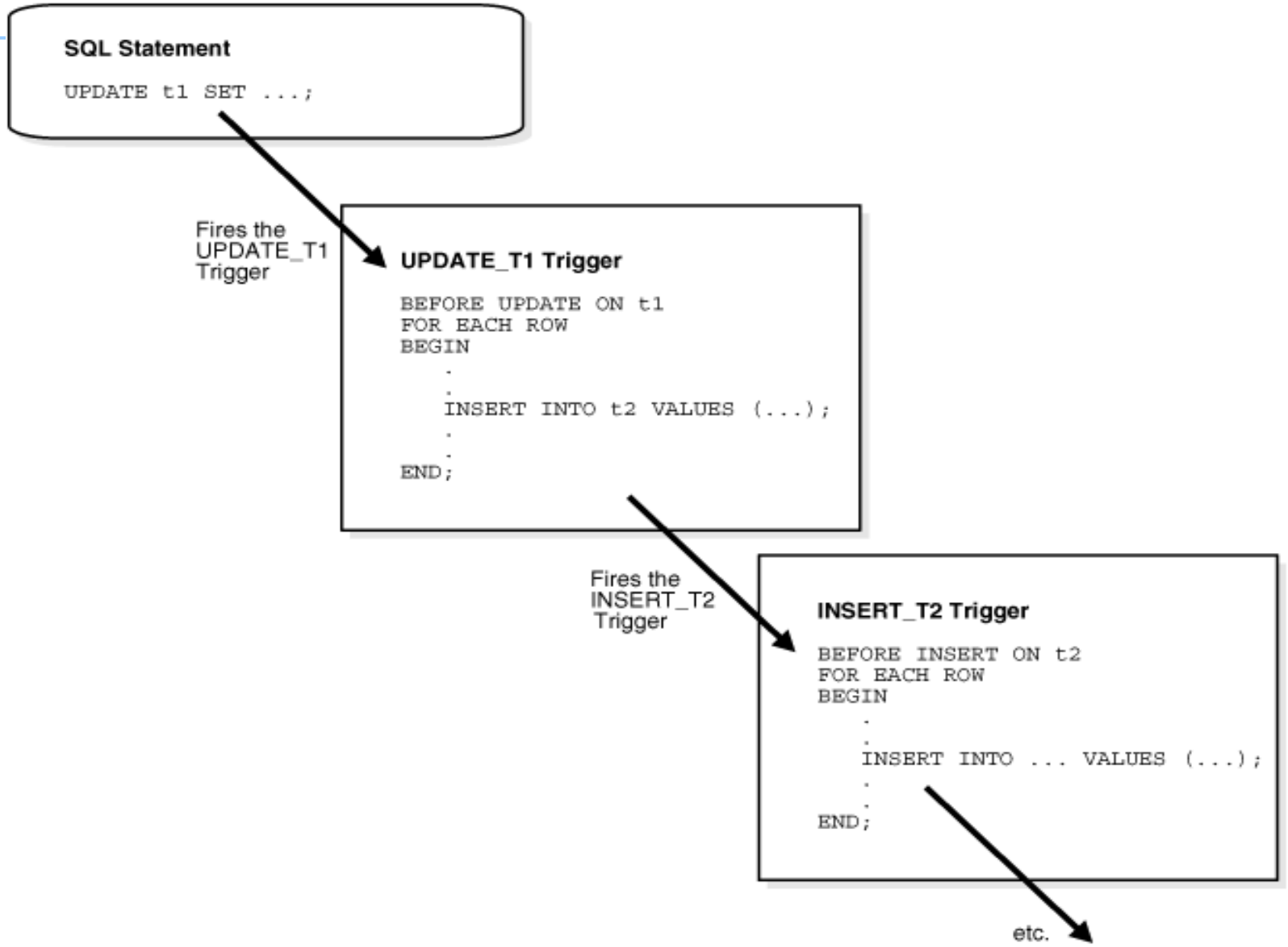
Trigger Execution Procedure

- Inference engine that controls trigger firing
- Specifies execution order among triggers, integrity constraints, and manipulation statements
- Trigger body execution can cause other triggers to fire (enrollment→offering)
- SQL: standard trigger execution procedure
- Most DBMSs deviate from the standard

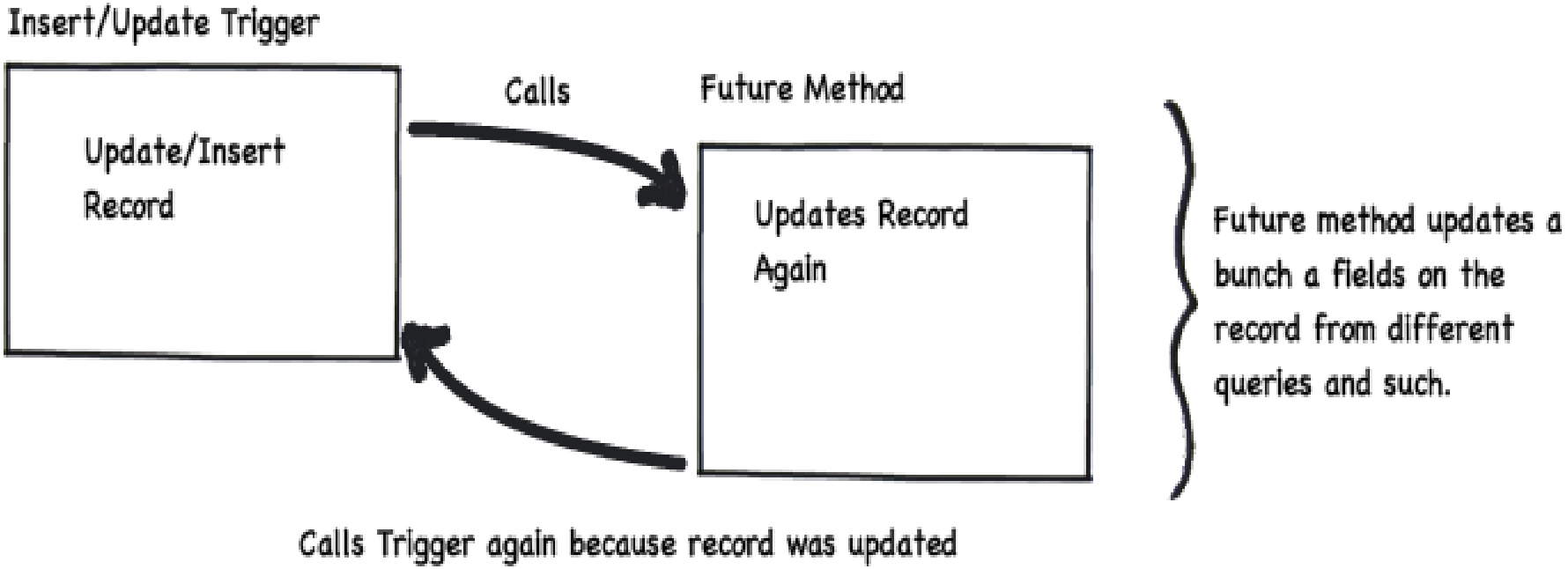
Simplified Oracle Trigger Execution Procedure

1. Execute the applicable ***BEFORE STATEMENT*** triggers.
2. For each row affected by the SQL manipulation statement:
    - 2.1 Execute the applicable **BEFORE ROW** triggers.
    - 2.2 Perform the data manipulation operation on the row.
    - 2.3 Perform integrity constraint checking.
    - 2.4 Execute the applicable **AFTER ROW** triggers.
3. Perform **deferred** integrity constraint checking.
4. Execute the applicable **AFTER statement** triggers.

Cascading trigger



Recursive Trigger



Overlapping Triggers

- Definition:
  - Two or more triggers with the same timing, granularity, and applicable event
  - Same SQL statement causes both triggers to fire
- SQL:2003 firing order based on trigger creation time
- Oracle: arbitrary firing order
- Carefully analyze overlapping triggers

Controlling Trigger Complexity

- Avoid data manipulation statements in BEFORE triggers
- Limit data manipulation statements in AFTER triggers.
- For triggers that fire on UPDATE statements, always list the columns.
- Ensure that overlapping triggers do not depend on a specific order to fire.

Summary

- Stored procedures and triggers are important for database application development and database administration
- Benefits for DBMS management of stored procedures
- Classification of triggers by granularity, timing, event, and purpose
- Knowledge of trigger execution procedures (depend on a DBMS)