Constraints

Foreign Keys

Local and Global Constraints

Triggers

Constraints and Triggers

- A *constraint* is a relationship among data elements that the DBMS is required to enforce.
  - Example: key constraints.
- *Triggers* are only executed when a specified condition occurs, e.g., insertion of a tuple.
  - Easier to implement than complex constraints.

Kinds of Constraints

- Keys.
- Foreign-key, or referential-integrity.
- Value-based constraints.
  - Constrain values of a particular attribute.
- Tuple-based constraints.
  - Relationship among components.
- Assertions: any SQL boolean expression.

Review: Single-Attribute Keys

- Place PRIMARY KEY or UNIQUE after the type in the declaration of the attribute.
- Example:

```
CREATE TABLE Lemonades (
    name    CHAR(20) UNIQUE,
    manf    CHAR(20)
);
```

Review: Multiattribute Key

- The bar and lemonade together are the key for Sells:

```
CREATE TABLE Sells (
        bar         CHAR(20),
        lemonade        VARCHAR(20),
        price       REAL,
        PRIMARY KEY (bar, lemonade)
);
```

Foreign Keys

- Values appearing in attributes of one relation must appear together in certain attributes of another relation.
- Example: in Sells(bar, lemonade, price), we might expect that a lemonade value also appears in Lemonades.name .

Expressing Foreign Keys

- Use keyword REFERENCES, either:
  1. After an attribute (for one-attribute keys).
  2. As an element of the schema:

  FOREIGN KEY (<list of attributes>)

  REFERENCES <relation> (<attributes>)
- Referenced attributes must be declared PRIMARY KEY or UNIQUE.

Example: With Attribute

```
CREATE TABLE Lemonades (
  name    CHAR(20) PRIMARY KEY,
  manf    CHAR(20) );
CREATE TABLE Sells (
  bar     CHAR(20),
  lemonade    CHAR(20) REFERENCES
  Lemonades(name),
  price   REAL );
```

Example: As Schema Element

```
CREATE TABLE Lemonades (
  name    CHAR(20) PRIMARY KEY,
  manf    CHAR(20) );
CREATE TABLE Sells (
  bar     CHAR(20),
  lemonade    CHAR(20),
  price   REAL,
  FOREIGN KEY(lemonade) REFERENCES
     Lemonades(name));
```

Enforcing Foreign-Key Constraints

- If there is a foreign-key constraint from relation *R* to relation *S*, two violations are possible:
  1. An insert or update to *R* introduces values not found in *S*.
  2. A deletion or update to S causes some tuples of *R* to "dangle."

Actions Taken --- (1)

- Example: suppose *R* = Sells, *S* = Lemonades.
- An insert or update to Sells that introduces a nonexistent lemonade must be rejected.
- A deletion or update to Lemonades that removes a lemonade value found in some tuples of Sells can be handled in three ways (next slide).

Actions Taken --- (2)

1. *Default* : Reject the modification.
2. *Cascade* : Make the same changes in Sells.
   - Deleted lemonade: delete Sells tuple.
   - Updated lemonade : change value in Sells.
3. *Set NULL* : Change the lemonade to NULL.

Example: Cascade

- Delete the Bud tuple from Lemonades:
  - Then delete all tuples from Sells that have lemonade = 'Bud'.
- Update the Bud tuple by changing 'Bud' to 'Budweiser':
  - Then change all Sells tuples with lemonade = 'Bud' to lemonade = 'Budweiser'.

Example: Set NULL

- Delete the Bud tuple from Lemonades:
  - Change all tuples of Sells that have lemonade = 'Bud' to have lemonade = NULL.
- Update the Bud tuple by changing 'Bud' to 'Budweiser':
  - Same change as for deletion.

Choosing a Policy

- When we declare a foreign key, we may choose policies SET NULL or CASCADE independently for deletions and updates.
- Follow the foreign-key declaration by:

ON [UPDATE, DELETE][SET NULL CASCADE]

- Two such clauses may be used.
- Otherwise, the default (reject) is used.

Example: Setting Policy

```
1)CREATE TABLE Sells (
2)  bar CHAR(20),
3)  lemonade    CHAR(20),
4)  price   REAL,
5)  FOREIGN KEY(lemonade)
6)      REFERENCES Lemonades(name)
7)      ON DELETE SET NULL
8)      ON UPDATE CASCADE
);
```

Attribute-Based Checks

- Constraints on the value of a particular attribute.
- Add CHECK(<condition>) to the declaration for the attribute.
- The condition may use the name of the attribute, but any other relation or attribute name must be in a subquery.

Example: Attribute-Based Check

```
CREATE TABLE Sells (
  bar    CHAR(20),
  lemonade  CHAR(20)    CHECK (
  lemonade IN
         (SELECT name FROM
  Lemonades)),
  price REAL CHECK ( price <= 5.00 )
);
```

Timing of Checks

- Attribute-based checks are performed only when a value for that attribute is inserted or updated.
  - Example: `CHECK (price <= 5.00)` checks every new price and rejects the modification (for that tuple) if the price is more than $5.
  - Example: `CHECK (lemonade IN (SELECT name FROM Lemonades))` not checked if a lemonade is deleted from Lemonades (unlike foreign-keys).

Tuple-Based Checks

- CHECK (<condition>) may be added as a relation-schema element.
- The condition may refer to any attribute of the relation.
  - But other attributes or relations require a subquery.
- Checked on insert or update only.

Example: Tuple-Based Check

- Only Joe's Bar can sell lemonade for more than $5:

```
CREATE TABLE Sells (
   bar       CHAR(20),
   lemonade      CHAR(20),
   price     REAL,
   CHECK (bar = 'Joe''s Bar' OR
                 price <= 5.00)
);
```

Assertions

- These are database-schema elements, like relations or views.
- Defined by:

  CREATE ASSERTION <name>

  CHECK (<condition>);

- Condition may refer to any relation or attribute in the database schema.

Example: Assertion

- In Sells(bar, lemonade, price), no bar may charge an average of more than $5.

```
CREATE ASSERTION NoRipoffBars CHECK (
   NOT EXISTS (
      SELECT bar FROM Sells
      GROUP BY bar
      HAVING 5.00 < AVG(price)
   ));
```

Bars with an average price above $5

Example: Assertion

- In Drinkers(name, addr, phone) and Bars(name, addr, license), there cannot be more bars than drinkers.

```
CREATE ASSERTION FewBar CHECK (
  (SELECT COUNT(*) FROM Bars) <=
  (SELECT COUNT(*) FROM Drinkers)
);
```

Timing of Assertion Checks

- In principle, we must check every assertion after every modification to any relation of the database.
- A clever system can observe that only certain changes could cause a given assertion to be violated.
  - Example: No change to Lemonades can affect FewBar. Neither can an insertion to Drinkers.

Triggers: Motivation

- Assertions are powerful, but the DBMS often can't tell when they need to be checked.
- Attribute- and tuple-based checks are checked at known times, but are not powerful.
- Triggers let the user decide when to check for any condition.

Event-Condition-Action Rules

- Another name for “trigger” is *ECA rule*, or *event-condition-action* rule.
- *Event* : typically a type of database modification, e.g., “insert on Sells.”
- *Condition* : Any SQL boolean-valued expression.
- *Action* : Any SQL statements.

Preliminary Example: A Trigger

- Instead of using a foreign-key constraint and rejecting insertions into Sells(bar, lemonade, price) with unknown lemonades, a trigger can add that lemonade to Lemonades, with a NULL manufacturer.

Example: Trigger Definition

```
CREATE TRIGGER LemonadeTrig
    AFTER INSERT ON Sells
    REFERENCING NEW ROW AS NewTuple
    FOR EACH ROW
    WHEN (NewTuple.lemonade NOT IN
        (SELECT name FROM Lemonades))
    INSERT INTO Lemonades(name)
        VALUES(NewTuple.lemonade);
```

The event

The condition

The action

Options: CREATE TRIGGER

- CREATE TRIGGER <name>
- Or:

CREATE OR REPLACE TRIGGER <name>

  - Useful if there is a trigger with that name and you want to modify the trigger.

Options: The Event

- AFTER can be BEFORE.
  - Also, INSTEAD OF, if the relation is a view.
    - A clever way to execute view modifications: have triggers translate them to appropriate modifications on the base tables.
- INSERT can be DELETE or UPDATE.
  - And UPDATE can be UPDATE . . . ON a particular attribute.

Options: FOR EACH ROW

- Triggers are either “row-level” or “statement-level.”
- FOR EACH ROW indicates row-level; its absence indicates statement-level.
- *Row level triggers* : execute once for each modified tuple.
- *Statement-level triggers* : execute once for a SQL statement, regardless of how many tuples are modified.

Options: REFERENCING

- INSERT statements imply a new tuple (for row-level) or new table (for statement-level).
  - The “table” is the set of inserted tuples.
- DELETE implies an old tuple or table.
- UPDATE implies both.
- Refer to these by

[NEW OLD][TUPLE TABLE] AS <name>

Options: The Condition

- Any boolean-valued condition.
- Evaluated on the database as it would exist before or after the triggering event, depending on whether BEFORE or AFTER is used.
  - But always before the changes take effect.
- Access the new/old tuple/table through the names in the REFERENCING clause.

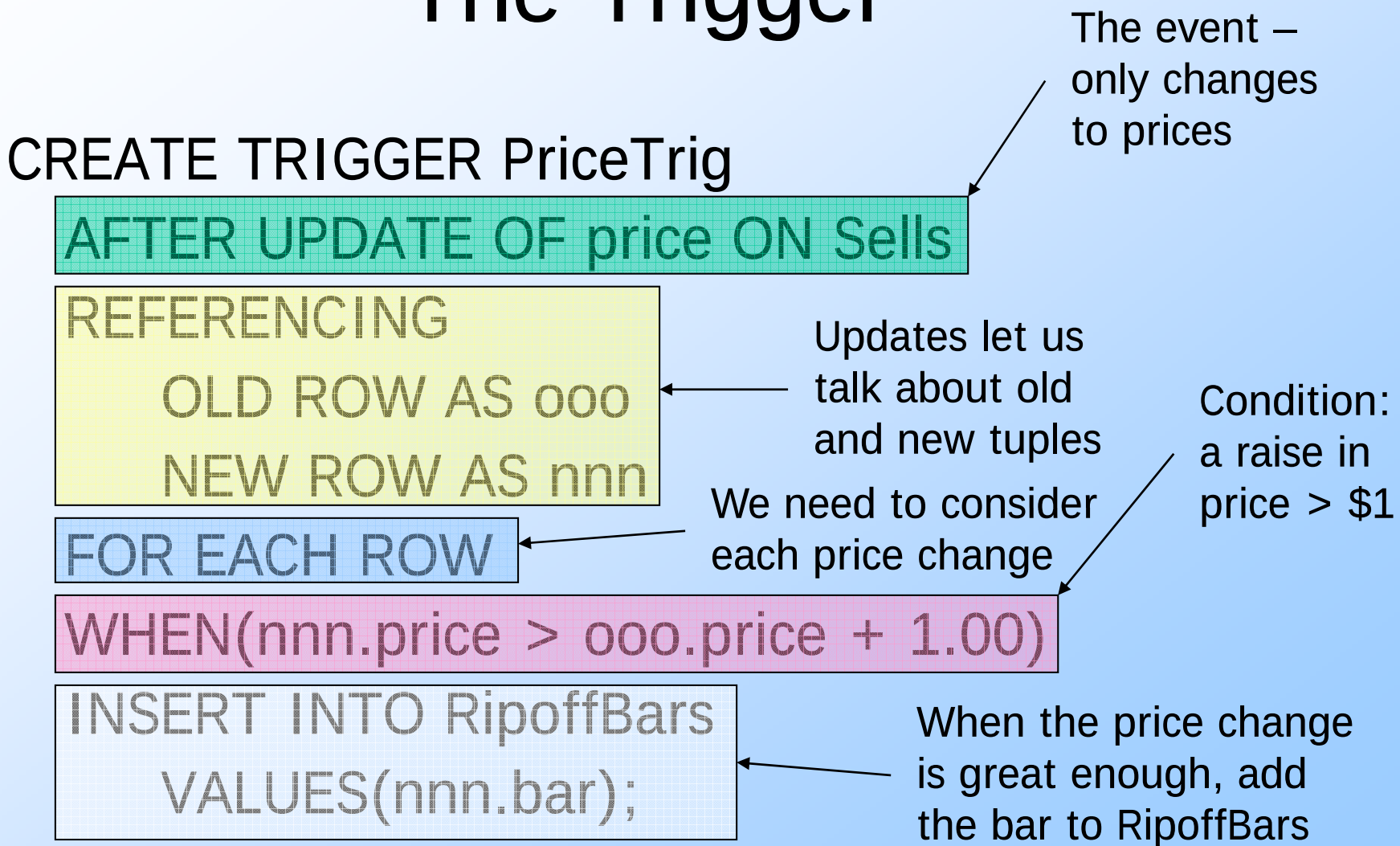
Options: The Action

- There can be more than one SQL statement in the action.
  - Surround by BEGIN . . . END if there is more than one.
- But queries make no sense in an action, so we are really limited to modifications.

Another Example

- Using Sells(bar, lemonade, price) and a unary relation RipoffBars(bar), maintain a list of bars that raise the price of any lemonade by more than $1.

The Trigger


CREATE TRIGGER PriceTrig
AFTER UPDATE OF price ON Sells
REFERENCING
OLD ROW AS ooo
NEW ROW AS nnn
FOR EACH ROW
WHEN(nnn.price > ooo.price + 1.00)
INSERT INTO RipoffBars
VALUES(nnn.bar);
The event – only changes to prices
Updates let us talk about old and new tuples
We need to consider each price change
Condition: a raise in price > $1
When the price change is great enough, add the bar to RipoffBars

MySQL Trigger Example

```
DELIMITER //
CREATE TRIGGER firmaEkle
  BEFORE INSERT ON Lemonades
  FOR EACH ROW
     BEGIN
       IF ISNULL(NEW.manf) THEN
          SET NEW.manf = ‘xxx';
       END IF;
     END
//
DELIMITER ;
```