3.2.4 Enforcing constraints

- Constraints ⇒ SQL definition of the schema
- Up to now: primary Key, foreign key, NOT NULL

- Different kinds of integrity constraints

  value constraints on attributes
  cardinalities
  semantic constraints
  referential constraints

- SQL-DDL:

  Column constraint: Specify constraint as part of column definition
  Table constraint: More than one row involved,
  specify constraint after the column definitions

Constraints may be violated when DB is **changed** (update, insert, delete)

⇨ **Exception**

```
ORA-02291: integrity constraint (SYS_C0067174)
  violated - parent key not found
```

Constraint name (optional):

```
CONSTRAINT <name> <def>
```

Advantage: error message shows violated constraint in a readable way

```
ORA-02291: integrity constraint
  (FK_Dep.SYS_C0067174)  violated - parent key
  not found
```

PRIMARY KEY

- Only once per table
- Not required, but omission is bad style

May be column constraint (single attribute) or multicolumn constraint

NOT NULL

- Simplest constraint on attribute values, column constraint

Default values

```
<attributeName> <attributeType> DEFAULT <value>
e.g.  ... population INTEGER DEFAULT 0
```

this is not: `NULL`

UNIQUE

- Column contains only unique values
- Left over from SQL-89 (no primary key constraint)
- Should be used for candidate keys
- Column constraint or table constraint

CHECK Clause

Enumeration:

```
CHECK (VALUES IN ('X', 'Y', 'Z'))
```

Interval restriction:

```
CHECK (population >= 0),
CHECK (population < 40000000)
```

equivalent to

```
 CHECK (population >= 0 AND population <
...)
```

Multicolumn constraints

```
CREATE TABLE Accounts (
 ... amount DECIMAL(9,2),
     credit DECIMAL(7,2),...,
  CONSTRAINT accountIsPos
  CHECK amount + credit > 0 )
```

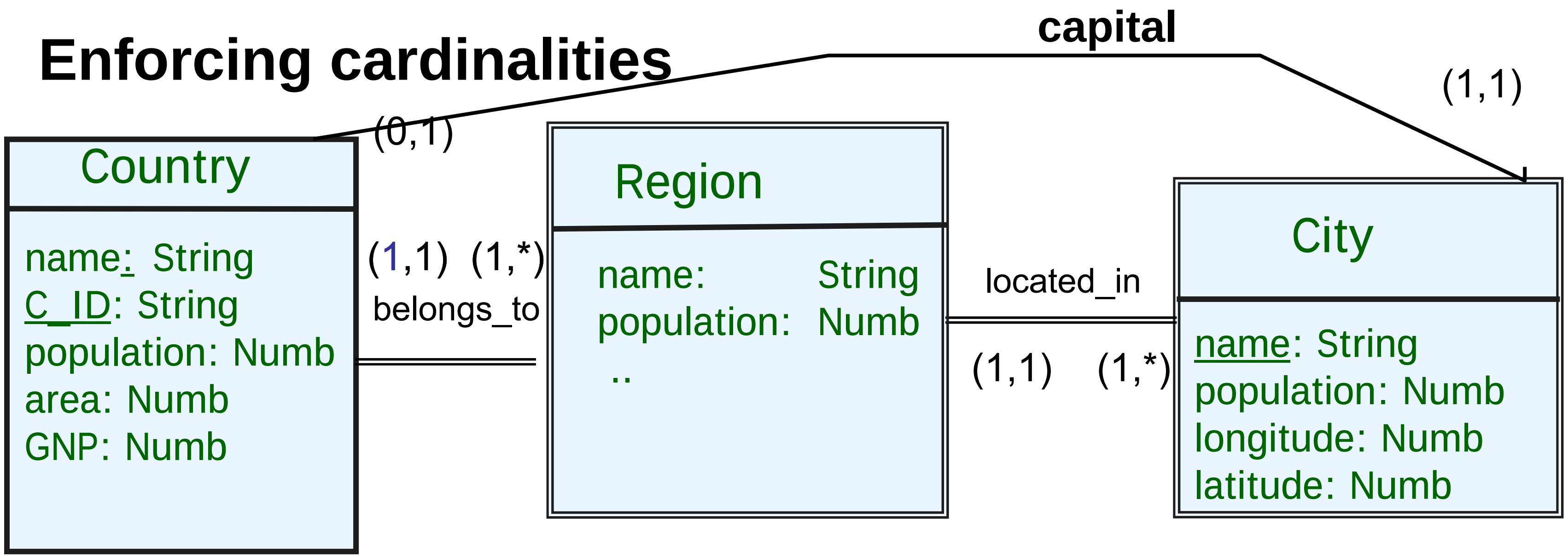
General constraint syntax

for column (except **NOT NULL**) and table constraints

```
CREATE TABLE <tab> (< listOfColumnSpecs>
   [[CONSTRAINT <constraintName>]
  <constraint on columns or table>]0..n
)
```

Constraint may be **UNIQUE / PRIMARY KEY**, **CHECK**, **REFERENCES**

Enforcing cardinalities



```
CREATE TABLE Country
(name           VARCHAR(32) NOT NULL,
C_ID            VARCHAR(4) PRIMARY KEY,
population      INT,
...
capital         VARCHAR(25) NOT NULL,
region_name     VARCHAR(30),NOT NULL ...
```

Since every country has a capital

```
CREATE TABLE Region
(name               VARCHAR(30) ,
C_ID                VARCHAR(4)NOT NULL,
area                 Int,
population           Int,
capital             VARCHAR(25),
CONSTRAINT region_pk
       PRIMARY KEY (name,C_ID),
CONSTRAINT
    fk_ctry FOREIGN  KEY (C_ID)
      REFERENCES Country

);
```

```
CREATE TABLE City
(name   VARCHAR(25) NOT NULL,
 C_ID           VARCHAR(4),
 reg_name       VARCHAR(30),
population      INT,
longitude       NUMERIC(5,2),
latitude        NUMERIC(5,2),
   CONSTRAINT city_pk
      PRIMARY KEY
      (name,reg_name,C_ID),
   CONSTRAINT region_country_fk
      FOREIGN KEY (R_ID,C_ID)

      REFERENCES Region
);
```

```
ALTER TABLE Country
 ADD CONSTRAINT fk_capital FOREIGN KEY
     (name, R_ID) REFERENCES City;
```

Constraint on `Country` assumes table `City`

Preserving referential integrity

Row and primary key deleted, what to do with foreign keys?

Do nothing: exception

Define actions on referenced tables:

```
ON DELETE CASCADE
```

delete all referenced tuples

if a department disappears, all referenced employees are deleted (??)

```
ON DELETE SET NULL
ON DELETE DEFAULT
ON UPDATE CASCADE   // not in Oracle!
```

update key in referencing table

e.g. new department name, propagate it to table with FK

```
ON UPDATE SET NULL
ON UPDATE SET DEFAULT
```

Circular relationships

Example

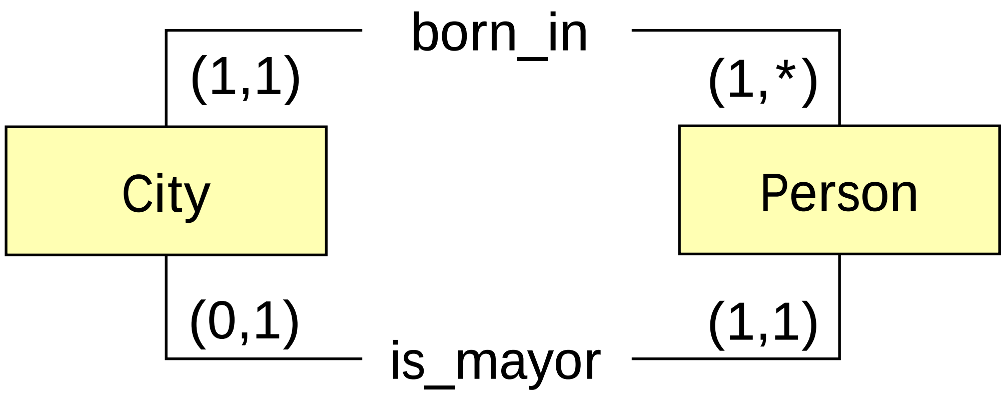


Table must be created in order to be referenced

How to define **circular constraints**?

Specify constraints after table definition

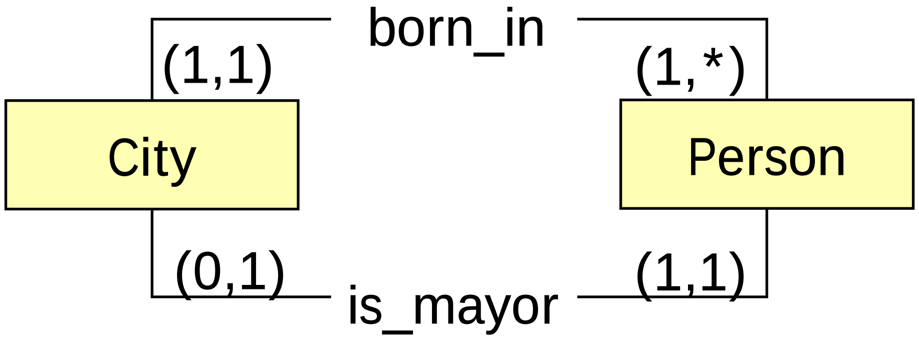
- Define tables without constraints.
- Use ALTER TABLE to define a constraint a posteriori

Circular constraint

```
ALTER TABLE Person
    ADD CONSTRAINT birthPlaceReference
    FOREIGN KEY (birthplace)
    REFERENCES city(id);
```

Which constraint is still missing?

```
ALTER TABLE City
    MODIFY COLUMN( mayor NOT NULL)
    Foreign Key;
```



3.2.5 Deferred constraints

The Chicken-Egg problem

```
CREATE TABLE chicken(cID INT PRIMARY KEY,
                     eID INT);
CREATE TABLE egg(eID INT PRIMARY KEY,
                 cID INT);


ALTER TABLE chicken
    ADD CONSTRAINT chickenREFegg
    FOREIGN KEY (eID) REFERENCES egg(eID);


ALTER TABLE egg
    ADD CONSTRAINT eggREFchicken
    FOREIGN KEY (cID) REFERENCES chicken(cID)  ;
```

What happens if an egg / chicken is inserted?

Deferred constraints

Insertion violates foreign key constraint

```
    INSERT INTO chicken VALUES(1, 2);
ORA-02291: integrity constraint
   (chickenREFegg.SYS_C0067174)  violated - parent key
   not found
     INSERT INTO egg VALUES(2, 1);
ORA-02291: integrity constraint
   (eggREFchicken.SYS_C0067174)  violated - parent key
   not found
```

Defer constraint checking!

```
  ALTER TABLE chicken
     ADD CONSTRAINT chickenREFegg
     FOREIGN KEY (eID) REFERENCES egg(eID)
     INITIALLY DEFERRED DEFERRABLE;
```

Deferred constraints and transactions

Deferred constraints checked at the end of a **transaction (*)**

```
 INSERT INTO chicken VALUES(1, 2);
-- constraint not checked here
INSERT INTO egg VALUES(2, 1);
COMMIT;  -- but here
```

Variants

```
INITIALLY DEFERRED DEFERRABLE
INITIALLY IMMEDIATE DEFERRABLE
SET CONSTRAINT <name>
               [DEFERED|IMMEDIATE]
```

allow checking at arbitrary times

(*) Transaction: unit of work consisting of one or more operations on the DB

3.3 Assertions and Triggers

Def.: An **Assertions** is an **integrity constraint** defined independently from table definitions

Similar to CHECK table constraints:
when evaluated to FALSE: exception

- Semantics
  Table assigned constraints always hold for empty tables

```
CREATE ASSERTION atLeastOneRegion
 CHECK (--always at least one region for each
        -- country in region table
        SELECT ...   )
```

Most current DBS *do not support* sophisticated constraints , e.g. table independent assertions …

Assertions and triggers   SQL / DDL

Trigger

(<predicate>, <action>)-rule

Semantics:

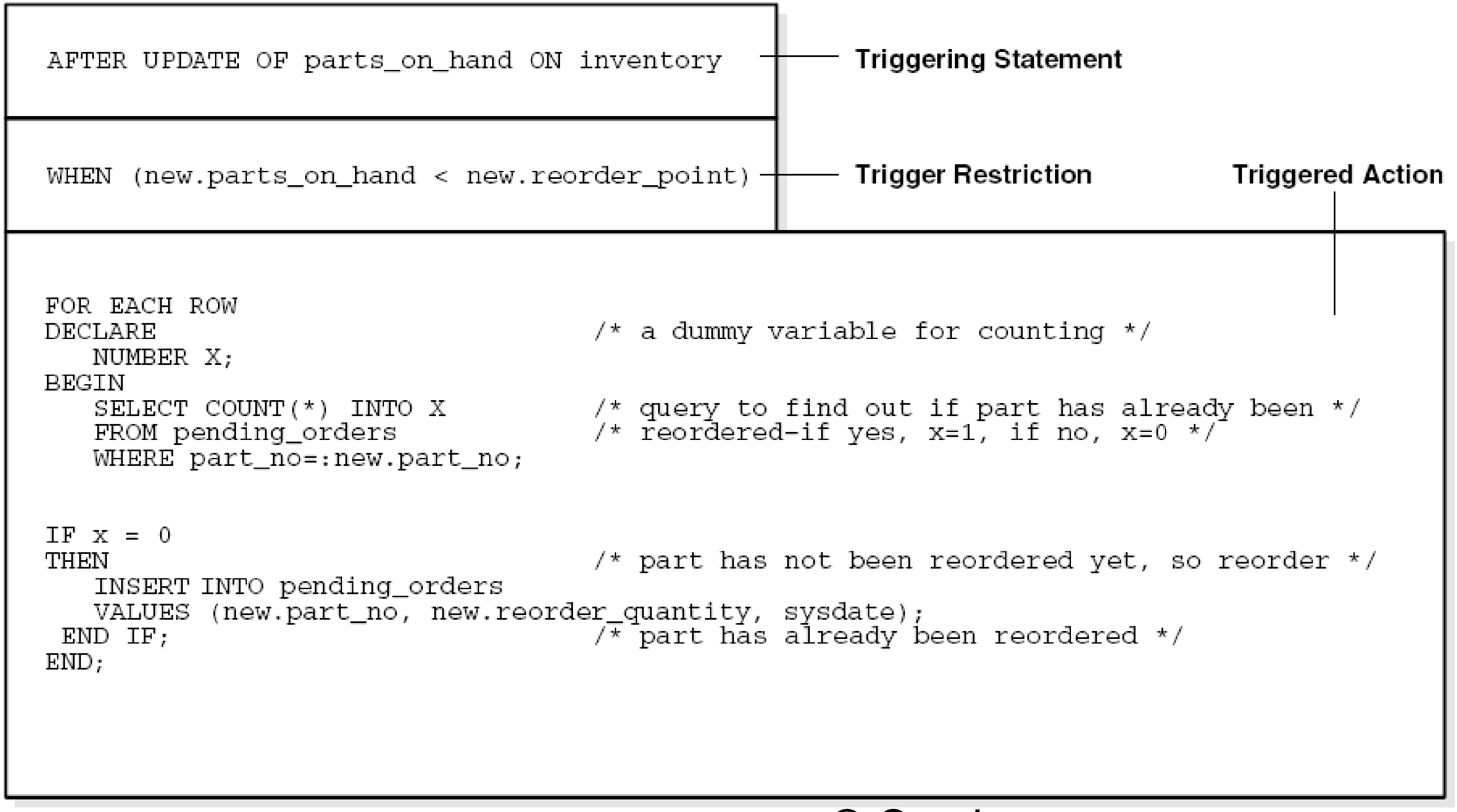
if <predicate> is true before |after DB state is changed

<action> is performed

```
CREATE TRIGGER salaryCheck
   AFTER INSERT ON Employee
   REFERENCING NEW ROW AS c
   FOR EACH ROW WHEN
      EXISTS (SELECT * FROM Employee e
               WHERE c.boss=e.emp# AND
                e.salary < c.salary)
      <do something>; -- e.g. print warning
                     -- may be expressed simpler
```

Trigger example

If **`parts_on_hand`** in **`inventory`** table too low: reorder!



```
AFTER UPDATE OF parts_on_hand ON inventory
```

Triggering Statement

```
WHEN (new.parts_on_hand < new.reorder_point)
```

Trigger Restriction

Triggered Action

```
FOR EACH ROW
DECLARE                           /* a dummy variable for counting */
   NUMBER X;
BEGIN
   SELECT COUNT(*) INTO X         /* query to find out if part has already been */
   FROM pending_orders            /* reordered-if yes, x=1, if no, x=0 */
   WHERE part_no=:new.part_no;


IF x = 0
THEN                              /* part has not been reordered yet, so reorder */
   INSERT INTO pending_orders
   VALUES (new.part_no, new.reorder_quantity, sysdate);
 END IF;                          /* part has already been reordered */
END;
```

© Oracle

Triggering applications

Triggers very **useful for triggering actions outside DB**

Triggering audit trails

If table is changed store an entry about this event in a special place (the audit trail)

Triggering an application program

If a customer has ordered a book in the online shop and she has a non-NULL email address, send a mail!

Trigger events

Trigger events are database events:

- INSERT, UPDATE, or DELETE statement on some table (*)
- Any creation or altering of schema objects
- A database startup or instance shutdown
- A specific error message or any error message
- A user logon or logoff

Action is performed **BEFORE** or **AFTER** the event happens or **INSTEAD OF** some event.

No external events ("msg arrives")**.**

(*) also on some views

Standard Query Language: Standards

SQL-92 compliance levels:

(1) Entry SQL: basically SQL-89, essential

(2) Intermediate SQL,

(3) Full SQL

No implementation of SQL-92 on level 2 or3

- **SQL 1999 (SQL3) l**evels:
  - Core SQL: essential for standard compliance
  - Additional Features, e.g. object features

First standard: SQL-89

Important: SQL-92

Core SQL:1999

enhanced SQL:1999

slight extension: **SQL:2003**

newest draft : SQL 2008

Standards in CS

Standards: not “nice to have” but **inevitable**

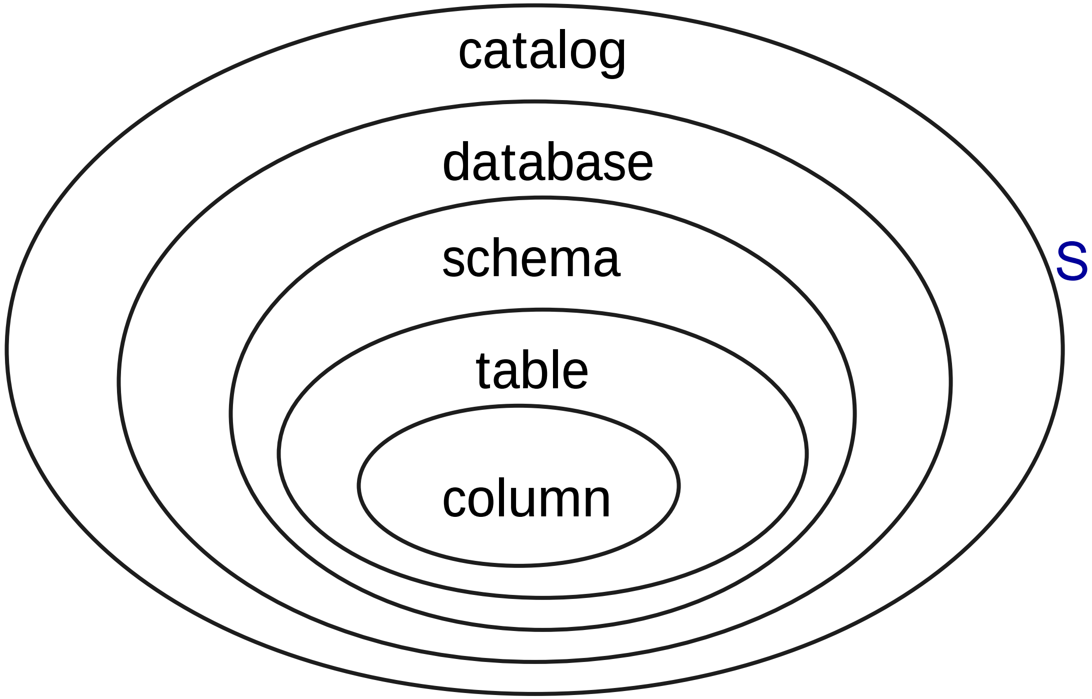
Heavy influenced by strategies of SW-Industry

All known implementations do not conform to every aspect of the standard

Standards may hinder scientific and technical improvement (!)

3.4 Data Types and name spaces in SQL / DDL

Database-name space? schema name space ?

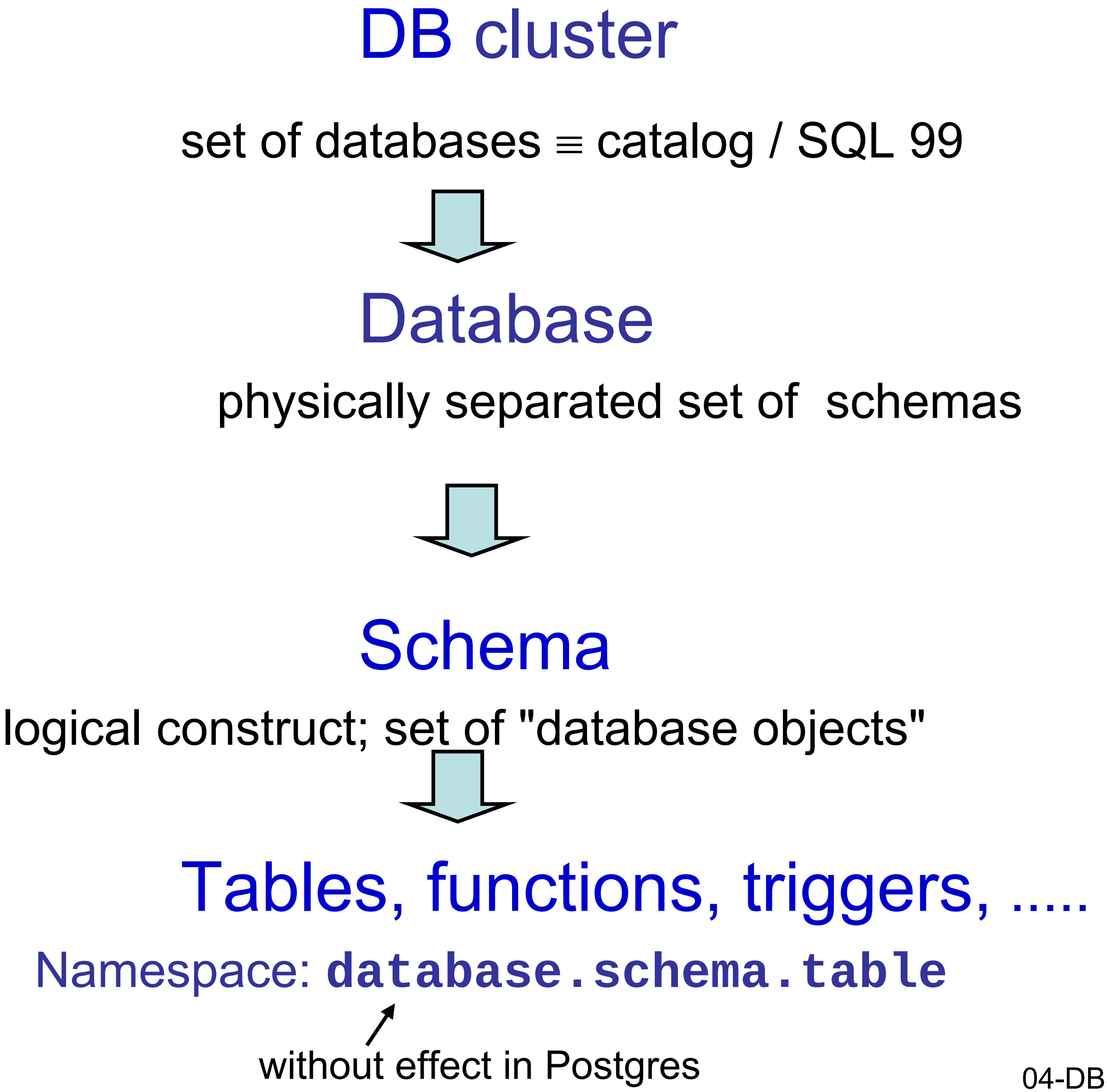


SQL-2 standard

Name structure:

`<cat>.<database>.<schema>.<table>.<column>`

Databases and schemas in Postgres



DB cluster

set of databases ≡ catalog / SQL 99

⇩

Database

physically separated set of schemas

⇩

Schema

logical construct; set of "database objects"

⇩

Tables, functions, triggers, ...

Namespace: **`database.schema.table`**

without effect in Postgres

Schemas in standard SQL / DDL

```
CREATE SCHEMA   <schemaName>
```

e.g `CREATE SCHEMA Mondial`
creates a namespace, in which relations (tables) have unambiguous names

Proposed by SQL-2, but no DBS supports the full naming scheme

Only **`<table>.<column>`** names are supported by all systems, confusing terminology in many systems

Name spaces

Oracle:

Database = set of physical storage areas
("tablespaces")

Name of **schema** = **dbsUsername** ,
all objects may be prefixed with **<dbUsername>**

MySQL:

Database = **directory in File system**
where data reside

Schema not defined in MySQL

3.4.2 SQL Data types

Primitive attribute (column) types

- Base types of the SQL and/or DB system
- No constructed types
  contradict „first normal form"
  – introduced by SQL99
- Types for numbers, characters, strings, date / time, Binary objects

Numeric datatypes in SQL-2 - the first standard

- **NUMERIC (p,s)** exact number, basically same
- **DECIMAL (p,s)** as **DECIMAL**
- **INTEGER** alias: **INT**
- **SMALLINT**
- **FLOAT (p,s)** approximate number
- **REAL** implementation dependent precision
- **DOUBLE PRECISION**

SQL Built-in types

Freie Universität Berlin

More datatypes in SQL-2: **Character** etc

Literal

CHARACTER [(n)]   CHAR   **'A padded string   '**

// fixed length character string

CHARACTER VARYING (n)

VARCHAR (n)   **'Hello SQL'**

// variable length string, n=maximum

NATIONAL CHARACTER (n) | NCHAR (n)

NCHAR VARYING (n)

BIT [(n)], BIT VARYING , BOOLEAN

DATE   **DATE '2001-5-2'**

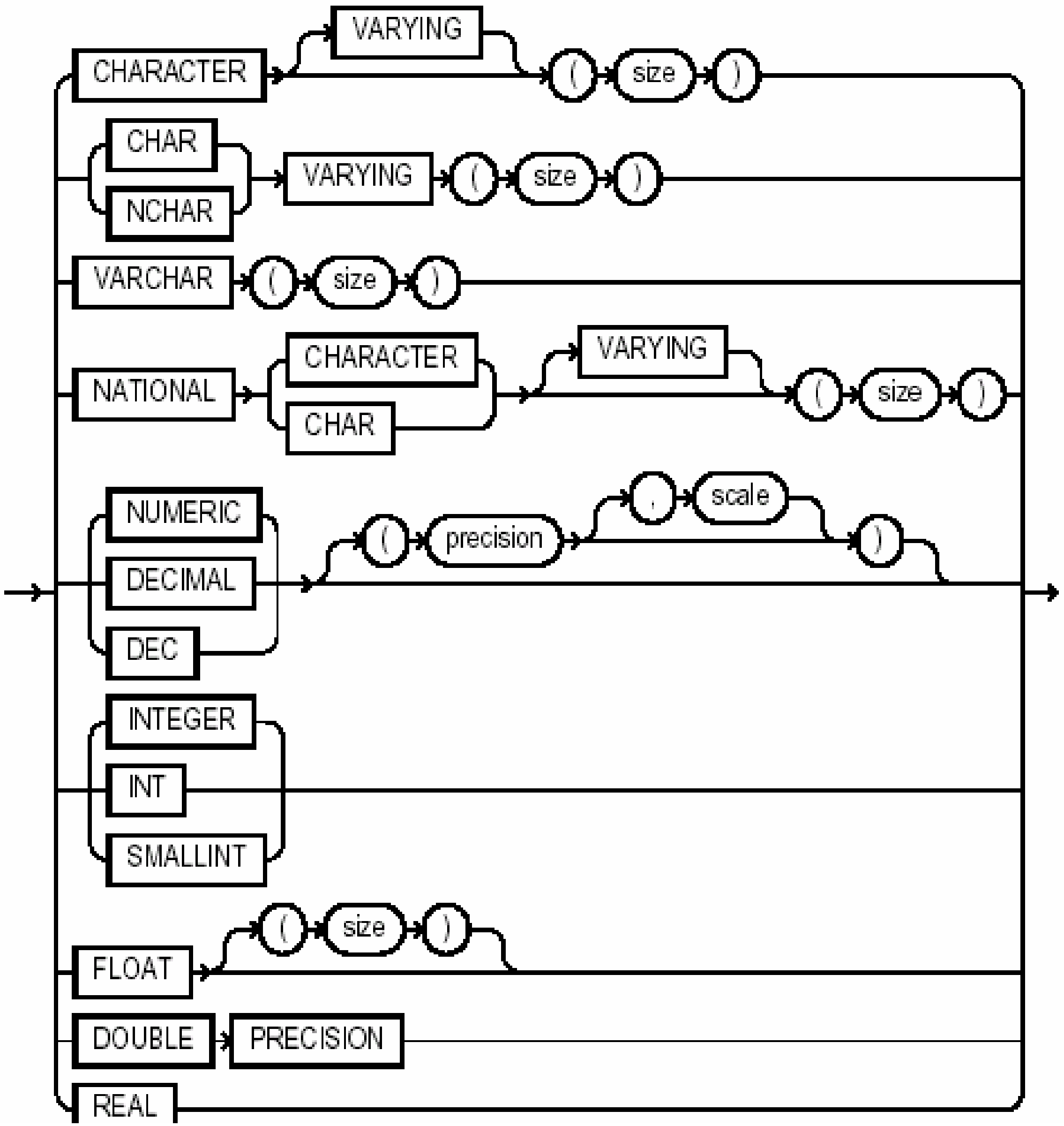
TIME   **TIME '01:00:05.011'**

TIMESTAMP   composed of **year, month, day, hour, minute, second**

INTERVAL FirstUnitofTime [LastUnitofTime]$_0^{max}$

e.g. '1 day 12 hours 59 min 10 sec'

ANSI_supported_datatypes::=



Syntax diagram for ANSI / SQL-2 character data type

“Large Objects”

Large Character / Binary Objects since SQL 1999

Restricted, implementation defined restriction of maximum character string length

`Char(n)  / VARCHAR(n) ,` typically 4000 Bytes

```
CHARACTER LARGE OBJECT              |  CLOB
NATIONAL CHARACTER LARGE OBJECT     |  NCLOB
BINARY LARGE OBJECT                 |  BLOB
```

Typically up to 2 GB or even more.

Useful for images, videos, …

No blobs in Postgres ... but binary data type

and arbitrary long 'text' data type.

Postgres specific data types

Net specific

`macaddr`	MAC address
`inet`	IPV4 / V6 address

Geometric types

`point`	
`lseg`	line segment
`path`	closed or open path
`polygon, box`	
`circle`	

Miscalleneous

serial	autoincremented 32-Bit-Integer

Constructed types

arrays and more....

Oracle SQL built-in types

Datatype	Description
VARCHAR2(*size*)	Variable-length character data
CHAR(*size*)	Fixed-length character data
NUMBER(*p,s*)	Variable-length numeric data
DATE	Date and time values
LONG	Variable-length character data up to 2 gigabytes
CLOB	Single-byte character data up to 4 gigabytes
RAW(n),LONG RAW	Raw binary data (up to 2 KB | 2 GB)
BLOB	Binary data up to 4 gigabytes
	e.g. **X'49FE'**
BFILE	Binary data stored in an external file; up to 4 gigabytes

Differences

Numeric types in different DBS:

Oracle

NUMBER(*p,s*) Variable-length numeric data

MySQL:

```
TINYINT[(M)], SMALLINT[(M)],
MEDIUMINT[(M)], INT[(M)],
BIGINT[(M)], FLOAT(precision),
FLOAT[(M,D)],  DOUBLE[(M,D)], DOUBLE
PRECISION[(M,D)], REAL[(M,D)],
DECIMAL[(M[,D])], NUMERIC[(M[,D])]
```

Many differences from standard

- always use standard types
- Makes database less dependent from the database system vendor

Generated columns (SQL 2003)

Extension in SQL 2003: Generated columns

"Identity column" using internal sequence:

```
CREATE TABLE employees (
EMP_ID INTEGER
GENERATED ALWAYS AS IDENTITY
START WITH 100
INCREMENT 1...
...)
```

Instance of the more general concept
"Generated column"

Generated columns (SQL 2003)

Any number of columns of a base table can be designated as **generated columns**.

Each generated column must be associated with a **scalar expression**. All column references in such expressions must be to **columns of the base table** containing that generated column.

Values for generated columns are **computed and assigned automatically** every time a row is inserted into such tables.

Generated columns: example

```
CREATE TABLE EMPLOYEES (
  EMP_ID INTEGER,
  SALARY DECIMAL(7,2),
  BONUS DECIMAL(7,2),
  TOTAL_COMP GENERATED ALWAYS AS (
                    SALARY + BONUS ),
  HR_CLERK GENERATED ALWAYS AS (
                    CURRENT_USER )
)
```

SQL/DDL Domains

Domain = named sets of values and value representation

```
CREATE DOMAIN <domainName> <typeDef>
 CREATE DOMAIN Money DECIMAL (10,2)
```

not really representation independent, but useful in order to avoid semantically meaningless operations, e.g. comparing money with length attributes

Not supported in most Systems (neither Oracle nor MySQL, exception Postgres, SAP-DB)

SQL / DDL: Type definitions (user defined type)

Core SQL:1999

Distinct type:

- Similar to domain definition
- Strong typing

Syntax:

```
CREATE TYPE <typeName> as <typeDef>
  [FINAL];
```

Examples:

```
CREATE TYPE Euro AS DECIMAL(8,2) FINAL;
CREATE TYPE Mark AS DECIMAL(8,2) FINAL;
CREATE Type Address AS(
       street    varchar (25),
       zipCode   Integer,....);
```

3.5 Metadata management

Meta data

All definitions and other data on data are called metadata

Stored in system data structures

Data structures for metadata called the **catalogue or data dictionary** in particular when used for more than one DB

In most systems stored as tables

Makes metadata first class:
may be queried und modified in the same way as the data tables

```
Select <Table_Name> from User_Tables;
```

Metadata management: example

Querying the catalog using SQL (ORACLE)

Attributes of the user_constraints table

```
SQL>  SELECT constraint_name,search_condition,
              delete_rule
      FROM   user_constraints
      WHERE  table_name = 'Region';
```

Result

```
CONSTRAINT_NAME  SEARCH_CONDITION                       DELETE_RULE
-----------------------------------------------------------------

SYS_C001360      TITLE IS NOT NULL

PLAUSIBLE_YEAR   year > TO_DATE('01.01.1900','DD.MM.YYYY')

ALLOWEDPRICE     pricePDay >= 0) AND (pricePDay < 100.0)

SYS_C001363      TAPE_MOVIE                              CASCADE
```

No standard for metadata management! completely different in Postgres!

Postgres Information Schema

All kinds of metadata on schemas of db

.. tables, columns, ... sql_features (implemented)

e.g....

```
SELECT * FROM information_schema.Columns WHERE
  table_schema = 'video'
   ORDER BY table_name
```

```
geo;video;rental;tape_id;1;;NO;integer;;;32...pg_catalog;int4;;;;;...
geo;video;rental;from_date;3;;NO;date;;; ...  pg_catalog;date;;;;;...
geo;video;rental;until_date;4;;YES;date;;;;;;;pg_catalog;date;;;;;...
.....
```

Virtual tables: views

More SQL Schema Definition Statements

`CREATE TABLE` defines base tables

Def.: A **view** is a virtual table, has a definition, but no extent, definition is executed when table is accessed

```
CREATE VIEW <name> AS  <SQL-select>
```

e.g.
```
CREATE VIEW GNP_Ratio
      SELECT c_id, name, GNP, GNP/popul
     FROM Country;
```

May be used as ordinary tables for reads, updates are much more involved

View and Materialized views

View: a construct for defining **virtual** tables

Views are used in statements just as ordinary tables

SELECT name, age FROM myView WHERE…

But updates?

Materialized view

Result auf executing view defining expression is a temporary table. Performance improvement!

Makes sense if basically read Operations on view

3.6 Modifying and deleting definitions

ALTER TABLE

```
ALTER TABLE<tableName><redefinition>;
```

Add a column:

```
ALTER TABLE City
  ADD (mayor CHAR(20));
```

Modify type:

```
ALTER TABLE City
  MODIFY (mayor CHAR(30));
```

Many more variants of ALTER statement
see manual

Deletion of schema elements

Table delete

Delete table **only if not referenced,**

drop references first!

```
DROP TABLE <tableName> restrict;
```

Delete table and references:

```
DROP TABLE <tableName> CASCADE ;
```

DROP TABLE <tableName> [, <tableName>]$^{0..n}$ constraints;

Data, metadata and indexes are deleted.

`Delete from <table>` only deletes data

Oracle and more

Oracle

PRIMARY KEY, NOT NULL, UNIQUE, FOREIGN KEY, REFERENCES, CHECK supported, uses sequence objects

Postgres

very similar to ORACLE (SQL99), SERIAL type as an abbreviation of sequence objects

MySQL (V3.x)

PRIMARY KEY, NOT NULL, UNIQUE supported

FOREIGN KEY, REFERENCES, CHECK accepted (for compatibility) but not supported.
Improved in V 5.X

Summary

Standard Query Language (SQL)

- Data definition language (DDL)
- Data manipulation language (DML)
- In almost all current DBMS
- All SQL *implementations differ from standard*
- Core SQL99 is basically supported by high-end DBS

Important terms and concepts

- Data types
- Create, change, delete tables
- Referential integrity
- Integrity constraints
- TRIGGERS