

Data Management

05 Query Languages (SQL)

Matthias Boehm

Graz University of Technology, Austria
Computer Science and Biomedical Engineering
Institute of Interactive Systems and Data Science
BMVIT endowed chair for Data Management

Last update: Nov 04, 2019

Announcements/Org

■ #1 Video Recording

- Link in [TeachCenter](#) & [TUBE](#) (lectures will be public)



■ #2 Exercise 1

- Submission through [TeachCenter](#) (max 5MB, draft possible)
- [Submission open](#) (deadline **Nov 05, 11.59pm**)

31/152

■ #3 Exercise 2

- Will be published **Nov 05**, incl Python/Java examples (schema by Nov 12)
- Introduced during [next lecture](#)

■ #4 Coding Contest

- IT Community Styria
- Online or in-person (teams/individuals)
- Inffeldgasse 25/D, HS i3, **Nov 08, 3pm**



Agenda

- **Structured Query Language (SQL)**
- **Other Query Languages (XML, JSON)**

What is a(n) SQL Query?

```
SELECT Firstname, Lastname, Affiliation, Location
FROM Participant AS R, Locale AS S
WHERE R.LID = S.LID
AND Location LIKE '%, GER'
```

#1 **Declarative:**
what not how



Firstname	Lastname	Affiliation	Location
Volker	Markl	TU Berlin	Berlin, GER
Thomas	Neumann	TU Munich	Munich, GER

#2 **Flexibility:**
closed → composability

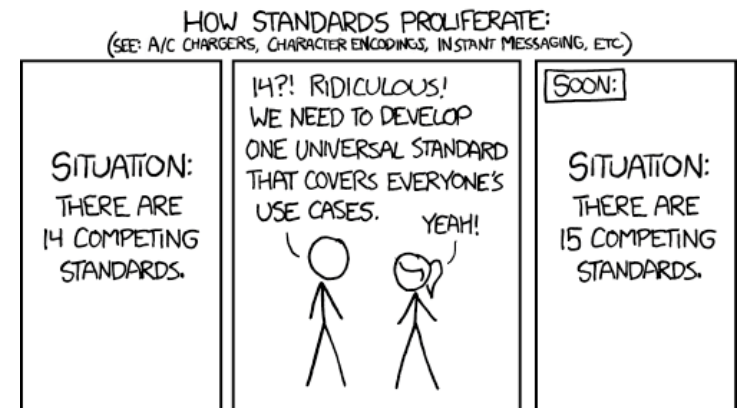
#3 **Automatic
Optimization**

#4 **Physical Data
Independence**

Why should I care?

■ SQL as a Standard

- Standards ensure **interoperability**, avoid **vendor lock-in**, and protect **application investments**
- Mature standard** with heavy industry support for decades
- Rich eco system** (existing apps, BI tools, services, frameworks, drivers, design tools, systems)



[<https://xkcd.com/927/>]

■ SQL is here to stay

- Foundation of mobile/server **application data management**
- Adoption of existing standard** by new systems (e.g., SQL on Hadoop, cloud DBaaS)
- Complemented by NoSQL abstractions, see lecture **10 NoSQL (key-value, document, graph)**



Structured Query Language (SQL)

Overview SQL

■ Structured Query Language (SQL)

- Current Standard: ISO/IEC 9075:2016 (SQL:2016)
- **Data Definition Language (DDL)** → Manipulate the database schema
- **Data Manipulation Language (DML)** → Update and query database
- **Data Control Language (DCL)** → Modify permissions

■ Dialects

- Spectrum of system-specific dialects for **non-core features**
- Data types and size constraints
- Catalog, builtin functions, and tools
- Support for new/optional features
- Case-sensitive identifiers

Name	Examples
T-SQL	Microsoft, Sybase
PL/SQL	Oracle, (IBM)
PL/pgSQL	PostgreSQL, derived
Unnamed	Most systems

The History of the SQL Standard

[C. J. Date: A Critique of the
SQL Database Language.
SIGMOD Record 1984]

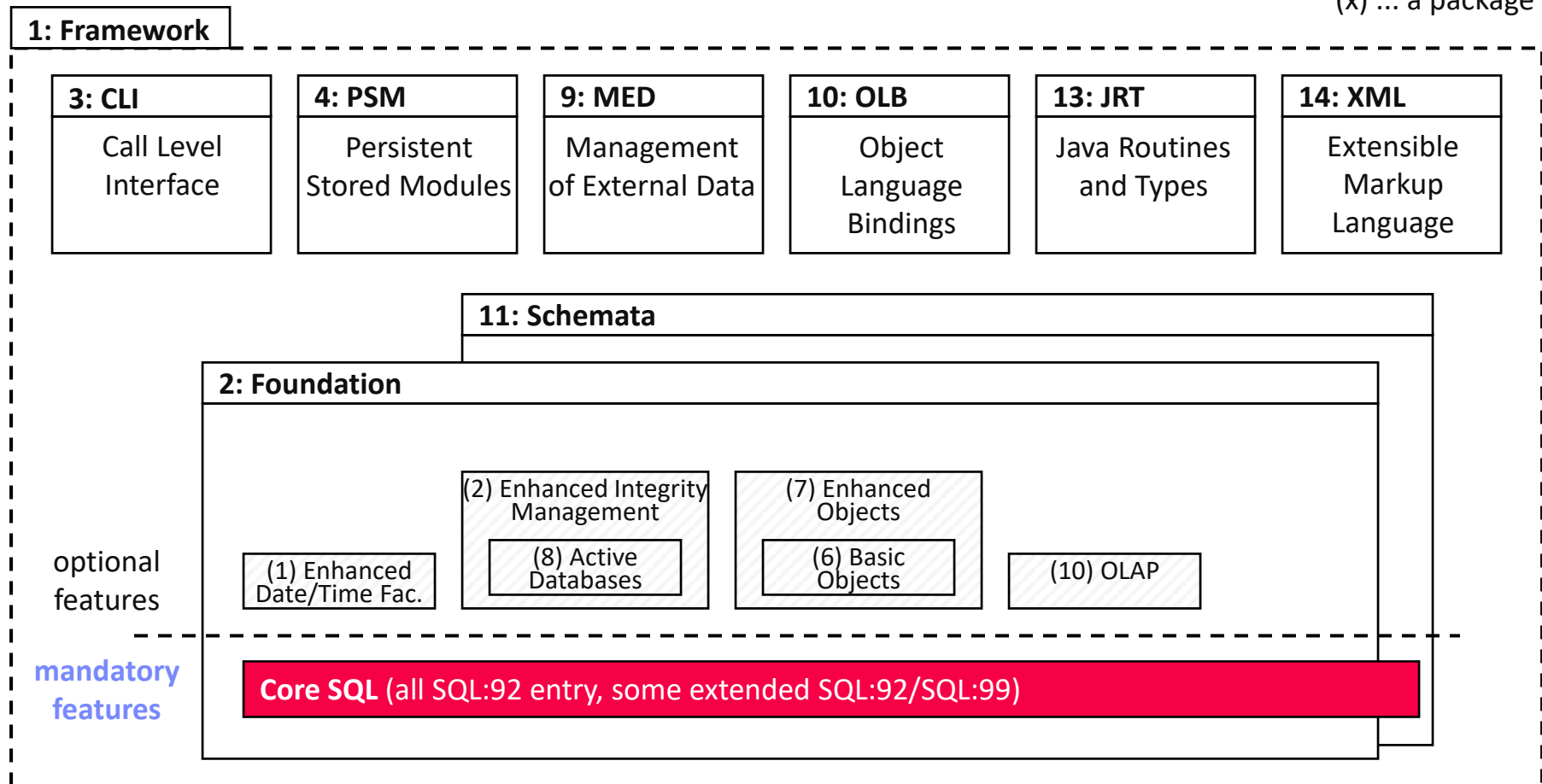


- **SQL:1986**
 - **Database Language SQL**, ANSI X3.135-1986, ISO-9075-1987(E)
 - '87 international edition
- **SQL:1989 (120 pages)**
 - **Database Language SQL with Integrity Enhancements**, ANSI X3.135-1989, ISO-9075-1989(E)
- **SQL:1992 (580 pages)**
 - **Database Language SQL**, ANSI X3-1992, ISO/IEC-9075 1992, DIN 66315
 - '95 SQL/CLI (part 3), '96 SQL/PSM (part 4)
- **SQL:1999 (2000 pages)**
 - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 1999
 - Complete reorg, '00 OLAP, '01 SQL/MED, '01 SQL/OLB, '02 SQL/JRT
- **SQL:2003 (3764 pages)**
 - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2003

The History of the SQL Standard, cont.

■ Overview SQL:2003

x: ... a part
(x) ... a package



The History of the SQL Standard, cont.

Since SQL:2003 overall structure remained unchanged ...

- **SQL:2008** (???? pages)
 - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2003
 - E.g., **XML** XQuery extensions, case/trigger extension
- **SQL:2011** (4079 pages)
 - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2011
 - E.g., time periods, temporal constraints, time travel queries
- **SQL:2016** (???? pages)
 - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2016
 - E.g., **JSON** documents and functions (optional)

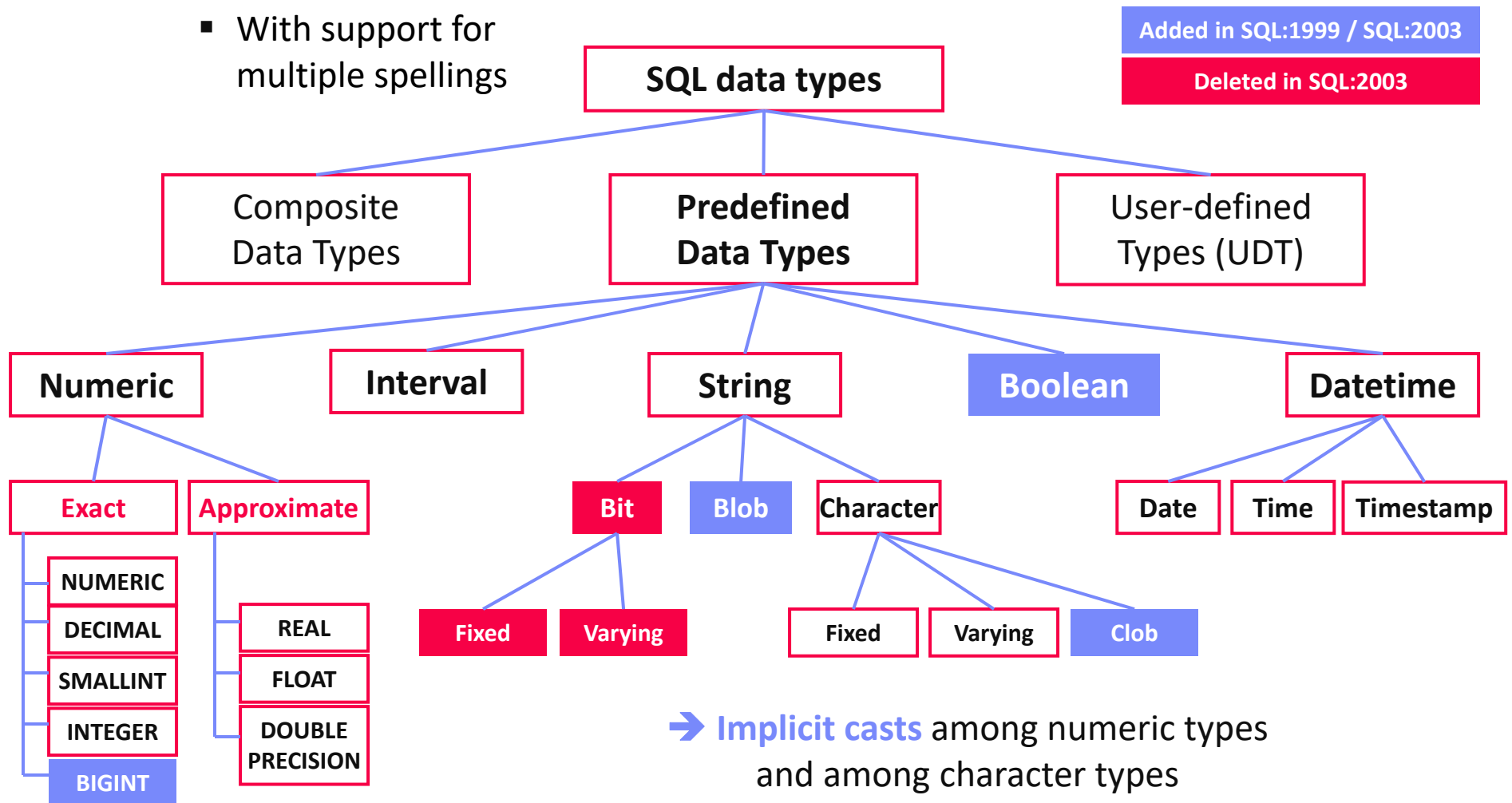
➔ **Note:** We can only discuss common primitives

[Working Draft SQL:2011:
[https://www.wiscorp.com/
SQLStandards.html](https://www.wiscorp.com/SQLStandards.html)]

Data Types in SQL:2003

Large Variety of Types

- With support for multiple spellings



Data Types in PostgreSQL

Appropriate, Brief, Complete

■ Strings

- **CHAR(n)** → fixed-length character sequence (padded to n)
- **VARCHAR(n)** → variable-length character sequence (n max)
- **TEXT** → variable-length character sequence

■ Numeric

- **SMALLINT** → 2 byte integer (signed short)
- **INT/INTEGER** → 4 byte integer (signed int)
- **SERIAL** → INTEGER w/ auto increment
- **NUMERIC(p, s)** → exact real with p digits and s after decimal point

■ Time

- **DATE** → date
- **TIMESTAMP/TIMESTAMPTZ** → date and time, timezone-aware if needed

■ JSON

- **JSON** → text JSON representation (requires reparsing)
- **JSONB** → binary JSON representation

Create, Alter, and Delete Tables

Templates in SQL
Examples in PostgreSQL

■ Create Table

- Typed attributes
- Primary and foreign keys
- **NOT NULL**, **UNIQUE** constraints
- **DEFAULT** values
- **CHECK** constraints

```
CREATE TABLE Students (  
    SID INTEGER PRIMARY KEY,  
    Fname VARCHAR(128) NOT NULL,  
    Lname VARCHAR(128) NOT NULL,  
    Mtime DATE DEFAULT CURRENT_DATE  
);
```

```
CREATE TABLE Students AS SELECT ...;
```

■ Alter Table

- **ADD/DROP** columns
- **ALTER** data type, defaults, constraints, etc

```
ALTER TABLE Students ADD DoB DATE;
```

```
ALTER TABLE Students ADD CONSTRAINT  
    PKStudent PRIMARY KEY(SID);
```

■ Delete Table

- Delete table
- **Note:** order of tables matters due to referential integrity

```
DROP TABLE Students; -- sorry
```

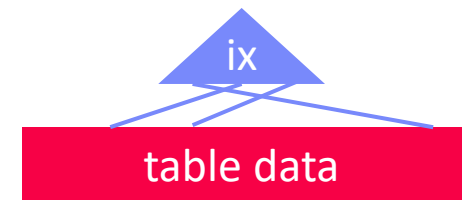
```
DROP TABLE Students CASCADE;
```

Create and Delete Indexes

■ Create Index

- Create a secondary (nonclustered) index on a set of attributes
- **Clustered**: tuples sorted by index
- **Non-clustered**: sorted attribute with tuple references
- Can specify uniqueness, order, and indexing method
- **PostgreSQL methods**: btree, hash, gist, and gin
→ see lecture **07 Physical Design and Tuning**

```
CREATE INDEX ixStudLname  
ON Students USING btree  
(Lname ASC NULLS FIRST);
```



■ Delete Index

- Drop indexes by name

```
DROP INDEX ixStudLname;
```

■ Tradeoffs

- Indexes often automatically created for **primary keys** / **unique** attributes
- **Lookup/scan performance** vs **insert performance**

Database Catalog

[Meikel Poess: **TPC-H**. Encyclopedia of Big Data Technologies 2019]

■ Catalog Overview

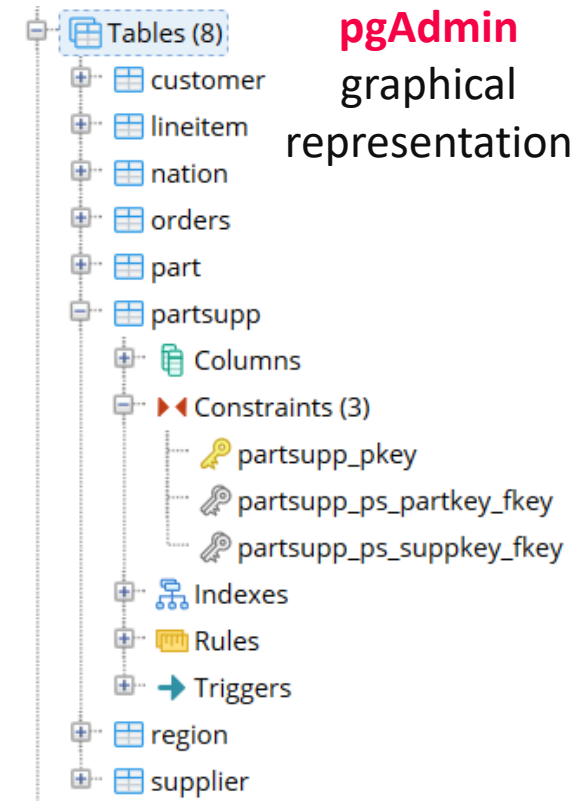
- **Meta data** of all database objects (tables, constraints, indexes) → **mostly read-only**
- **Accessible through SQL**
- Organized by schemas (**CREATE SCHEMA tpch;**)

■ SQL Information_Schema

- Schema with tables for all tables, views, constraints, etc
- **Example:** check for existence of accessible table

```
SELECT 1 FROM information_schema.tables
WHERE table_schema = 'tpch'
      AND table_name = 'customer'
```

(defined as views over PostgreSQL catalog tables)



Insert

■ Insert Tuple

- **Insert a single tuple** with implicit or explicit attribute assignment

```
INSERT INTO Students (SID, Lname, Fname, MTime, DoB)  
  VALUES (7, 'Boehm', 'Matthias', '2002-10-01', '1982-06-25');
```

- Insert attribute key-value pairs to use auto increment, defaults, NULLs, etc

```
INSERT INTO Students (Lname, Fname, DoB) SERIAL SID,  
  VALUES ('Boehm', 'Matthias', '1982-06-25'), DEFAULT MTime  
  (...), (...);
```

■ Insert Table

- **Redirect query result into**
INSERT (append semantics)

```
INSERT INTO Students  
  SELECT * FROM NewStudents;
```

Analogy Linux redirect (append):
cat NewStudents.txt >> Students.txt

Update and Delete

■ Update Tuple/Table

- **Set-oriented update** of attributes
- Update single tuple via predicate on **primary key**

```
UPDATE Students  
  SET MTime = '2002-10-02'  
  WHERE LName = 'Boehm';
```

■ Delete Tuple/Table

- **Set-oriented delete** of tuples
- Delete single tuple via predicate on **primary key**

```
DELETE FROM Students  
  WHERE extract(year  
    FROM mtime) < 2010;
```

■ **Note:** Time travel and multi-version concurrency control

- Deleted tuples might be just **marked as inactive**
- See lecture **09 Transaction Processing and Concurrency**

Basic Queries

Basic Query Template

- **Select-From-Where**
- Grouping and Aggregation
- Having and ordering
- Duplicate elimination

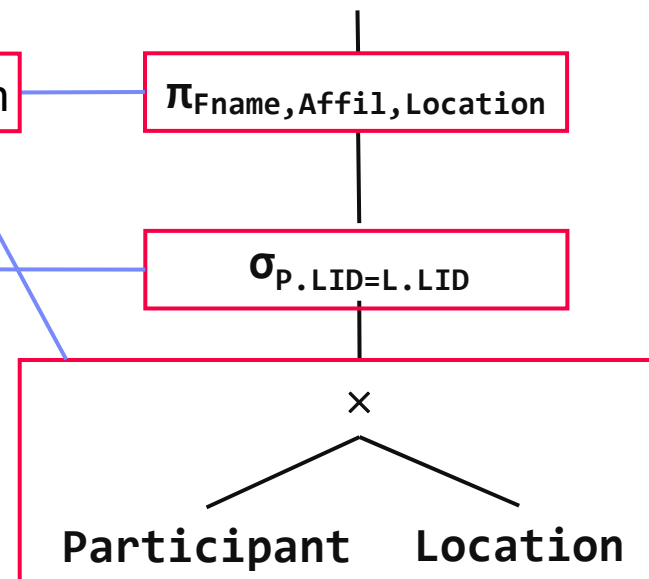
```

SELECT [DISTINCT] <column_list>
FROM [<table_list> |
  <table1> [RIGHT | LEFT | FULL] JOIN
  <table2> ON <condition>]
[WHERE <predicate>]
[GROUP BY <column_list>]
[HAVING <grouping predicate>]
[ORDER BY <column_list> [ASC | DESC]]

```

Example

- **SELECT** Fname, Affil, Location
FROM Participant AS R,
 Locale AS S
WHERE R.LID=S.LID;



Basic Queries, cont.

■ Distinct and All

- **Distinct and all** alternatives
- Projection w/ **bag semantics** by default

```
SELECT DISTINCT Lname, Fname  
FROM Students;
```

■ Sorting

- Convert a **bag** into a **sorted list** of tuples; order lost if used in other ops
- Single order: (Lname, Fname) **DESC**
- Evaluated last in a query tree

```
SELECT * FROM Students  
ORDER BY Lname DESC,  
Fname DESC;
```

■ Set Operations

- See **04 Relational Algebra and Calculus**
→ **UNION, INTERSECT, EXCEPT**
- Set operations **set semantics** by default
→ **DISTINCT** (set) vs **ALL** (bag)

```
SELECT Firstname, Lastname  
FROM Participant2018  
UNION DISTINCT  
SELECT Firstname, Lastname  
FROM Participant2013
```

Grouping and Aggregation

■ Grouping and Aggregation

- **Grouping:** determines the distinct groups
- **Aggregation:** compute aggregate $f(B)$ per group
- Column list can only contain **grouping columns**, **aggregates**, or **literals**
- **Having:** selection predicate on groups and aggregates

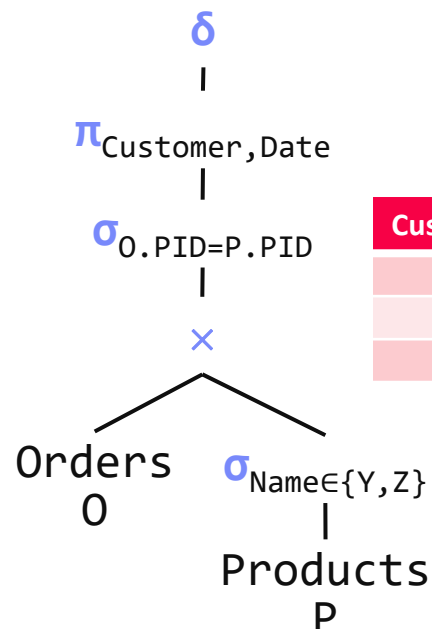
■ Example

- Sales (Customer, Location, Product, Quantity, Price)
- **Q: Compute number of sales and revenue per product**

```
SELECT Product, sum(Quantity), sum(Quantity*Price)
FROM Sales
GROUP BY Product
```

BREAK (and Test Yourself)

- Task: SQL queries for the following query trees.



Customer	Date
A	'2019-06-22'
C	'2019-06-23'
D	'2019-06-23'

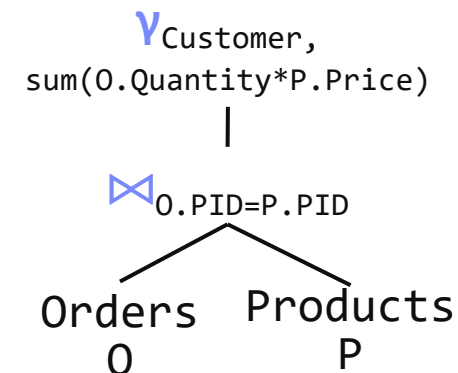
```
SELECT DISTINCT Customer, Date
FROM Orders O, Products P
WHERE O.PID = P.PID
AND Name IN('Y', 'Z')
```

Orders

<u>OID</u>	Customer	Date	Quantity	PID
1	A	'2019-06-22'	3	2
2	B	'2019-06-22'	1	3
3	A	'2019-06-22'	1	4
4	C	'2019-06-23'	2	2
5	D	'2019-06-23'	1	4
6	C	'2019-06-23'	1	1

Products

<u>PID</u>	Name	Price
1	X	100
2	Y	15
4	Z	75
3	W	120



Customer	Sum
A	120
B	120
C	130
D	1

```
SELECT Customer,
       sum(O.Quantity * P.Price)
FROM Orders O, Products P
WHERE O.PID = P.PID
GROUP BY Customer
```

Subqueries

■ Subqueries in Table List

- Use a subquery result like a base table
- Modularization with **WITH C AS (SELECT ...)**

```
SELECT S.Fname, S.Lname, C.Name
FROM Students AS S,
      (SELECT CID, Name FROM Country
       WHERE ...) AS C
WHERE S.CID=C.CID;
```

■ Subqueries w/ IN

- Check containment of values in result set of sub query

```
SELECT Product, Quantity, Price
FROM Sales
WHERE Product NOT IN(
  SELECT Product FROM Sales
  GROUP BY Product
  HAVING sum(Quantity*Price)>1e6)
```

■ Other subqueries

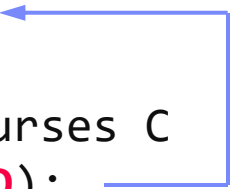
- **EXISTS**: existential quantifier $\exists x$ for correlated subqueries
- **ALL**: comparison (w/ universal quantifier $\forall x$)
- **SOME/ANY**: comparison (w/ existential quantifier $\exists x$)

Correlated and Uncorrelated Subqueries

■ Correlated Subquery

- **Evaluated subquery for every tuple** of outer query
- Use of attribute from table bound in outer query inside subquery

```
SELECT P.Fname, P.Lname
FROM Professors P,
WHERE NOT EXISTS(
    SELECT * FROM Courses C
    WHERE C.PID=P.PID);
```



■ Uncorrelated Subquery

- Evaluate subquery just once
- No attribute correlations between subquery and outer query

```
SELECT P.Fname, P.Lname
FROM Professors P,
WHERE P.PID NOT IN(
    SELECT PID FROM Courses);
```

■ Query Unnesting (de-correlation)

- Rewrite during query compilation
- See lecture **08 Query Processing**

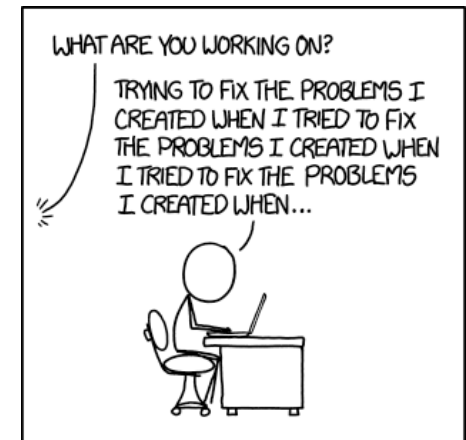
[Thomas Neumann, Alfons
Kemper: Unnesting Arbitrary
Queries. **BTW 2015**]



Recursive Queries

Approach

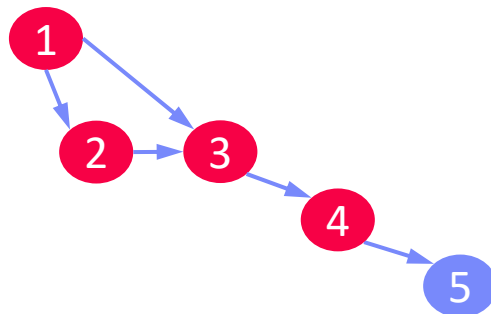
- **WITH RECURSIVE** <name> (<arguments>)
- Compose recursive table from **non-recursive term**, **union all/distinct**, and **recursive term**
- Terminates when recursive term yields empty result



<https://xkcd.com/1739/>

Example

- Courses(CID, Name),
Precond(pre REF CID, suc REF CID)
- Dependency graph (pre → suc)



```

WITH RECURSIVE rPrereq(p,s) AS(
  (SELECT pre, suc
   FROM Precond WHERE suc=5)
  UNION DISTINCT
  (SELECT B.pre, B.suc
   FROM Precond B, rPrereq R
   WHERE B.suc = R.p)
)
SELECT DISTINCT p FROM rPrereq
  
```

4

3

1

2

Procedures and Functions

■ Overview Procedures and Functions

- Stored programs, written in **PL/pgSQL** or other languages
- **Control flow (loops, branches) and SQL queries**

■ (Stored) Procedures

- Can be called standalone via **CALL** <proc_name>(<args>);
- Procedures return no outputs

```
CREATE PROCEDURE prepStud(a INT)
LANGUAGE PLPGSQL AS $$
BEGIN
    DELETE FROM Students;
    INSERT INTO Students
        SELECT * FROM NewStudents;
END; $$;
```

■ Functions

- Can be called standalone or inside queries
- Functions are value mappings
- Table functions can return sets of records with multiple attributes

```
CREATE FUNCTION sampleProp(FLOAT)
RETURNS FLOAT
AS 'SELECT $1 * (1 - $1);'
LANGUAGE SQL;
```

Triggers

■ Overview Trigger

- Similar to stored procedure but register ON INSERT, DELETE, or UPDATE
- Allows complex check constraints and active behavior such as replication, auditing, etc (good and bad)

■ Trigger **CREATE TRIGGER** <triggername>

Template

```

BEFORE | AFTER | INSTEAD OF
INSERT | DELETE | (UPDATE OF <column_list>)
ON <tablename>
[REFERENCING <old_new_alias_list>]
[FOR EACH {ROW | STATEMENT}]
[WHEN (<search condition>)]
<SQL procedure statement> |
BEGIN ATOMIC
    {<SQL Procedure statement>;}...
END

```

Event

Condition

Action

Not supported in
PostgreSQL
(need single UDF)



Views and Authorization

■ Creating Views

- **Create a logical table from a query**
- Inserts can be propagated back to base relations only in special cases
- **Allows authorization** for subset of

```
CREATE VIEW TeamDM AS  
SELECT * FROM  
    Employee E, Employee M  
WHERE E.MgrID = M.EID  
    AND M.login = 'mboehm';
```

■ Access Permissions Tables/Views

- **Grant** query/modification rights on database objects for specific users, roles
- **Revoke** access rights from users, roles (recursively revoke permissions of dependent views via **CASCADE**)

```
GRANT SELECT  
    ON TABLE TeamDM  
    TO mboehm;
```

```
REVOKE SELECT  
    ON TABLE TeamDM  
    FROM mboehm;
```

Beware of SQL Injection



- Problematic SQL String Concatenation

```
INSERT INTO Students (Lname, Fname)
VALUES ('"+ @lname +"', '"+ @fname +"' );";
```

- Possible **SQL-Injection Attack**



[<https://xkcd.com/327/>]

```
INSERT INTO Students (Lname, Fname) VALUES ('Smith', 'Robert');
DROP TABLE Students; --');
```

Other Query Languages (XML, JSON)

No really, why should I care?

- **Semi-structured XML and JSON**

- **Self-contained documents** for representing nested data
- **Common data exchange formats** without redundancy of flat files
- Human-readable formats → often used for SW configuration

- **Goals**

- **Awareness of XML and JSON** as data models
- Query languages and embedded querying in SQL

XML (Extensible Markup Language)

■ XML Data Model

- Meta language to define specific **exchange formats**
- Document format for **semi-structured data**
- Well formedness
- XML schema / DTD

```
<?xml version="1.0" encoding="UTF-8"?>
<data>
  <student id="1">
    <course id="INF.01017UF" name="DM"/>
    <course id="706.550" name="AMLS"/>
  </student>
  <student id="5">
    <course id="706.520" name="DIA"/>
  </student>
</data>
```

■ XPath (XML Path Language)

/data/**student**[@id='1']/course/@name

- Query language for **accessing collections of nodes** of an XML document
- Axis specifies for ancestors, descendants, siblings, etc

↓
"DM"
"AMLS"

■ XSLT (XML Stylesheet Language Transformations)

- Schema mapping (transformation) language for XML documents

■ XQuery

- Query language to extract, transform, and analyze XML documents

XML in PostgreSQL, cont.

■ Overview XML in PostgreSQL

- Data types **TEXT** or **XML** (well-formed, type-safe operations)
- ISO/IEC 9075-14 XML-related specifications (SQL/XML)

■ Creating XML

- Various **builtin functions** to parse documents, and create elements/attributes
- XMLPARSE(<xml_document>) → **XML type**
- XMLELEMENT / XMLATTRIBUTES

INSERT INTO Students

```
(Fname, Lname, Doc)  
VALUES('John', 'Smith',  
xmlparse(<source_doc>));
```

■ Processing XML

- Execute **XPath** expressions on XML types
- XMLEXIST with **XPath instead of XQuery**
- XPATH with optional namespace handling

```
SELECT Fname, Lname,  
xpath('/student/@id', Doc)  
FROM Students
```

JSON (JavaScript Object Notation)

■ JSON Data Model

- Data exchange format for **semi-structured data**
- **Not as verbose as XML**
(especially for arrays)
- Popular format (e.g., Twitter)



```
{“students:”[  
  {“id”: 1, “courses”: [  
    {“id”: “INF.01017UF”, “name”: “DM”},  
    {“id”: “706.550”, “name”: “AMLS”}]},  
  {“id”: 5, “courses”: [  
    {“id”: “706.520”, “name”: “DIA”}]},  
]}
```

■ Query Languages

- **Most common: libraries** for tree traversal and data extraction
- **JSONiq**: XQuery-like query language
- **JSONPath**: XPath-like query language

JSONiq Example:

```
declare option jsoniq-version “...”;  
for $x in collection(“students”)  
  where $x.id lt 10  
  let $c := count($x.courses)  
  return {“sid”: $x.id, “count”: $c}
```

[<http://www.jsoniq.org/docs/JSONiq/html-single/index.html>]

JSON in PostgreSQL, cont.

■ Overview JSON in PostgreSQL

- Alternative data types: **JSON** (text), **JSONB** (binary, with restrictions)
- Implements RFC 7159, built-ins for conversion and access

■ Creating JSON

- Built-in functions for creating JSON from tables and tables from JSON input

```
SELECT row_to_json(t) FROM  
      (SELECT Fname, Lname  
       FROM Students) t
```

■ Processing JSON

- Specialized operators for **tree traversal and data extraction**
- **-> operator**: get JSON array element/object
- **->> operator**: get JSON array element/object as text
- Built-in functions for extracting json (e.g., json_each)

```
SELECT Fname, Lname,  
       Doc->students->>id  
FROM Students
```

Conclusions and Q&A

■ Summary

- History and fundamentals of the **Structured Query Language (SQL)**
- Awareness of **XML and JSON** (data model and querying)

■ Exercise 1 Reminder

- All background to solve tasks 1.1-1.3 since lecture 03
- Submission deadline: **Nov 05, 11.59pm**

■ Next Lectures

- Nov 11: **06 APIs (ODBC, JDBC, OR frameworks), incl. Exercise 2**