Introduction to SQL (Structured Query Language)

EECS3421 - Introduction to Database Management Systems

Standard language for
1. Storing
2. Manipulating
3. Retrieving data

1. Domain-specific
2. Manages data

What is SQL?

→ Structured Query language

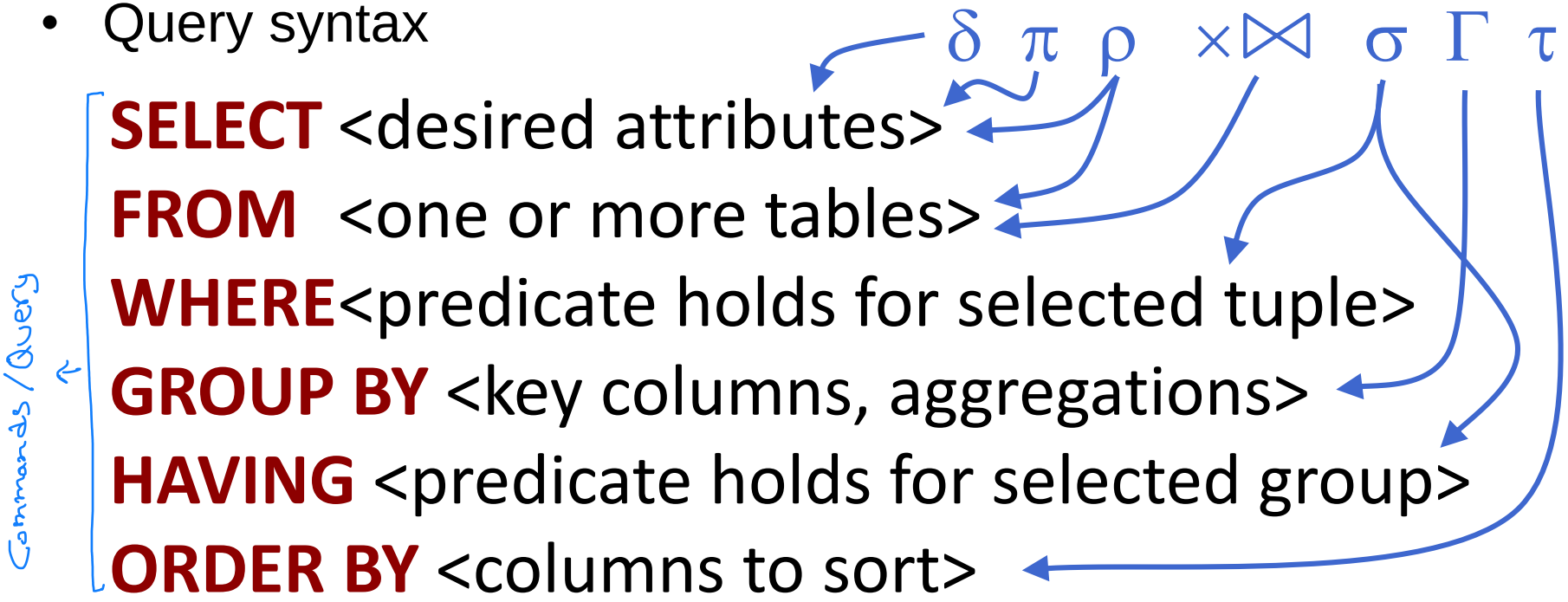
- **Declarative**
  1. – Say "what to do" rather than "how to do it"
     - Avoid data-manipulation details needed by procedural languages
  2. – Database engine figures out "best" way to execute query
     - Called "query optimization"
     - Crucial for performance: "best" can be a million times faster than "worst"
- **Data independent**
  1. – Decoupled from underlying data organization
     - Views (= precomputed queries) increase decoupling even further
     - Correctness always assured… performance not so much
  2. – SQL is standard and (nearly) identical among vendors
     - Differences often shallow, syntactical

Fairly thin wrapper around relational algebra

→ Lets Accessing and manipulating data.

What does SQL look like?

- Query syntax



Note:
→ SQL is for relational database
→ Query → request for data in a database.

Example

Orders

OID	OrderDate	OrderPrice	Customer
1	2008/11/12	1000	Hansen
2	2008/10/23	1600	Nilsen
3	2008/09/02	700	Hansen
4	2008/09/03	300	Hansen
5	2008/08/30	2000	Jensen
6	2008/10/04	100	Nilsen

Find if the customers "Hansen" or "Jensen“ have a total order of more than 1500

Query:

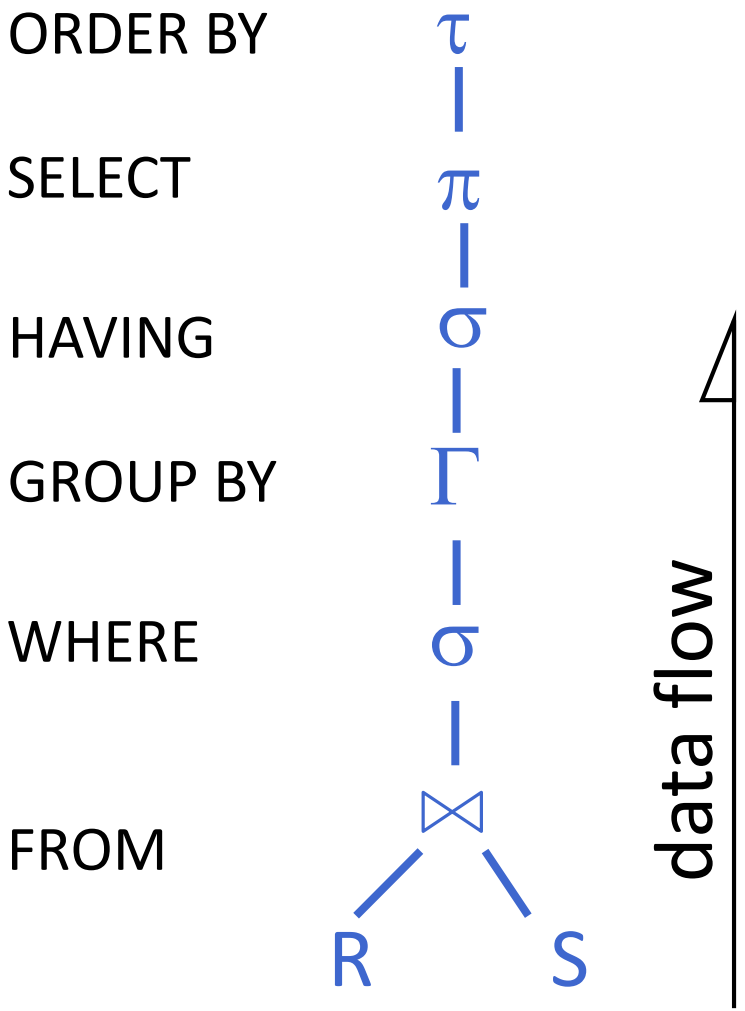
```
SELECT      Customer, SUM(OrderPrice) AS Total
FROM        Orders
WHERE       Customer = 'Hansen' OR Customer = 'Jensen'
GROUP BY    Customer
HAVING      SUM(OrderPrice) > 1500
ORDER BY    Customer DESC
```

Query Result:

Customer	Total
Jensen	2000
Hansen	2000

- This table is formed as a result of the query.
- This is called result-set

What does SQL *really* look like?



That's not so bad, is it?

Other aspects of SQL

- **Data Definition Language ("DDL")**
  - Manipulate database schema
  - Specify, alter physical data layout
- **Data Manipulation Language ("DML")**
  - Manipulate data in databases
  - Insert, delete, update rows
- **"Active" Logic**
  - Triggers and constraints
  - User-defined functions, stored procedures
  - Transaction management/ Consistency levels

We'll come back to these later in the course

SELECT-FROM-WHERE QUERIES

'SELECT' clause

select data from a database
data returned, stored in a result-table
select is lat like return statement

- Identifies which attribute(s) query returns
  - Comma-separated list

  => Determines schema of query result
- (Optional) extended projection
  - Compute arbitrary expressions
  - Usually based on selected attributes, but not always
- (Optional) rename attributes
  - "Prettify" column names for output
  - Disambiguate (E1.name vs. E2.name)
- (Optional) specify groupings
  - More on this later
- (Optional) duplicate elimination
  - SELECT DISTINCT …

↳ return only distinct/unique values in DB

‘SELECT’ clause – examples

- **SELECT** E.name …
  => Explicit attribute
- **SELECT** name …
  => Implicit attribute (error if R.name and S.name exist)
- **SELECT** E.name **AS** ‘Employee name’ …
  => Prettified for output (like table renaming, ‘AS’ usually not required)
- **SELECT** sum(S.value) …
  => Grouping (compute sum)
- **SELECT** sum(S.value)*0.13 ‘HST’ …
  => Scalar expression based on aggregate
- **SELECT** * …

  => Select all attributes (no projection)
- **SELECT** E.* …
  => Select all attributes from E (no projection)

‘FROM’ clause

command to choose the Database table where we will work on.

- Identifies the tables (relations) to query
  - Comma-separated list

→ chooses from the table.

- Optional: specify joins
  - … but often use WHERE clause instead
- Optional: rename table (“tuple variable”)
  - Using the same table twice (else they’re ambiguous)
  - Nested queries (else they’re unnamed)

‘FROM’ clause – examples

- … **FROM** Employees

  => Explicit relation
- … **FROM** Employees **AS** E

  => Table alias (most systems don’t require “AS” keyword)
- … **FROM** Employees, Sales

  => Cartesian product
- … **FROM** Employees E **JOIN** Sales S

  => Cartesian product (*no join condition given!*)
- … **FROM** Employees E **JOIN** Sales S **ON** E.EID=S.EID

  => Equi-join

‘FROM’ clause – examples (cont)

- … **FROM** Employees **NATURAL JOIN** Sales

  => Natural join (bug-prone, use equijoin instead)

- … **FROM** Employees E
  LEFT JOIN Sales S **ON** E.EID=S.EID

  => Left join

- … **FROM** Employees E1
  JOIN Employees E2 **ON** E1.EID < E2.EID

  => Theta self-join (*what does it return?*)

Check

Gotcha: natural join in practice

↳ valid construct in system.

- Uses *all* same-named attributes
  - May be too many or too few
- Implicit nature reduces readability
  - Better to list explicitly all join conditions
- Fragile under schema changes
  - Nasty interaction of above two cases..

Moral of the story: Avoid using Natural Join

Gotcha: join selectivity

- Consider tables **R**, **S**, **T** with **T=Ø** and this query:

```
SELECT R.x
FROM R,S,T
WHERE R.x=S.x OR R.x=T.x
```

(*what does it return?*)

- Result contains no rows!
  - Selection (WHERE) operates on pre-joined tuples
  - R × S × T = R × S × Ø = Ø

  => No tuples for WHERE clause to work with!
- Workaround?
  - Two coming up later

Moral of the story: WHERE cannot create tuples

Explicit join ordering

- Use parentheses to group joins
  - e.g. (A join B) join (C join D)
- Special-purpose feature
  - Helps some (inferior) systems optimize better
  - Helps align schemas for natural join
- Recommendation: avoid
  - People are notoriously bad at optimizing things
  - Optimizer usually does what it wants anyway

    … but sometimes treats explicit ordering as a constraint

‘WHERE’ clause

→ used to filter records
→ used in SELECT, UPDATE, DELETE statements
→ used to extract those records that fulfil a specified condition.

- Conditions which all returned tuples must meet
  - Arbitrary boolean expression
  - Combine multiple expressions with AND/OR/NOT
- Attention to data of interest
  - Specific people, dates, places, quantities
  - Things which do (or do not) correlate with other data
- Often used instead of JOIN
  - FROM tables (Cartesian product, e.g. A, B)
  - Specify join condition in WHERE clause (e.g. A.ID=B.ID)
  - Optimizers (usually) understand and do the right thing

Scalar expressions in SQL

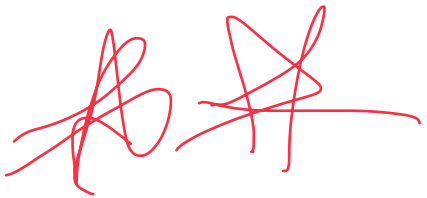
- Literals, attributes, single-valued relations
- Boolean expressions
  - Boolean T/F coerce to 1/0 in arithmetic expressions
  - Zero/non-zero coerce to F/T in boolean expressions
- Logical connectors: AND, OR, NOT
- Conditionals

  = != < > <= >= <>

  BETWEEN, [NOT] LIKE, IS [NOT] NULL, …
- Operators: + - * / % & | ^
- Functions: math, string, date/time, etc. (more later)

Similar to expressions in C, python, etc.

‘WHERE’ clause – examples



- … **WHERE** S.date > ‘01-Jan-2010’

  => Simple tuple-literal condition
- … **WHERE** E.EID = S.EID

  => Simple tuple-tuple condition (equi-join)
- … **WHERE** E.EID = S.EID **AND** S.PID = P.PID

  => Conjunctive tuple-tuple condition (three-way equijoin)
- … **WHERE** S.value < 10 **OR** S.value > 10000

  => Disjunctive tuple-literal condition

Pattern matching

- Compare a string to a pattern
  - <attribute> **LIKE** <pattern>
  - <attribute> **NOT LIKE** <pattern>
- Pattern is a quoted string

  % => “any string”

  _ => “any character”
- To escape ‘%’ or ‘_’:
  - LIKE ‘%x_%’ ESCAPE ‘x’ (replace ‘x’ with character of choice)

  ⇒matches strings containing ‘_’ (the underscore character)

DBMS increasingly allow regular expressions

Pattern matching – examples

- … **WHERE** phone **LIKE** ‘%268-_ _ _ _’
  - phone numbers with exchange 268
  - WARNING: spaces are wrong, only shown for clarity
- … **WHERE** last_name **LIKE** ‘Jo%’
  - Jobs, Jones, Johnson, Jorgensen, etc.
- … **WHERE** Dictionary.entry **NOT LIKE** ‘%est’
  - Ignore ‘biggest’, ‘tallest’, ‘fastest’, ‘rest’, …
- … **WHERE** sales **LIKE** '%30!%%' **ESCAPE** ‘!’
  - Sales of 30%

MORE COMPLEX QUERIES (GROUP BY-HAVING-ORDER BY)

‘GROUP BY’ clause

Used with aggregate function COUNT, MAX, MIN, SUM, AVG

Used to group the result-set by one or more column.

Lot like sorts the database

- Specifies **grouping key** of relational operator Γ
  - Comma-separated list of attributes (names or positions) which identify groups
  - Tuples agreeing in their grouping key are in same “group”
  - SELECT gives attributes to aggregate (and functions to use)
- SQL specifies several **aggregation functions**
  - COUNT, MIN, MAX, SUM, AVG, STD (standard deviation)
  - Some systems allow user-defined aggregates

‘GROUP BY’ clause – gotchas

- WHERE clause cannot reference aggregated values (sum, count, etc.)
  - Aggregates don’t “exist yet” when WHERE runs

  => Use **HAVING** clause instead (coming next)
- GROUP BY **must** list all non-aggregate attributes used in SELECT clause
  - Think projection

  => Some systems do this implicitly, others throw error
- Grouping often (but not always!) sorts on grouping key
  - Depends on system and/or optimizer decisions

  => Use **ORDER BY** to be sure (coming next)

‘GROUP BY’ clause – examples

- SELECT EID, SUM(value)
  FROM Sales **GROUP BY** EID
  - Show total sales for each employee ID
- SELECT EID, SUM(value), MAX(value)
  FROM Sales **GROUP BY** 1
  - Show total sales and largest sale for each employee ID
- SELECT EID, COUNT(EID)
  FROM Complaints **GROUP BY** EID
  - Show how many complaints each salesperson triggered

‘GROUP BY’ clause – examples (cont)

- SELECT EID, SUM(value) FROM Sales
  - Error: non-aggregate attribute (EID) missing from GROUP BY
- SELECT EID, value FROM Sales **GROUP BY** 1,2
  - Not an error – eliminates duplicates
- SELECT SUM(value) FROM Sales **GROUP BY** EID
  - Not an error, but rather useless: report per-employee sales anonymously
- SELECT SUM(value) FROM Sales
  - No GROUP BY => no grouping key => all tuples in same group

Eliminating duplicates in aggregation

- Use **DISTINCT** inside an aggregation

```
SELECT EmpID, COUNT(DISTINCT CustID)
FROM CustomerComplaints
GROUP BY 1
```

=> Number of customers who complained about the employee

=> What if `COUNT(CustID)` >> `COUNT(DISTINCT CustID)`?

‘HAVING’ clause

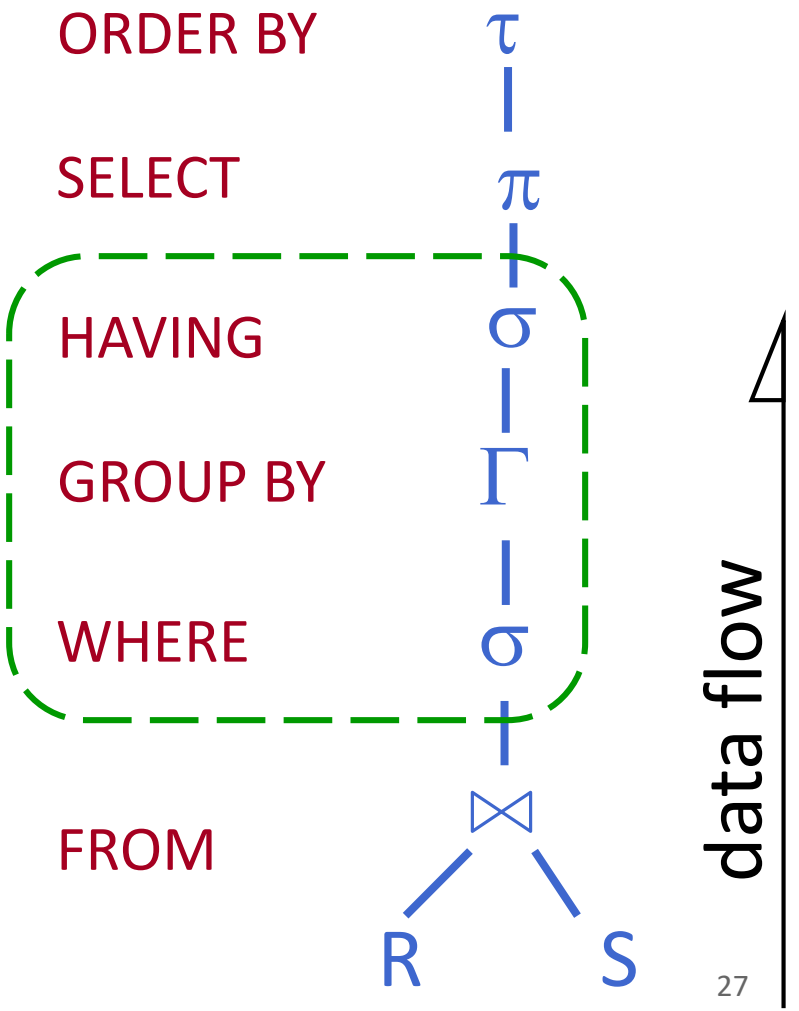
- Allows predicates on aggregate values
  - Groups which do not match the predicate are eliminated

  => **HAVING** is to groups what **WHERE** is to tuples
- Order of execution
  - WHERE is before GROUP BY

  => Aggregates not yet available when WHERE clause runs
  - GROUP BY is before HAVING

  => Scalar attributes still available

In tree form:



‘HAVING’ clause – examples

- SELECT EID, SUM(value)
  FROM Sales GROUP BY EID
  HAVING SUM(Sales.value) > 10000
  - Highlight employees with “impressive” sales

- SELECT EID, SUM(value)
  FROM Sales GROUP BY EID
  HAVING AVG(value) < (
  SELECT AVG(GroupAVG)
  FROM (SELECT EID, AVG(value) AS GroupAVG
  FROM Sales
  GROUP BY EID) AS B);
  - Highlight employees with below-average sales
  - Subquery to find the avg value of average employee sales

'ORDER BY' clause

Used to sort result-set in ascending or descending order.

Sorts the records in ascending order by default.
To sort records in descending order use DESC keyword.

- Each query can sort by one or more attributes
  - Refer to attributes by name or position in SELECT
  - Ascending (default) or descending (reverse) order
  - Equivalent to relational operator τ
- Definition of 'sorted' depends on data type
  - Numbers use natural ordering
  - Date/time uses earlier-first ordering
  - NULL values are not comparable, cluster at end or beginning
- Strings are more complicated
  - Intuitively, sort in "alphabetical order"
  - Problem: which alphabet? case sensitive?
  - Answer: user-specified "collation order"
  - Default collation: case-sensitive latin (ASCII) alphabet

String collation not covered in this class

‘ORDER BY’ clause – examples

- **… ORDER BY** E.name
  => Defaults to ascending order
- **… ORDER BY** E.name **ASC**
  => Explicitly ascending order
- **… ORDER BY** E.name **DESC**
  => Explicitly descending order
- **… ORDER BY** CarCount **DESC**, CarName **ASC**
  => Matches our car example from previous lecture
- SELECT E.name … **ORDER BY** 1
  => Specify attribute’s position instead of its name

What’s next?

- Examples

WORKING EXAMPLES

Example Database

Check this.

Employee(FirstName,Surname,Dept,Office,Salary,City)
Department(DeptName,Address,City)

Home city

EMPLOYEE

FirstName	Surname	Dept	Office	Salary	City
Mary	Brown	Administration	10	45	London
Charles	White	Production	20	36	Toulouse
Gus	Green	Administration	20	40	Oxford
Jackson	Neri	Distribution	16	45	Dover
Charles	Brown	Planning	14	80	London
Laurence	Chen	Planning	7	73	Worthing
Pauline	Bradshaw	Administration	75	40	Brighton
Alice	Jackson	Production	20	46	Toulouse

DEPARTMENT

DeptName	Address	City
Administration	Bond Street	London
Production	Rue Victor Hugo	Toulouse
Distribution	Pond Road	Brighton
Planning	Bond Street	London
Research	Sunset Street	San José

City of work

Example: Simple SQL Query

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the salaries of employees named Brown"

→ Return statement

```
SELECT Salary AS Remuneration
FROM Employee
WHERE Surname = 'Brown'
```

// rename salary as remuneration
// select from employee table

refers to the column

Result:

result table

Remuneration
45
80

Example: * in the Target List

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find all the information relating to employees named Brown" :

```
SELECT *
FROM Employee
WHERE Surname = 'Brown'
```

// selects entire tuple/row

Result:

FirstName	Surname	Dept	Office	Salary	City
Mary	Brown	Administration	10	45	London
Charles	Brown	Planning	14	80	London

Example: Attribute Expressions

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the monthly salary of employees named White" :

arithmatic to get the monthly salary

```
SELECT Salary / 12 AS MonthlySalary
FROM Employee
WHERE Surname = 'White'
```

//rename salary to MonthlySalary

Result:

MonthlySalary
3.00

result table

Example: Simple (Equi-)Join Query

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the names of employees and their cities of work"

```
SELECT Employee.FirstName, Employee.Surname, Department.City
FROM Employee, Department
WHERE Employee.Dept = Department.DeptName
```

Result:

FirstName	Surname	City
Mary	Brown	London
Charles	White	Toulouse
Gus	Green	London
Jackson	Neri	Brighton
Charles	Brown	London
Laurence	Chen	London
Pauline	Bradshaw	London
Alice	Jackson	Toulouse

(alternative?)

Alternative (and more correct):

```
SELECT Employee.FirstName, Employee.Surname, Department.City
FROM Employee E JOIN Department D ON E.Dept = D.DeptName
```

Example: Table Aliases

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the names of employees and their cities of work" (using an alias):

```
SELECT FirstName, Surname, D.City
FROM Employee, Department D
WHERE Dept = DeptName
```

Result:

FirstName	Surname	City
Mary	Brown	London
Charles	White	Toulouse
Gus	Green	London
Jackson	Neri	Brighton
Charles	Brown	London
Laurence	Chen	London
Pauline	Bradshaw	London
Alice	Jackson	Toulouse

Example: Predicate Conjunction

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the first names and surnames of employees who work in office number 20 of the Administration department":

```
SELECT FirstName, Surname
FROM Employee
WHERE Office = '20' AND Dept = 'Administration'
```

Result:

FirstName	Surname
Gus	Green

Example: Predicate Disjunction

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the first names and surnames of employees who work in either the Administration or the Production department":

```
SELECT FirstName, Surname
FROM Employee
WHERE Dept = 'Administration' OR Dept = 'Production'
```

'OR' Conjunction

Result:

FirstName	Surname
Mary	Brown
Charles	White
Gus	Green
Pauline	Bradshaw
Alice	Jackson

Example: Complex Logical Expressions

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the first names of employees named Brown who work in the Administration department or the Production department":

→ dept either Admin or Production

SELECT FirstName

FROM Employee

WHERE Surname = 'Brown' **AND** (Dept = 'Administration' **OR** Dept = 'Production')

Result:

FirstName
Mary

Example: String Matching Operator LIKE

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find employees with surnames that have 'r' as the second letter and end in 'n'":

```
SELECT *
FROM Employee
WHERE Surname LIKE '_r%n'
```

Selects all employees

LIKE Operator

Result:

FirstName	Surname	Dept	Office	Salary	City
Mary	Brown	Administration	10	45	London
Gus	Green	Administration	20	40	Oxford
Charles	Brown	Planning	14	80	London

Example: Aggregate Queries: Operator **Count**

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the number of employees":

SELECT count(*) **FROM** Employee

"Find the number of different values on attribute Salary for **all** tuples in Employee":

SELECT count(**DISTINCT** Salary) **FROM** Employee

"Find the number of tuples in Employee having **non-null values** on the attribute Salary":

SELECT count(**ALL** Salary) **FROM** Employee

Example: Operators **Sum**, **Avg**, **Max** and **Min**

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the sum of all salaries for the Administration department":

```
SELECT sum(Salary) AS SumSalary
FROM Employee
WHERE Dept = 'Administration'
```

Result:

SumSalary
125

Example: Operators **Sum**, **Avg**, **Max** and **Min**

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the maximum and minimum salaries among all employees":

```
SELECT max(Salary) AS MaxSal, min(Salary) AS MinSal
FROM Employee
```

Result:

MaxSal	MinSal
80	36

Example: Aggregate Operators with Join

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the maximum salary among the employees who work in a department based in London":

```
SELECT max(Salary) AS MaxLondonSal
FROM Employee, Department
WHERE Dept = DeptName AND Department.City = 'London'
```

Result:

MaxLondonSal
80

MORE COMPLEX QUERIES

Example: GROUP BY

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find the sum of salaries of all the employees of each department":

```
SELECT Dept, sum(Salary) as TotSal
FROM Employee
GROUP BY Dept
```

Result:

Dept	TotSal
Administration	125
Distribution	45
Planning	153
Production	82

Example: GROUP BY Semantics

GROUP BY Processing:

- the query is executed without **GROUP BY** and without aggregate operators

  SELECT Dept, Salary as TotSal

  FROM Employee

- … then the query result is divided in subsets characterized by the same values for the **GROUP BY** attributes (in this case, Dept):
- the aggregate operator **sum** is applied separately to each group

Dept	Salary
Administration	45
Production	36
Administration	40
Distribution	45
Planning	80
Planning	73
Administration	40
Production	46

Dept	Salary
Administration	45
Administration	40
Administration	40
Distribution	45
Planning	80
Planning	73
Production	36
Production	46

Dept	TotSal
Administration	125
Distribution	45
Planning	153
Production	82

GROUP BY in practice

Used with aggregate function COUNT, MAX, MIN, SUM, AVG to group result-set by one or more column.

GROUP BY

- is useful for retrieving information about a group of data

  (If you only had one product of each type, it won't be that useful)
- is useful when you have many similar things

  (if you have a number of products of the same type, and you want to find some statistical information like the min, max, etc.)

SQL technical rules:

- The attribute(s) that you **GROUP BY** must appear in the **SELECT**
- **GROUP BY** must list all non-aggregate attributes used in **SELECT**
- Remember to **GROUP BY** the column you want information about and not the one you are applying the aggregate function on

GROUP BY in practice (cont.)

Incorrect query:

```
SELECT Office
FROM Employee
GROUP BY Dept
```

Incorrect query:

```
SELECT DeptName, D.City, count(*)
FROM Employee E JOIN Department D ON (E.Dept = D.DeptName)
GROUP BY DeptName
```

Correct query:

```
SELECT DeptName, D.City, count(*)
FROM Employee E JOIN Department D ON (E.Dept = D.DeptName)
GROUP BY DeptName, D.City
```

Example: HAVING

used because WHERE couldn't be used with aggregate function.

Employee(FirstName, Surname, Dept, Office, Salary, City)
Department(DeptName, Address, City)

"Find which departments spend more than 100 on salaries":

```
SELECT Dept
FROM Employee
GROUP BY Dept
HAVING sum(Salary) > 100
```

sorts by dept

checks for sum of salary > 100

Result:

Dept
Administration
Planning

HAVING in practice

- If a condition refers to an aggregate function, put that condition in the **HAVING** clause. Otherwise, use the **WHERE** clause.
- You can't use **HAVING** unless you also use **GROUP BY**.

"Find the departments where the average salary of employees working in office number 20 is higher than 25":

SELECT Dept
FROM Employee
WHERE office = ‘20’
GROUP BY Dept
HAVING avg(Salary) > 25

EXERCISE

Exercise

Professor(Id, Name, DeptId)
Course(CrsCode, DeptId, CrsName, Description)
Teaching(ProfId, CrsCode, Semester)

Note: Values for Semester are YYYY (F | S | W), e.g., ‘2018F', ‘2019W‘

Questions:

- “Find the names of all professors who taught in Fall 2018”
- “Find the names of all courses taught in Fall 2018, together with the names of professors who taught them”
- “Find the average number of courses taught by professors in Comp. Sc. (CS)”
- “Find the number of courses taught by each professor in Comp. Sc. (CS)”
- “Find the number of courses taught by each professor in Comp. Sc. (CS) in 2018”

OTHER CONCEPTS

NULL values in SQL

↳ no values

- Values allowed to be NULL
  - Explicitly stored in relations
  - Result of outer joins ↳ check this
- Possible meanings
  - Not present (homeless man's address)
  - Unknown (Julian Assange's address)
- Effect: "poison"
  - Arithmetic: unknown value takes over expression
  - Conditionals: ternary logic (TRUE, FALSE, UNKNOWN)
  - Grouping: "not present"

Effect of NULL in expressions

- Arithmetic: NaN (Not a Number)
  - NULL*0 → NULL
  - NULL – NULL → NULL
- Logic: TRUE, FALSE, NULL
  - NULL OR FALSE → NULL
  - NULL OR TRUE → TRUE
  - NULL AND TRUE → NULL
  - NULL AND FALSE → FALSE
  - NOT NULL → NULL

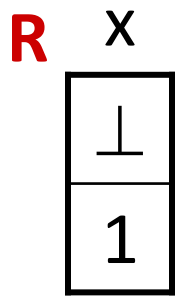
Ternary logic tricks:

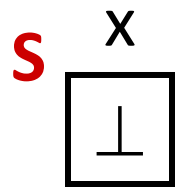
TRUE = 1
FALSE = 0
NULL = ½

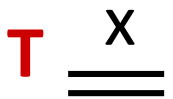
AND = min(…)
OR = max(…)
NOT = 1-x

Effects of NULL on grouping

- Short version: complicated
  - Usually, “not present”
- COUNT
  - COUNT(R.*) = 2 COUNT(R.x) = 1
  - COUNT(S.*) = 1 COUNT(S.x) = 0
  - COUNT(T.*) = 0 COUNT(T.x) = 0
- Other aggregations (e.g. MIN/MAX)
  - MIN(R.x) = 1 MAX(R.x) = 1
  - MIN(S.x) = NULL MAX(S.x) = NULL
  - MIN(T.x) = NULL MAX(T.x) = NULL







SET Queries: Union, Intersection, Difference

Combine result Combine common results Combine the uncommon results.

- Operations on pairs of subqueries
- Expressed by the following forms
  - (<subquery>) **UNION [ALL]** (<subquery>)
  - (<subquery>) **INTERSECT [ALL]** (<subquery>)
  - (<subquery>) **EXCEPT [ALL]** (<subquery>)
- All three operators are **set-based**
  - Adding '**ALL**' keyword forces **bag semantics** (duplicates allowed)
- Another solution to the join selectivity problem!

```
(SELECT R.x FROM R JOIN S ON R.x=S.x)
 UNION
(SELECT R.x FROM R JOIN T ON R.x=T.x)
```

Example: Union

➔ "Find all first names and surnames of employees"

SELECT FirstName **AS** Name **FROM** Employee

UNION

SELECT Surname **AS** Name **FROM** Employee

Duplicates are removed, unless the **ALL** option is used:

SELECT FirstName **AS** Name **FROM** Employee

UNION ALL

SELECT Surname **AS** Name **FROM** Employee

Example: Intersection

finding the common value

➔ "Find surnames of employees that are also first names"

SELECT FirstName **AS** Name **FROM** Employee

INTERSECT

SELECT Surname **AS** Name **FROM** Employee

equivalent to:

SELECT E1.FirstName **AS** Name

FROM Employee E1, Employee E2

WHERE E1.FirstName = E2.Surname

Example: Difference

➔ “Find the surnames of employees that are not first names”

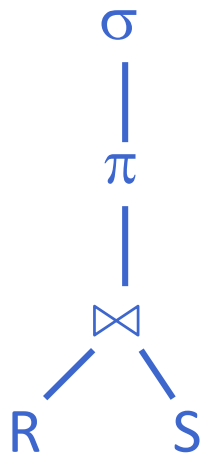
```
SELECT SurName AS Name FROM Employee
EXCEPT
SELECT FirstName AS Name FROM Employee
```

(Can also be represented with a nested query. See later)

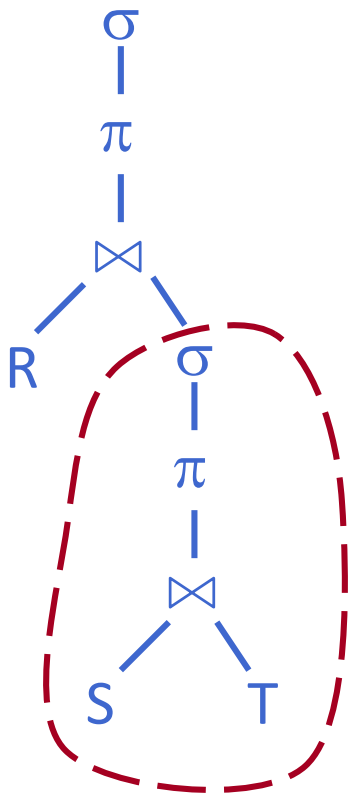
Nested queries

AKA. Subquery, Inner query, Nested query
Query within another query and embedded within the WHERE clause.
→ used to return data that will be used in main query as a condition.

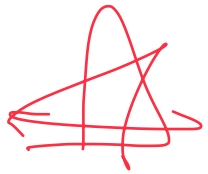
- Scary-looking syntax, simple concept
  - Treat one query's output as input to another query
  - Inner schema determined by inner SELECT clause
- Consider the expression tree



vs.



Nested queries – uses



- Explicit join ordering
  - `FROM (A join B)` is a (very simple) query to run first
- Input relation for a set operation
  - Union, intersect, difference
- Input relation for a larger query
  - Appears in FROM clause
  - Usually joined with other tables (or other nested queries)

  => `FROM A, (SELECT …) B WHERE …`

  => Explicit join ordering is a degenerate case

Nested queries – more uses

- Conditional relation expression
  - Dynamic list for [NOT] IN operator

  => `WHERE (E.id,S.name) IN (SELECT id,name FROM …)`
  - Special [NOT] EXISTS operator

  => `WHERE NOT EXISTS (SELECT * FROM …)`
- Scalar expression
  - Must return single tuple (usually containing a single attribute)

  => `0.13*(SELECT sum(value) FROM Sales WHERE taxable)`

  => `S.value > (SELECT average(S.value) FROM Sales S)`

List comparisons: ANY, ALL, [NOT] IN

- Compares a value against many others
  - List of literals
  - Result of nested query

Let op be any comparator (>, <=, !=, etc.)

- x op ANY (a, b, c)
  = x op a OR x op b OR x op c
- x op ALL (a, b, c)
  = x op a AND x op b AND x op c
- [NOT] IN
  - **x NOT IN (…)** equivalent to **x != ALL(…)**
  - **x IN (…)** equivalent to **x = ANY(…)**

ANY is ∃ (exist), ALL is ∀ (for each) (English usage often different!)

Example: Simple Nested Query

➔ "Find the names of employees who work in departments in London"

```
SELECT FirstName, Surname
FROM Employee
WHERE Dept = ANY(
                    SELECT DeptName
                    FROM Department
                    WHERE City = 'London')
```

equivalent to:

```
SELECT FirstName, Surname
FROM Employee, Department D
WHERE Dept = DeptName AND D.City = 'London'
```

Example: Another Nested Query

➔ "Find employees of the Planning department, having the same first name as a member of the Production department"

```
SELECT FirstName,Surname
FROM Employee
WHERE Dept = 'Plan' AND FirstName = ANY (
                                        SELECT FirstName
                                        FROM Employee
                                        WHERE Dept = 'Prod')
```

equivalent to:

```
SELECT E1.FirstName,E1.Surname
FROM Employee E1, Employee E2
WHERE E1.FirstName=E2.FirstName
                AND E2.Dept='Prod' AND E1.Dept='Plan'
```

Example: Negation with Nested Query

➔ “Find departments where there is no employee named Brown”

```
SELECT DeptName
FROM Department
WHERE DeptName <> ALL (
        SELECT Dept FROM Employee WHERE Surname = ‘Brown’)
```

equivalent to:

```
SELECT DeptName FROM Department
EXCEPT
SELECT Dept FROM Employee WHERE Surname = ‘Brown’
```

Operators IN and NOT IN

- Operator **IN** is a shorthand for **= ANY**

```
SELECT FirstName, Surname
FROM Employee
WHERE Dept IN (
        SELECT DeptName FROM Department WHERE City = 'London')
```

- Operator **NOT IN** is a shorthand for **<> ALL**

```
SELECT DeptName
FROM Department
WHERE DeptName NOT IN (
        SELECT Dept FROM Employee WHERE Surname = 'Brown')
```

max, min as Nested Queries

"Find the department of the employee earning the highest salary"

with max:

SELECT Dept **FROM** Employee

WHERE Salary **IN** (**SELECT** max(Salary) **FROM** Employee)

without max:

SELECT Dept **FROM** Employee

WHERE Salary **>= ALL** (**SELECT** Salary **FROM** Employee)

Operator: [NOT] EXISTS

- Checks whether a subquery returned results

"Find all persons who have the same first name and surname with someone else (synonymous folks) but different tax codes"

```
SELECT * FROM Person P1
WHERE EXISTS (
        SELECT * FROM Person P2
        WHERE P2.FirstName = P1.FirstName
                AND P2.Surname = P1.Surname
                AND P2.TaxCode <> P1.TaxCode)
```

Operator: [NOT] EXISTS (cont.)

"Find all persons who have no synonymous persons"

```
SELECT * FROM Person P1
WHERE NOT EXISTS (
        SELECT * FROM Person P2
        WHERE P2.FirstName = P1.FirstName
                AND P2.Surname = P1.Surname
                AND P2.TaxCode <> P1.TaxCode)
```

Tuple Constructors

- The comparison within a nested query may involve several attributes bundled into a tuple
- A tuple constructor is represented in terms of a pair of angle brackets
  - The previous query can also be expressed as:

```
SELECT * FROM Person P1
WHERE <FirstName,Surname> NOT IN (
        SELECT FirstName,Surname
        FROM Person P2
        WHERE P2.TaxCode <> P1.TaxCode)
```

Comments on Nested Queries

- Use of nesting
  (-) may produce less declarative queries
  (+) often results in improved readability
- Complex queries can become very difficult to understand
- The use of variables must respect scoping conventions:
  - a variable can be used only within the query where it is defined, OR
  - within a query that is recursively nested within the query where it is defined

What's next?

- The Data Definition Language (DDL)
  - Subset of SQL used to manage schema
  - CREATE, ALTER, RENAME, DROP
  - Data types
- Data Manipulation Language (DML)
  - Subset of SQL used to manipulate data
  - INSERT, UPDATE, DELETE