# Introduction to SQL
# (Structured Query Language)

EECS3421 - Introduction to Database Management Systems

# What is SQL?

- **Declarative**
  - Say “what to do” rather than “how to do it”
    - Avoid data-manipulation details needed by procedural languages
  - 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**
  - Decoupled from underlying data organization
    - Views (= precomputed queries) increase decoupling even further
    - Correctness always assured… performance not so much
  - SQL is standard and (nearly) identical among vendors
    - Differences often shallow, syntactical

*Fairly thin wrapper around relational algebra*

# What does SQL look like?

- Query syntax

$\delta \quad \pi \quad \rho \quad \times \bowtie \quad \sigma \quad \Gamma \quad \tau$

**SELECT** <desired attributes>
**FROM** <one or more tables>
**WHERE**<predicate holds for selected tuple>
**GROUP BY** <key columns, aggregations>
**HAVING** <predicate holds for selected group>
**ORDER BY** <columns to sort>

# 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 |

# What does SQL *really* look like?

ORDER BY

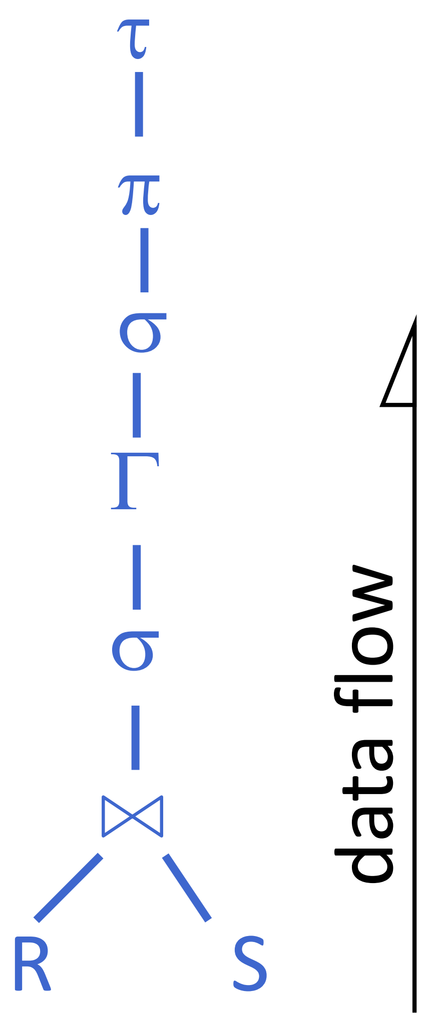
SELECT

HAVING

GROUP BY

WHERE

FROM




*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

- 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 …

# ‘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

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

# Gotcha: natural join in practice

- 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
  - $R \times S \times T = R \times S \times Ø = Ø$

  => 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

- 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

- Specifies **grouping key** of relational operator $\Gamma$
  - 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

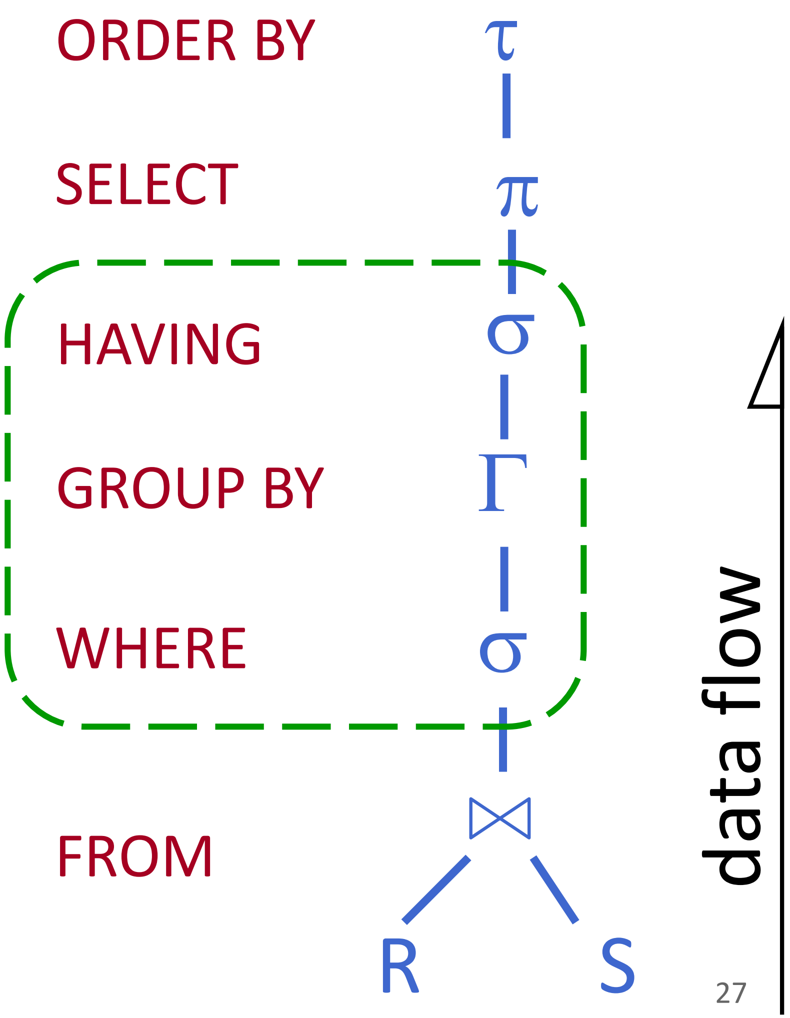
- Allows predicates on aggregate values
  - Groups which do not match the predicate are eliminated

  => **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

- 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 $\tau$
- 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

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"

**SELECT** Salary **AS** Remuneration
**FROM** Employee
**WHERE** Surname = ‘Brown’

Result:

| 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'

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" :

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

Result:

| MonthlySalary |
|---|
| 3.00 |

# 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’

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”:

**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’

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

**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** <u>Office</u>

**FROM** Employee

**GROUP BY** Dept

Incorrect query:

**SELECT** DeptName, <u>D.City</u>, 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

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
```

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(<u>Id</u>, Name, DeptId)
Course(<u>CrsCode</u>, DeptId, CrsName, Description)
Teaching(<u>ProfId</u>, <u>CrsCode</u>, 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”

# Answers

Professor(<u>Id</u>, Name, DeptId)
Course(<u>CrsCode</u>, DeptId, CrsName, Description)
Teaching(<u>ProfId</u>, <u>CrsCode</u>, Semester)

➔ "Find the names of all professors who taught in Fall 2018"

**SELECT** P.Name
**FROM** Professor P, Teaching T
**WHERE** P.Id=T.ProfId **AND** T.Semester='2018F'

➔ "Find the names of all courses taught in Fall 2018, together with the names of professors who taught them"

**SELECT** C.CrsName, P.Name
**FROM** Professor P, Teaching T, Course C
**WHERE** T.Semester = '2018F' **AND** P.Id = T.ProfId **AND** T.CrsCode = C.CrsCode

# Answers (cont.)

Professor(<u>Id</u>, Name, DeptId)

Course(<u>CrsCode</u>, DeptId, CrsName, Description)

Teaching(<u>ProfId</u>, <u>CrsCode</u>, Semester)

➔ "Find the average number of courses taught by professors in Comp. Sc. (CS)"

**SELECT** count(CrsCode)/count(DISTINCT ProfId) AS avgCrsTaughtinCS
**FROM** Teaching T, Course C
**WHERE** T.CrsCode=C.CrsCode **AND** C.DeptId = 'CS'

➔ "Find the number of courses taught by each professor in Comp. Sc. (CS)"

**SELECT** T.ProfId, count(*)
**FROM** Teaching T, Course C
**WHERE** T.CrsCode=C.CrsCode **AND** C.DeptId='CS'
**GROUP BY** ProfId

# Answers (cont.)

Professor(Id, Name, DeptId)

Course(CrsCode, DeptId, CrsName, Description)

Teaching(ProfId, CrsCode, Semester)

➔ "Find the number of courses taught by each professor in Comp. Sc. (CS) in 2018"

**SELECT** T.ProfId, count(*)

**FROM** Teaching T, Course C

**WHERE** T.CrsCode=C.CrsCode **AND** C.DeptId='CS' **AND** Semester **LIKE** ‘2018_'

**GROUP BY** ProfId

# OTHER CONCEPTS

# NULL values in SQL

- Values allowed to be NULL
  - Explicitly stored in relations
  - Result of outer joins
- 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

**R**

| x |
|---|
| ⊥ |
| 1 |

**S**

| x |
|---|
| ⊥ |

**T**

| x |
|---|

# SET Queries: Union, Intersection, Difference

- 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

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

```sql
SELECT FirstName AS Name FROM Employee
INTERSECT
SELECT Surname AS Name FROM Employee
```

equivalent to:

```sql
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

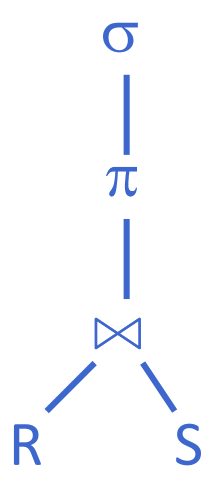
**EXCEPT**

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

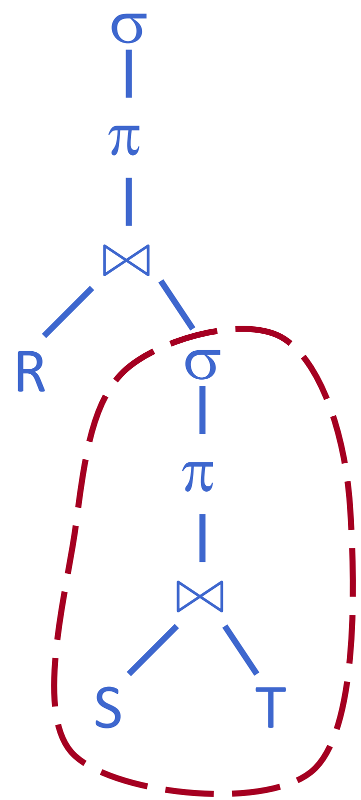
(Can also be represented with a nested query. See later)

# Nested queries

- 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

- Used to test for the existence of any record in a subquery
- Returns true if the subquery returns one or more records

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

```sql
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