



SQL: `SELECT` Statement select-project-join-order by

COSC 304 – Introduction to Database Systems





SQL Queries using SELECT

A query in SQL has the form:

SELECT (list of columns or expressions)

FROM (list of tables)

WHERE (filter *conditions*)

GROUP BY (columns)

ORDER BY (columns)

Notes:

- 1) Separate the list of columns/expressions and list of tables by commas.
- 2) The "*" is used to select all columns.
- 3) Only SELECT required. FROM, WHERE, GROUP BY, ORDER BY are optional.



SQL and Relational Algebra

The SELECT statement can be mapped directly to relational algebra.

```
SELECT  $A_1, A_2, \dots, A_n$   
FROM    $R_1, R_2, \dots, R_m$   
WHERE   $P$ 
```

is equivalent to:

$$\Pi_{A_1, A_2, \dots, A_n}(\sigma_P(R_1 \times R_2 \times \dots \times R_m))$$

Example Database - WorksOn

emp Table

<u>eno</u>	ename	bdate	title	salary	supereno	dno
E1	J. Doe	01-05-75	EE	30000	E2	null
E2	M. Smith	06-04-66	SA	50000	E5	D3
E3	A. Lee	07-05-66	ME	40000	E7	D2
E4	J. Miller	09-01-50	PR	20000	E6	D3
E5	B. Casey	12-25-71	SA	50000	E8	D3
E6	L. Chu	11-30-65	EE	30000	E7	D2
E7	R. Davis	09-08-77	ME	40000	E8	D1
E8	J. Jones	10-11-72	SA	50000	null	D1

proj Table

<u>pno</u>	pname	budget	dno
P1	Instruments	150000	D1
P2	DB Develop	135000	D2
P3	Budget	250000	D3
P4	Maintenance	310000	D2
P5	CAD/CAM	500000	D2

workson Table

<u>eno</u>	<u>pno</u>	resp	hours
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36

dept Table

<u>dno</u>	dname	mgreno
D1	Management	E8
D2	Consulting	E7
D3	Accounting	E5
D4	Development	null

SQL: Retrieving Only Some of the Columns

The **projection operation** creates a new table that has some of the columns of the input table. In SQL, provide the table in the FROM clause and the fields in the output in the SELECT.

Example: Return only the `eno` field from the `emp` table:

```
SELECT eno
FROM emp
```

emp Table

eno	ename	bdate	title	salary	supereno	dno
E1	J. Doe	01-05-75	EE	30000	E2	null
E2	M. Smith	06-04-66	SA	50000	E5	D3
E3	A. Lee	07-05-66	ME	40000	E7	D2
E4	J. Miller	09-01-50	PR	20000	E6	D3
E5	B. Casey	12-25-71	SA	50000	E8	D3
E6	L. Chu	11-30-65	EE	30000	E7	D2
E7	R. Davis	09-08-77	ME	40000	E8	D1
E8	J. Jones	10-11-72	SA	50000	null	D1



Result

eno
E1
E2
E3
E4
E5
E6
E7
E8

SQL Projection Examples

emp Table

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

SELECT eno,ename
FROM emp

<u>eno</u>	ename
E1	J. Doe
E2	M. Smith
E3	A. Lee
E4	J. Miller
E5	B. Casey
E6	L. Chu
E7	R. Davis
E8	J. Jones

SELECT title
FROM emp

title
EE
SA
ME
PR
SA
EE
ME
SA

Notes: 1) Duplicates are not removed during SQL projection.
2) **SELECT *** will return all columns.

Projection Question

Question: Given this table and the query:

```
SELECT eno, ename, salary
FROM   emp
```

How many columns are returned?

- A) 0
- B) 1
- C) 2
- D) 3
- E) 4

emp Table

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

Projection Question #2

Question: Given this table and the query:

```
SELECT salary
FROM emp
```

How many rows are returned?

- A) 0
- B) 2
- C) 4
- D) 8

emp Table

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

Duplicates in SQL

One major difference between SQL and relational algebra is that relations in SQL are **bags** instead of sets.

- It is possible to have two or more identical rows in a relation.

Consider the query: Return all titles of employees.

```
SELECT title
FROM emp
```

emp Table

eno	ename	bdate	title	salary	supereno	dno
E1	J. Doe	01-05-75	EE	30000	E2	null
E2	M. Smith	06-04-66	SA	50000	E5	D3
E3	A. Lee	07-05-66	ME	40000	E7	D2
E4	J. Miller	09-01-50	PR	20000	E6	D3
E5	B. Casey	12-25-71	SA	50000	E8	D3
E6	L. Chu	11-30-65	EE	30000	E7	D2
E7	R. Davis	09-08-77	ME	40000	E8	D1
E8	J. Jones	10-11-72	SA	50000	null	D1



Result

title
EE
SA
ME
PR
SA
EE
ME
SA

Duplicates in SQL - DISTINCT clause

To remove duplicates, use **DISTINCT** clause in the SQL statement:

```
SELECT DISTINCT title
FROM emp
```

Result

title
EE
SA
ME
PR

DISTINCT Question

Question: Given this table and the query:

```
SELECT DISTINCT a, b
FROM R
```

How many rows are returned?

A) 1

B) 3

C) 4

D) 6

R Table

a	b	c
1	1	A
1	2	B
1	1	A
3	1	C
2	2	A
2	2	B

Try it: SQL `SELECT` and Projection

Question: Using the `proj` table, write these three queries:

- 1) Show all rows and all columns.
- 2) Show all rows but only the `pno` column.
- 3) Show all rows but only the `pno` and `budget` columns.
- 4) Show unique `budget` values.

Retrieving Only Some of the Rows

The **selection operation** creates a new table with some of the rows of the input table. A condition specifies which rows are in the new table. The condition is similar to an `if` statement.

Example: Return the projects in department 'D2':

```
SELECT pno, pname, budget, dno
FROM   proj
WHERE  dno = 'D2'
```

proj Table

<u>pno</u>	pname	budget	dno
P1	Instruments	150000	D1
P2	DB Develop	135000	D2
P3	Budget	250000	D3
P4	Maintenance	310000	D2
P5	CAD/CAM	500000	D2

Result

pno	pname	budget	dno
P2	DB Develop	135000	D2
P4	Maintenance	310000	D2
P5	CAD/CAM	500000	D2

Algorithm: Scan each tuple and check if matches condition in WHERE clause.

Selection Conditions

The condition in a selection statement specifies which rows are included. It has the general form of an if statement.

The condition may consist of attributes, constants, comparison operators ($<$, $>$, $=$, \neq , \leq , \geq), and logical operators (AND, OR, NOT).

SQL Selection Examples

emp Table

eno	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

```

SELECT *
FROM emp
WHERE title = 'EE'
  
```

eno	ename	title	salary
E1	J. Doe	EE	30000
E6	L. Chu	EE	30000

```

SELECT eno, ename, title, salary
FROM emp
WHERE salary > 35000 OR
        title = 'PR'
  
```

eno	ename	title	salary
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

Selection Question

Question: Given this table and the query:

```
SELECT *
FROM emp
WHERE title='SA'
```

How many rows are returned?

A) 0

B) 1

C) 2

D) 3

emp Relation

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

Selection Question #2

Question: Given this table and the query:

```
SELECT *
FROM emp
WHERE salary > 50000 or title='PR'
```

emp Table

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

How many rows are returned?

A) 0

B) 1

C) 2

D) 3

Try it: SQL **SELECT** and Filtering Rows

Question: Write these queries:

- 1) Return all projects with `budget > $250000`.
- 2) Show the `pno` and `pname` for projects in `dno = 'D1'`.
- 3) Show `pno` and `dno` for projects in `dno='D1' or dno='D2'`.
- 4) Return the employee numbers who make less than \$30000.
- 5) Return list of `workson` responsibilities (`resp`) with no duplicates.
- 6) Return the employee (names) born after July 1, 1970 that have a `salary > 35000` and have a title of `'SA'` or `'PR'`.

Joins for Combining Tables

A **join** combines two tables by matching columns in each table.

workson Table

eno	pno	resp	hours
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36

proj Table

pno	pname	budget
P1	Instruments	150000
P2	DB Develop	135000
P3	CAD/CAM	250000
P4	Maintenance	310000
P5	CAD/CAM	500000

```

SELECT *
FROM workson JOIN proj
ON workson.pno = proj.pno
    
```

Equijoin

eno	pno	resp	hours	proj.pno	pname	budget
E1	P1	Manager	12	P1	Instruments	150000
E2	P1	Analyst	24	P1	Instruments	150000
E2	P2	Analyst	6	P2	DB Develop	135000
E3	P3	Consultant	10	P3	DB Develop	135000
E3	P4	Engineer	48	P4	Maintenance	310000
E4	P2	Programmer	18	P2	DB Develop	135000
E5	P2	Manager	24	P2	DB Develop	135000
E6	P4	Manager	48	P4	Maintenance	310000
E7	P3	Engineer	36	P3	CAD/CAM	250000

Join Details and Examples

Listing multiple tables in the FROM clause separated by commas creates a cross product of tables. Must specify JOIN and ~~ON~~ or provide ~~join~~ condition in WHERE clause.

Goal: For each employee, return their name and department name.

Wrong! Cross Product

```
SELECT  ename, dname
FROM    emp, dept
```

Correct! Join in WHERE

```
SELECT  ename, dname
FROM    emp, dept
WHERE    emp.dno = dept.dno
```

Correct! JOIN-ON Clause

```
SELECT  ename, dname
FROM    emp JOIN dept
          ON emp.dno = dept.dno
```

Correct! Order does not matter.

```
SELECT  ename, dname
FROM    dept JOIN emp
          ON emp.dno = dept.dno
```

Join Query with Selection Example

You can use join, selection, and projection in the same query.

- Recall: Projection returns columns listed in `SELECT`, selection filters out rows using condition in `WHERE`, and join combines tables in `FROM` using a condition.

Example: Return the employee names who are assigned to the 'Management' department.

Projection: only name field in result (indicated by an orange arrow pointing to `ename`)

```

SELECT ename
FROM   emp JOIN dept
      ON emp.dno = dept.dno
WHERE  dname = 'Management'
  
```

Selection: filter rows (indicated by a purple arrow pointing to `dname = 'Management'`)

tables in query joined together (indicated by a yellow arrow pointing to `emp JOIN dept`)

Result

ename
R. Davis
J. Jones

Three Table Join Query Example

Return all projects who have an employee working on them whose title is 'EE':

```
SELECT pname
FROM    emp JOIN workson ON emp.eno = workson.eno
          JOIN proj ON workson.pno = proj.pno
WHERE    emp.title = 'EE'
```

Or:

```
SELECT pname
FROM    emp, proj, workson
WHERE    emp.title = 'EE' and workson.eno = emp.eno
          and workson.pno = proj.pno
```

Note: Parentheses () can be used to specify order of joins when using JOIN-ON.

SQL Query Question

Question: What query would return the name and salary of employees working on project 'P3':

A) `SELECT ename, salary
FROM emp, workson
WHERE emp.eno = workson.eno and pno = 'P3'`

B) `SELECT ename, salary
FROM emp, workson, proj
WHERE emp.eno = workson.eno and pno = "P3"`

Duplicate attribute name Variable name

Ordering Result Data

The query result returned is not ordered on any column by default. We can order the data using the **ORDER BY** clause:

```
SELECT    ename, salary, bdate
FROM      emp
WHERE     salary > 30000
ORDER BY salary DESC, ename ASC;
```

- 'ASC' sorts the data in ascending order, and 'DESC' sorts it in descending order. The default is 'ASC'.
- The order of sorted attributes is significant. The first column specified is sorted on first, then the second column is used to break any ties, etc.

LIMIT and OFFSET

If you only want the first N rows, use a **LIMIT** clause:

```
SELECT      ename, salary FROM emp
ORDER BY salary DESC LIMIT 5
```

To start from a row besides the first, use **OFFSET**:

```
SELECT      eno, salary FROM emp
ORDER BY eno DESC
LIMIT 3 OFFSET 2
```

- **LIMIT** improves performance by reducing amount of data processed and sent by the database system.
- **OFFSET 0** is first row, so **OFFSET 2** would return the 3rd row.
- LIMIT/OFFSET syntax support differs between databases.

Try it: SQL `SELECT` with Joins and Ordering

Question: Write these queries:

- 1) Return all projects with `budget < $500000` sorted by `budget` descending.
- 2) List only the top 5 employees by `salary` descending. Show only their name and `salary`.
- 3) List each project `pno`, `dno`, `pname`, and `dname` ordered by `dno` ascending then `pno` ascending. Only show projects if department name `> 'D'`. Note: This query will require a join.
- 4) Return the list of project names for the department with name `'Consulting'`.
- 5) Return `workson` records (`eno`, `pno`, `resp`, `hours`) where project budget is `> $50000` and hours worked is `< 20`.
- 6) **Challenge:** Return a list of all department names, the names of the projects of that department, and the name of the manager of each department.

Calculated Fields

Expressions are allowed in `SELECT` clause to perform calculations.

- When an expression is used to define an attribute, the DBMS gives the attribute a unique name such as `col1`, `col2`, etc.

Example: Return how much employee 'A. Lee' will get paid for his work on each project.

```
SELECT  ename, pname, salary/52/5/8*hours
FROM    emp JOIN workson ON emp.eno=workson.eno
        JOIN proj ON workson.pno=proj.pno
WHERE   ename='A. Lee'
```

Result

ename	pname	col3
A. Lee	Budget	192.31
A. Lee	Maintenance	923.08

Renaming and Aliasing

Often it is useful to rename an attribute in the final result (especially when using calculated fields). Renaming is accomplished using the keyword **AS**:

```
SELECT  ename, pname, salary/52/5/8*hours AS pay
FROM    emp JOIN workson ON emp.eno = workson.eno
          JOIN proj ON proj.pno = workson.pno
WHERE    ename = 'A. Lee'
```

Result

ename	pname	pay
A. Lee	Budget	192.31
A. Lee	Maintenance	923.08

Note: AS keyword is optional.

Renaming and Aliasing Tables

Renaming is also used when two or more copies of the same table are in a query. Using *aliases* allows you to uniquely identify what table you are talking about.

\rho

Example: Return the employees and their managers where the managers make less than the employee.

```
SELECT E.ename, M.ename
FROM   emp as E JOIN emp as M ON E.supereno = M.eno
WHERE  E.salary > M.salary
```


Advanced Conditions - BETWEEN

Used when the condition in the `WHERE` clause will request tuples where one attribute value must be in a *range* of values.

Example: Return the employees who make at least \$20,000 and less than or equal to \$45,000.

```
SELECT  ename
FROM    emp
WHERE   salary >= 20000 and salary <= 45000
```

We can use the keyword **BETWEEN** instead:

```
SELECT  ename
FROM    emp
WHERE   salary BETWEEN 20000 and 45000
```

Advanced Conditions - LIKE

For strings, the **LIKE** operator is used to search for partial matches.

- Partial string matches are specified by using either "%" that replaces zero or more characters or underscore "_" that replaces a single character.

Example: Return all employee names that start with 'A'.

```
SELECT  ename
FROM    emp
WHERE   ename LIKE 'A%'
```

Example: Return all employee names who have a first name that starts with 'J' and whose last name is 3 characters long.

```
SELECT  ename
FROM    emp
WHERE   ename LIKE 'J. _ _ _'
```

Performance Concerns of LIKE

Warning: Do not use the LIKE operator if you do not have to.

It is often an inefficient operation as the DBMS may not be able to optimize lookup using LIKE as it can for equal (=) comparisons. The result is the DBMS often has to examine ALL TUPLES in the relation.

In almost all cases, adding indexes will **not** increase the performance of LIKE queries because the indexes cannot be used.

- Most indexes are implemented using B-trees that allow for fast equality searching and efficient range searches.

Advanced Conditions - IN

To specify that an attribute value should be in a given set of values, the **IN** keyword is used.

- Example: Return employees who are in one of the departments {'D1', 'D2', 'D3'}.

```
SELECT  ename
FROM    emp
WHERE   dno IN ( 'D1' , 'D2' , 'D3' )
```

Note that this is equivalent to using OR:

```
SELECT  ename
FROM    emp
WHERE   dno = 'D1' OR dno = 'D2' OR dno = 'D3'
```

We will see more uses of IN and NOT IN with nested subqueries.

Advanced Conditions - NULL

Remember NULL indicates that an attribute does not have a value. To determine if an attribute is NULL, we use the clause **IS NULL**.

- Note that you should not test NULL values using = and <>.

Example: Return all employees who are not in a department.

```
SELECT  ename
FROM    emp
WHERE   dno IS NULL
```

Example: Return all departments that have a manager.

```
SELECT  dname
FROM    dept
WHERE   mgreno IS NOT NULL
```

Set Operations

Union, intersection, and difference combine results of two queries.

- UNION, INTERSECT, EXCEPT, UNION ALL (returns all rows)
- **Union-compatible**: same # of attributes and compatible data types. Do not need to have the same name.

Example: Return the employees who are either directly supervised by 'R. Davis' or directly supervised by 'M. Smith'.

```
(SELECT E.ename
FROM   emp as E JOIN emp as M ON E.supereno = M.eno
WHERE  M.ename='R. Davis')
UNION
(SELECT E.ename
FROM   emp as E JOIN emp as M ON E.supereno = M.eno
WHERE  M.ename='M. Smith')
```

Set Operations Examples

emp Table

eno	ename	title	salary
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

(SELECT eno FROM emp)

UNION

(SELECT eno FROM workson)

eno
E1
E2
E3
E4
E5
E6
E7
E8

(SELECT eno FROM emp)

INTERSECT

(SELECT eno FROM workson)

eno
E1
E2
E3
E5
E6
E7

workson Table

eno	pno	resp	hours
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36

(SELECT eno FROM emp)

EXCEPT

(SELECT eno FROM workson)

eno
E4
E8

(SELECT eno FROM workson)

EXCEPT

(SELECT eno FROM emp)

Question: What is the meaning of this query?

Set Operations Union-compatible Question

Question: Two tables have the same number of fields in the same order with the same types, but the names of some fields are different.

True or false: The two tables are union-compatible.

A) true

B) false

SELECT INTO

The result of a select statement can be stored in a temporary table using the **INTO** keyword.

```
SELECT E.ename  
INTO   davisMgr  
FROM   emp as E JOIN emp as M ON E.supereno = M.eno  
WHERE  M.ename = 'R. Davis'
```

SQL Querying with NULL and LIKE

Question: What query would return the department names that do not have a manager or contain 'ent'.

A) `SELECT dname
FROM dept
WHERE mgreno = NULL OR dname LIKE '_ent'`

B) `SELECT dname
FROM dept
WHERE mgreno IS NULL OR dname LIKE '%ent%'`

Try it: SQL **SELECT** Expressions, **LIKE**, **IS NULL**



Question: Write these queries:

- 1) Calculate the monthly salary for each employee.
- 2) List all employee names who do not have a supervisor.
- 3) List all employee names where the employee's name contains an 'S' and workson responsibility that ends in 'ER'.
- 4) Return the list of employees (names) who make less than their managers and how much less they make.
- 5) Return only the top 3 project budgets in descending order.

Try it: SQL SELECT Set Operations, ORDER BY

Question: Write these queries:

- 1) Return the list of employees sorted by salary (desc) and then title (asc).
- 2) Return the employees (names) who either manage a department or manage another employee.
- 3) Return the employees (names) who manage an employee but do not manage a department.
- 4) Give a list of all employees who work on a project for the 'Management' department ordered by project number (asc).
- 5) **Challenge:** Return the projects (names) that have their department manager working on them.

Conclusion

The **SELECT** statement is used to query data and combines the operations of selection, projection, and join.

SELECT features covered:

- **SELECT** clause to provide column list and calculate expressions
- **DISTINCT** clause to eliminate duplicates
- **FROM** clause to list tables
- **JOIN ON** syntax to join tables on a join condition
- **UNION, EXCEPT, INTERSECT** set operations
- **IS NULL** for checking if column value is null
- **ORDER BY** clause for sorting output
- **LIMIT/OFFSET** for only reducing a part of the result set

Objectives

Translate English questions into SQL queries that may require:

- `SELECT-FROM-WHERE` syntax for selection, projection, and join
- renaming and aliasing including queries with multiple copies of the same relation
- `ORDER BY`
- `LIMIT/OFFSET`
- `DISTINCT` to eliminate duplicates
- `UNION, EXCEPT, INTERSECT` set operations
- `IS NULL` or `IS NOT NULL`
- `LIKE` string pattern matching

Read SQL queries to determine their output and English meaning



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