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Chapter 3: Introduction to SQL

Database System Concepts, 6th Ed.

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Chapter 3: Introduction to SQL

- Overview of the SQL Query Language
- Data Definition
- Basic Query Structure
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries
- Modification of the Database



History

- IBM Sequel language developed as part of System R project at the IBM San Jose Research Laboratory
- Renamed Structured Query Language (SQL)
- Standard SQL:
 - SQL-86, SQL-89, SQL-92
 - SQL:1999, SQL:2003, SQL:2008
- Commercial systems offer most, if not all, SQL-92 features, plus varying feature sets from later standards and special proprietary features
 - Not all examples here may work on your particular system.
 - Some interfaces require each statement to end with a semicolon
 - In some interfaces, SQL is not case-sensitive



SQL

■ Parts

- DDL
- DML
- DCL



Data Definition Language

The SQL **Data Definition language (DDL)** allows the specification of information about relations, including:

- The schema for each relation
- The domain of values associated with each attribute
- Integrity constraints
- And as we will see later, also other information such as
 - The set of indices to be maintained for each relations
 - Security and authorization information for relation by access rights
 - The physical storage structure of each relation on disk
- Example: CREATE, ALTER, DROP, RENAME, and TRUNCATE



Data Manipulation Language

The SQL **Data Manipulation language (DML)** provides the ability

- To query information from the database
 - To insert tuples into
 - To delete tuples from
 - To modify tuples in the database
-
- Example: SELECT, INSERT, UPDATE, and DELETE.



Data Control Language

The SQL **Data Control language (DCL)** used for providing security to database objects.

- Example: GRANT and REVOKE.



Domain Types in SQL

- **char(*n*)**. Fixed length character string, with user-specified length *n*
- **varchar(*n*)**. Variable length character strings, with user-specified maximum length *n*
- **int**. Integer (a finite subset of the integers that is machine-dependent)
- **smallint**. Small integer (a machine-dependent subset of the integer domain type)
- **numeric(*p,d*)**. Fixed point number, with user-specified precision of *p* digits, with *n* digits to the right of decimal point
- **real, double precision**. Floating point and double-precision floating point numbers, with machine-dependent precision
- **float(*n*)**. Floating point number, with user-specified precision of at least *n* digits
- Date, Boolean, etc. more are covered in Chapter 4



Special Value - NULL

- Each type may include a special value called the **null value**
- A **null value** indicates an absent value that may exist but be unknown or that may not exist at all.
- In certain cases, we may wish to prohibit null values from being entered for integrity constraints....



Char vs Varchar

- **char data type** stores fixed length strings.
 - For example, an attribute *A* of type $\text{char}(10)$. If we store a string “Avi” in this attribute, 7 spaces are appended to the string to make it 10 characters long.
- **varchar data type**
 - if store “Avi” in attribute *B*, no spaces would be added.
- When comparing two values of type **char**, if they are of different lengths extra spaces are automatically added to the shorter one to make them the same size, before comparison.
- When comparing a **char type with a varchar type**, one may expect extra spaces to be added to the **varchar type to make the lengths equal, before comparison**;
 - may or may not to be done, depends on the database system.



Create Table Construct

- An SQL relation is defined using the **create table** command:

```
create table r (A1 D1, A2 D2, ..., An Dn,  
    (integrity-constraint1),  
    ...,  
    (integrity-constraintk));
```

- r is the name of the relation
- each A_i is an attribute name in the schema of relation r
- D_i is the data type of values in the domain of attribute A_i



Create Table and Insert

- **Example:** Create table department having department name, building information and budget.
- **create table *department***

```
(dept name varchar (20),  
building varchar (15),  
budget numeric (12,2),  
);
```



Create Table

- Example: Create Table *instructor* having ID, Name, Salary and department to which he belongs

- **create table** *instructor* (

<i>ID</i>	char(5),
<i>name</i>	varchar(20),
<i>dept_name</i>	varchar(20),
<i>salary</i>	numeric(8,2));

- **insert into** *instructor* **values** ('10211', 'Smith', 'Biology', 66000);
- **insert into** *instructor* **values** ('10211', null, 'Biology', 66000);
- Check: **insert into** *instructor* **values** ("", null, 'XYZ', 0);

DML



Integrity Constraints in Create Table

- **not null**
- **primary key (A_1, \dots, A_n)**
- **foreign key (A_m, \dots, A_n) references r**



Integrity Constraints in Create Table

■ not null

- The **not null constraint on an attribute specifies that the null value is not allowed for that attribute**

- Excludes the null value from the domain of that attribute
- For example, the **not null constraint on the *name* attribute of the *instructor* relation ensures that** the name of an instructor cannot be null.



Integrity Constraints in Create Table

- **primary key** (A_1, \dots, A_n)

- ***The primary-key specification says that attributes A_1, \dots, A_n form the primary key for the relation***
- ***The primary key attributes are required to be **non null** and **unique*****
 - *No tuple can have a null value for a primary-key attribute, and*
 - ***No two tuples in the relation can be equal on all the primary-key attributes***
- Although the primary-key specification is optional, it is generally a good idea to specify a primary key for each relation
- **primary key** declaration on an attribute automatically ensures **not null**



Create Table and Insert

- **Example:** Create table department having department name, building information and budget.
- **create table *department***

```
(dept_name varchar (20),  
building varchar (15),  
budget numeric (12,2),  
Primary key (dept_name);
```



Integrity Constraints in Create Table

- **foreign key (A_m, \dots, A_n) references r**
 - *The foreign key specification says* that the values of attributes (A_m, \dots, A_n) for any tuple in the relation must correspond to values of the primary key attributes of some tuple in relation s
 - The definition of the *course table* has a declaration “**foreign key (dept name) references department**”
 - *This foreign-key declaration specifies that* for each course tuple, the department name specified in the tuple must exist in the primary key attribute (*dept name*) of the *department relation*.
 - *Without* this constraint, it is possible for a course to specify a nonexistent department name.
 - Other foreign key constraints on tables *section*, *instructor* and *teaches*.



Integrity Constraints in Create Table

- **not null**
- **primary key** (A_1, \dots, A_n)
- **foreign key** (A_m, \dots, A_n) **references** r

Example: Declare *ID* as the primary key for *instructor*, *name* requires value and *dept_name* should belong to *department* table

```
create table instructor (
    ID          char(5),
    name        varchar(20) not null,
    dept_name   varchar(20),
    salary      numeric(8,2),
    primary key (ID),
    foreign key (dept_name) references department)
```

primary key declaration on an attribute automatically ensures **not null**



Schema of University

1. **department**(*dept name, building, budget*)
2. **course**(*course id, title, dept name, credits*)
3. **student**(*ID, name, dept name, tot cred*)
4. **classroom**(*building, room number, capacity*)
5. **instructor**(*ID, name, dept name, salary*)
6. **section**(*course id, sec id, semester, year, building, room number, time slot id*)
7. **teaches**(*ID, course id, sec id, semester, year*)
8. **takes**(*ID, course id, sec id, semester, year, grade*)
9. **advisor**(*s ID, i ID*)
10. **time slot**(*time slot id, day, start time, end time*)
11. **prereq**(*course id, prereq id*)



And a Few More Relation Definitions

- **create table student (**
 ID **varchar(5),**
 name **varchar(20) not null,**
 dept_name **varchar(20),**
 tot_cred **numeric(3,0),**
 primary key (*ID***),**
 foreign key (*dept_name***) references department);**
- **create table takes (**
 ID **varchar(5),**
 course_id **varchar(8),**
 sec_id **varchar(8),**
 semester **varchar(6),**
 year **numeric(4,0),**
 grade **varchar(2),**
 primary key (*ID, course_id, sec_id, semester, year***),**
 foreign key (*ID***) references student,**
 foreign key (*course_id, sec_id, semester, year***) references section);**
- Note: *sec_id* can be dropped from primary key above, to ensure a student cannot be registered for two sections of the same course in the same semester



And more still

- **create table course (**
course_id **varchar(8) primary key,**
title **varchar(50),**
dept_name **varchar(20),**
credits **numeric(2,0),**
foreign key (dept_name) references department);
 - Primary key declaration can be combined with attribute declaration as shown above



Alter Table Construct

■ alter table

- To modify the structure of the table
- **alter table r add $A D$**
 - ▶ where A is the name of the attribute to be added to relation r and D is the domain of A
 - ▶ **All tuples in the relation are assigned *null* as the value for the new attribute.**
- **alter table r drop A**
 - ▶ where A is the name of an attribute of relation r
 - ▶ Dropping of attributes **not supported by many databases**



Drop Table Construct

■ **drop table student**

- Deletes the table and its structure
- If dropped the table, cannot get it back and all the references to the table will not be valid



Truncate Table

- Removes all rows from the table, but the table structure and its columns, constraints, indexes and so on remain
- To remove the table definition with its data, one can use drop table
 - Truncate table <tablename>;
- Restrictions
 - Cannot use truncate on table that is referenced by a foreign key constraint



Rename Table

- Rename Table OLD_NAME to NEW_NAME
- E.g.
 - Rename Table Employees to New_Employees



DML

- Provides the ability to query information
 - Select
- Insert, delete and update tuples
 - Insert, Delete, Update



The Select Clause (Cont.)

- A typical SQL query has the form:

```
select A1, A2, ..., An  
from r1, r2, ..., rm  
where P
```

- A_i represents an attribute
 - R_i represents a relation
 - P is a predicate.
- **The result of an SQL query is a relation**



The Select Clause

- The **select** clause lists the attributes desired in the result of a query
 - Corresponds to the projection operation of the relational algebra
- Example: Find the names of all instructors:
 - ▶ **select name from instructor**
- NOTE: SQL names are case insensitive (i.e., you may use upper- or lower-case letters.)
 - E.g. $Name \equiv NAME \equiv name$
 - Some people use upper case wherever we use bold font.



The Select Clause (Cont.)

- SQL allows duplicates in relations as well as in query results
- To force the elimination of duplicates, insert the keyword **distinct** after select.
- Find the names of all departments with instructor, and remove duplicates
 - **select distinct dept_name from instructor**



The select Clause (Cont.)

- An asterisk in the select clause denotes “all attributes”

```
select *
from instructor
```

- The **select** clause can contain
 - Arithmetic expressions involving the operation, +, −, *, and /, and operating on constants or attributes of tuples
 - Character Functions (uppercase...), Numeric functions (round...), Truncating numeric data, Concatenating character data, etc.
- The query:

```
select ID, name, salary/12 from instructor;
```

would return a relation that is the same as the *instructor* relation, except that the value of the attribute *salary* is divided by 12.



The where Clause

- The **where** clause specifies conditions that the result must satisfy
 - Corresponds to the **selection predicate of the relational algebra**
- To find all instructors in Comp. Sci. dept with salary > 80000

```
select name from instructor  
where dept_name = 'Comp. Sci.' and salary > 80000
```
- Comparison results can be combined using the logical connectives **and, or, and not**
- Comparisons can be applied to results of arithmetic expressions



The Select Clause (Cont.)

- Display single/multiple/all column(s)
- Display single/multiple/all column(s) with new headings
 - Select id Emp_ID, name Emp_FirstName from instructor;
 - Select id “Emp ID”, name “Emp FirstName” from instructor;



The Select Clause (Cont.)

- Display data that satisfies condition
 - Select id Emp_ID from instructor where dept_id='12001' and name = 'Srinivasan';
 - Select id Emp_ID from instructor where dept_id in ('12001', '12002', '10001');
 - Select id name from instructor where name like 'Sri%';
 - Select id name from instructor where name like '%ni%';
 - Select id name from instructor where REGEXP_LIKE (name, '([AEIOU])\1', 'i'); // i for case insensitive
 - ▶ REGEXP_REPLACE to display data in different format
 - ▶ REGEXP_SUBSTR to extract the substring from the data
 - ▶ REGEXP_COUNT to count the specific character within the data
 - ▶ REGEXP_INSTR to report the position of first occurrence of character



The from Clause

- Display data from more than one table
- The **from** clause lists the relations involved in the query
 - Corresponds to the Cartesian product operation of the relational algebra.
- Find the Cartesian product *instructor X teaches*

```
select * from instructor, teaches;
```

 - **Generates every possible instructor – teaches pair, with all attributes from both relations**
- Cartesian product
 - Not very useful directly
 - But useful combined with where-clause condition (selection operation in relational algebra)



Cartesian Product: *instructor* X *teaches*

instructor

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
...

teaches

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	CS-101	1	Fall	2009
10101	CS-315	1	Spring	2010
10101	CS-347	1	Fall	2009
12121	FIN-201	1	Spring	2010
15151	MU-199	1	Spring	2010
22222	PHY-101	1	Fall	2009

select * from *instructor*, *teaches*

<i>inst.ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>teaches.ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2009
...
...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2009
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2010
12121	Wu	Finance	90000	10101	CS-347	1	Fall	2009
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2010
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2010
12121	Wu	Finance	90000	22222	PHY-101	1	Fall	2009
...
...



The Select Clause (Cont.)

■ *Other options*

- *Group by group_by_expression*
 - ▶ *Using the Aggregate function (count,...)*
- *Having search_condition*
- *Order by ASC|DESC*
- *Union, except, intersect operator can be used between queries to combine or compare their results into one result set*



Insert into Table

- To insert the values without the column names
 - **insert into *instructor* values ('10211', 'Smith', 'Biology', 66000);**
- To insert the values with the corresponding column names
 - **insert into *instructor* (*Id*, *name*, *dept_name*, *Salary*) values ('10211', 'Smith', 'Biology', 66000);**
- To insert values from other table
 - All the columns
 - ▶ **insert into *instructor* select * from *old_instructor*;**
 - Specific column
 - ▶ **insert into *instructor* (*id*, *name*) select *id*, *name* from *old_instructor*;**
 - Specific rows
 - ▶ **insert into *instructor* select * from *old_instructor* where *id* = '10211';**



Delete From Table

- **delete from <tablename> [where condition]**
 - **Retaining the table structure and**
 - ▶ Deletes all the rows if written without where condition
 - ▶ Deletes only the rows satisfying the condition
- Check: delete * from <tablename>;



Update

- Update single or multiple columns as per requirement
 - **Update** instructor **set** salary = 20000
 - ▶ Single column, for all the Rows
 - **Update** instructor **set** name = ‘Sudarshan’ **where** name = ‘Srinivasan’
 - ▶ Only for the specific Row
 - **Update** instructor **set** name = ‘Sudarshan’, salary=20000 **where** name = ‘Srinivasan’
 - ▶ Multiple columns for the specific row



■ Relational Algebra



Relax

1. The result of an SQL query is a _____.
2. Select statement corresponds to the _____ operation of the relational algebra.
3. Do the dependencies updated if one change the table name using rename command?
4. The SQL command to delete rows of the table without retaining the table structure is _____.
5. The SQL command to delete rows of the table while retaining the table structure is _____.
6. Check the validity of the command: Select EID, Salary from instructor order by name;



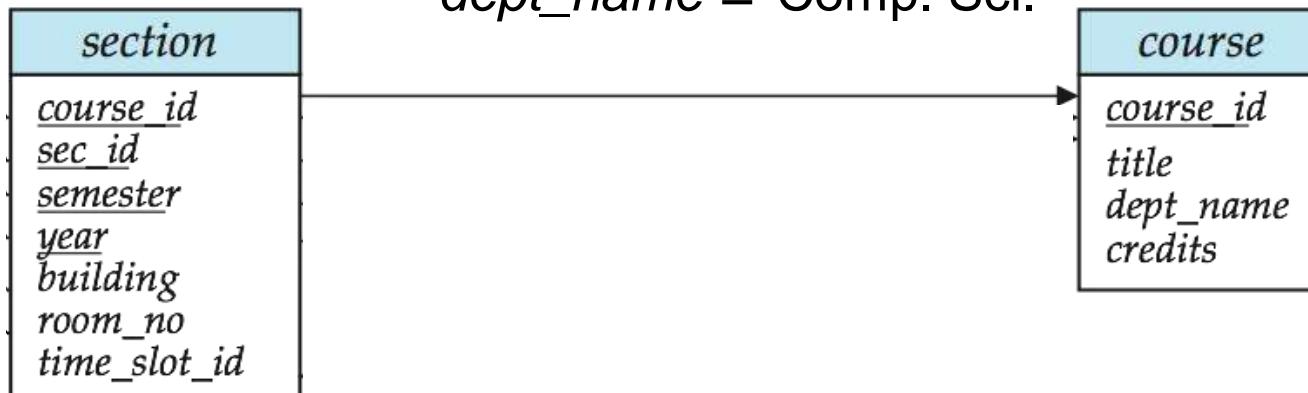
Relax

1. The result of an SQL query is a _____.
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3. Do the dependencies updated if one change the table name using rename command?
4. The SQL command to delete rows of the table without retaining the table structure is _____.
5. The SQL command to delete rows of the table while retaining the table structure is _____.
6. Check the validity of the command: Select EID, Salary from instructor order by name;
 1. Relation
 2. Projection
 3. All the dependencies will be automatically updated on renaming of table
 4. Drop table
 5. Delete From Table
 6. It is valid command and results the data sorted by name in ascending order as the sort criteria can and cannot be the part the select list



Joins

- For all instructors who have taught some course, find their names and the course ID of the courses they taught.
 - **select** *name, course_id*
from *instructor, teaches*
where *instructor.ID = teaches.ID*
- Find the course ID, semester, year and title of each course offered by the Comp. Sci. department
 - **select** *section.course_id, semester, year, title*
from *section, course*
where *section.course_id = course.course_id and dept_name = 'Comp. Sci.'*





Natural Join

- Matches tuples with the same values for all common attributes, and retains only one copy of each common column
- `select * from instructor natural join teaches;`

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	CS-347	1	Fall	2009
12121	Wu	Finance	90000	FIN-201	1	Spring	2010
15151	Mozart	Music	40000	MU-199	1	Spring	2010
22222	Einstein	Physics	95000	PHY-101	1	Fall	2009
32343	El Said	History	60000	HIS-351	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-101	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-319	1	Spring	2010
76766	Crick	Biology	72000	BIO-101	1	Summer	2009
76766	Crick	Biology	72000	BIO-301	1	Summer	2010



Natural Join Example

- List the names of instructors along with the course ID of the courses that they taught.

- **select** *name, course_id*
from *instructor, teaches*
where *instructor.ID = teaches.ID;*

OR

- **select** *name, course_id*
from *instructor natural join teaches;*



The Rename Operation

- The SQL allows renaming relations and attributes using the **as** clause:
$$\text{old-name as new-name}$$
- E.g.
 - **select** *ID, name, salary/12 as monthly_salary*
from *instructor*
- Find the names of all instructors who have a higher salary than some instructor in ‘Comp. Sci’.
 - **select distinct** *T.name*
from *instructor as T, instructor as S*
where *T.salary > S.salary and S.dept_name = ‘Comp. Sci.’*
- Keyword **as** is optional and may be omitted
$$\text{instructor as } T \equiv \text{instructor } T$$
 - Keyword **as** must be omitted in Oracle



String Operations

- SQL includes a string-matching operator for comparisons on character strings. The operator “like” uses patterns that are described using two special characters:
 - percent (%). The % character matches any substring.
 - underscore (_). The _ character matches any character.
- Find the names of all instructors whose name includes the substring “dar”.
 - **select name
from instructor
where name like '%dar%'**
- Match the string “100 %”
like '100 \%' -----→ **escape character '\'**



String Operations (Cont.)

- Patterns are case sensitive.
- Pattern matching examples:
 - ‘Intro%’
 - ▶ matches any string beginning with “Intro”.
 - ‘%Comp%’
 - ▶ matches any string containing “Comp” as a substring.
 - ‘____’
 - ▶ matches any string of exactly three characters.
 - ‘___ %’
 - ▶ matches any string of at least three characters.



String Operations (Cont.)

- SQL supports a variety of string operations such as
 - Concatenation (using “||”)
 - Converting from upper to lower case (and vice versa)
 - Finding string length, extracting substrings, etc.



Ordering the Display of Tuples

- List in alphabetic order the names of all instructors
 - **select distinct name
from instructor
order by name**
- Specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
 - Example: **order by name desc**
- Can sort on multiple attributes
 - Example: **order by dept_name, name**



Where Clause Predicates

- SQL includes a **between** comparison operator
- Example: Find the names of all instructors with salary between \$90,000 and \$100,000 (that is, $\geq \$90,000$ and $\leq \$100,000$)
 - **select name
from instructor
where salary between 90000 and 100000**



Set Operations

- Union
- Intersect
- Except



Set Operations

- Find courses that ran in Fall 2009 or in Spring 2010 or both

(**select course_id from section where sem = 'Fall' and year = 2009**)
union

(**select course_id from section where sem = 'Spring' and year = 2010**)

- Find courses that ran in Fall 2009 and in Spring 2010

(**select course_id from section where sem = 'Fall' and year = 2009**)
intersect

(**select course_id from section where sem = 'Spring' and year = 2010**)

- Find courses that ran in Fall 2009 but not in Spring 2010

(**select course_id from section where sem = 'Fall' and year = 2009**)
except

(**select course_id from section where sem = 'Spring' and year = 2010**)



Set Operations

- Set operations **union**, **intersect**, and **except**
 - Each of the above operations **automatically eliminates duplicates**
- To retain all duplicates use the corresponding multiset versions **union all**, **intersect all** and **except all**.
- Suppose a duplicate tuple occurs m times in r and n times in s , then, it occurs:
 - $m + n$ times in r **union all** s
 - $\min(m,n)$ times in r **intersect all** s
 - ? \mid times in r **except all** s



Null Values

- It is possible for tuples to have a null value, denoted by *null*, for some of their attributes
- *null* signifies an **unknown value** or that a value does not exist.
- The result of any arithmetic expression involving *null* is *null*
 - Example: $5 + \text{null}$ returns null
- The predicate **is null** can be used to check for null values.
 - Example: Find all instructors whose salary is null.
 - ▶ **select name
from instructor
where salary is null**



Null Values and Three Valued Logic

- Any comparison with *null* returns *unknown*
 - Example: $5 < \text{null}$ or $\text{null} < > \text{null}$ or $\text{null} = \text{null}$
- Three-valued logic using the truth value *unknown*:
 - OR: (*unknown or true*) = *true*,
(*unknown or false*) = *unknown*
(*unknown or unknown*) = *unknown*
 - AND: (*true and unknown*) = ?
(*false and unknown*) = ?
(*unknown and unknown*) = ?
 - NOT: (**not** *unknown*) = ?
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*



Aggregate Functions

- These functions operate on the multiset of values of a column of a relation, and return a value

avg: average value

min: minimum value

max: maximum value

sum: sum of values

count: number of values



Aggregate Functions (Cont.)

- Find the average salary of instructors in the Computer Science department
 - **select avg (salary)**
from instructor
where dept_name= 'Comp. Sci.';
- Find the total number of instructors who teach a course in the Spring 2010 semester
 - **select count (distinct ID)**
from teaches
where semester = 'Spring' and year = 2010
- Find the number of tuples in the course relation
 - **select count (*)**
from course;

From → Where → Aggregate Function



Aggregate Functions – Group By

- Find the average salary of instructors in each department
 - `select dept_name, avg (salary)
from instructor
group by dept_name;`
 - Note: departments with no instructor will not appear in result

ID	name	dept_name	salary
76766	Crick	Biology	72000
45565	Katz	Comp. Sci.	75000
10101	Srinivasan	Comp. Sci.	65000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000
12121	Wu	Finance	90000
76543	Singh	Finance	80000
32343	El Said	History	60000
58583	Califieri	History	62000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
22222	Einstein	Physics	95000

dept_name	avg_salary
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
Physics	91000



Aggregation (Cont.)

- Attributes in **select** clause outside of aggregate functions must appear in **group by** list
 - /* erroneous query */
select *dept_name*, *ID*, **avg** (*salary*)
from *instructor*
group by *dept_name*; ?
- Each instructor in a particular group (defined by *dept name*) *can have a different ID, and since only one tuple is output for each group, there is no unique way of choosing which ID value to output.*
- As a result, such cases are **disallowed by SQL**.



Aggregate Functions – Having Clause

- Useful to state a condition that applies to groups rather than to tuples.
- Find the names and average salaries of all departments whose average salary is greater than 42000

```
select dept_name, avg (salary)  
from instructor  
group by dept_name  
having avg (salary) > 42000;
```

Note: predicates in the **having** clause are applied **after the formation of groups** whereas predicates in the **where** clause are applied **before forming groups**



Sequence of Steps of Query with Having

■ `select dept_name, avg (salary) from instructor group by dept_name having avg (salary) > 42000;`

1. As was the case for queries without aggregation, **the from clause is first evaluated to get a relation**.
2. If a where clause is present, the predicate in the **where clause is applied on the result relation** of the from clause.
3. Tuples satisfying the where predicate are then **placed into groups by the group by clause if it is present**.
 - If the **group by clause is absent**, the **entire set of tuples** satisfying the where predicate is treated as being in one group.
4. The **having clause**, if it is present, **is applied to each group**; the groups that do not satisfy the having clause predicate are removed.
5. The **select clause** uses the remaining groups to generate tuples of the result of the query, **applying the aggregate functions to get a single result tuple for each group**.

From → Where → Group by → Having → Aggregate Function



Null Values and Aggregates

- Salary: 20000
30000
null
40000
- Total all salaries

select sum (salary) from instructor

- Above statement ignores null amounts
- Result is *null* if there is no non-null amount
 - **select count (salary) from instructor**
 - **select count(vehicles) from instructor**



Nested Subqueries

- SQL provides a mechanism for the nesting of subqueries.
- A **subquery** is a **select-from-where** expression that is nested within another query.
- A common use of subqueries is to perform tests for set membership, set comparisons, and set cardinality.
- Can use
 - With where clause
 - With from clause



Example Query-with where clause

- Find courses offered in Fall 2009 and in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
course_id in (select course_id
from section
where semester = 'Spring' and year= 2010);
```

- Find courses offered in Fall 2009 but not in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
course_id not in (select course_id
from section
where semester = 'Spring' and year= 2010);
```



Example Query

- Find the total number of (distinct) students who have taken course sections taught by the instructor with *ID* 10101

```
select count (distinct ID)
from takes
where (course_id, sec_id, semester, year) in
      (select course_id, sec_id, semester, year
       from teaches
       where teaches.ID= 10101);
```



Set Comparison

- Find names of instructors with salary greater than that of some (at least one) instructor in the Biology department.

```
select distinct T.name  
from instructor as T, instructor as S  
where T.salary > S.salary and S.dept_name = 'Biology';
```

- Same query using > **some** clause

```
select name  
from instructor  
where salary > some (select salary  
                 from instructor  
                 where dept_name = 'Biology');
```



Definition of Some Clause

- SQL allows $< \text{some}$, $\leq \text{some}$, $\geq \text{some}$, $= \text{some}$, and $\neq \text{some}$ comparisons
- $F <\text{comp}> \text{some } r \Leftrightarrow \exists t \in r \text{ such that } (F <\text{comp}> t)$
Where $<\text{comp}>$ can be: $<$, \leq , $>$, $=$, \neq

(5 < some	<table border="1"><tr><td>0</td></tr><tr><td>5</td></tr><tr><td>6</td></tr></table>	0	5	6) = true	(read: 5 < some tuple in the relation)
0						
5						
6						
(5 < some	<table border="1"><tr><td>0</td></tr><tr><td>5</td></tr></table>	0	5) = false		
0						
5						
(5 = some	<table border="1"><tr><td>0</td></tr><tr><td>5</td></tr></table>	0	5) = true		
0						
5						
(5 ≠ some	<table border="1"><tr><td>0</td></tr><tr><td>5</td></tr></table>	0	5) = true (since $0 \neq 5$)		
0						
5						

$(= \text{some}) \equiv \text{in}$

However, $(\neq \text{some}) \not\equiv \text{not in}$



Example Query

- Find the names of all instructors whose salary is greater than the salary of all instructors in the Biology department.

```
select name
from instructor
where salary > all (select salary
from instructor
where dept_name = 'Biology');
```



Definition of all Clause

- $F <\text{comp}> \text{all } r \Leftrightarrow \forall t \in r (F <\text{comp}> t)$

$(5 < \text{all} \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{false}$

$(5 < \text{all} \begin{array}{|c|} \hline 6 \\ \hline 10 \\ \hline \end{array}) = \text{true}$

$(5 = \text{all} \begin{array}{|c|} \hline 4 \\ \hline 5 \\ \hline \end{array}) = \text{false}$

$(5 \neq \text{all} \begin{array}{|c|} \hline 4 \\ \hline 6 \\ \hline \end{array}) = \text{true} (\text{since } 5 \neq 4 \text{ and } 5 \neq 6)$

$(\neq \text{all}) \equiv \text{not in}$

However, $(= \text{all}) \neq \text{in}$



Test for Empty Relations

- SQL includes a feature **for testing whether a subquery has any tuples in its result.**
- The **exists construct returns the value true if the argument subquery is nonempty.**



Correlation Variables

- Yet another way of specifying the query “Find all courses taught in both the Fall 2009 semester and in the Spring 2010 semester”
- ```
select course_id
 from section as S
 where semester = 'Fall' and year= 2009 and
 exists (select *
 from section as T
 where semester = 'Spring' and year= 2010
 and S.course_id= T.course_id);
```
- **Correlation name** or **correlation variable** from an outer query (*S* in the above query), can be used in a subquery in the where clause
- **Correlated subquery**
  - A subquery that uses a correlation name from an outer query is called a **correlated subquery**.



# Not Exists

- Find all students who have taken all courses offered in the Biology department.

```
select distinct S.ID, S.name
from student as S
where not exists ((select course_id
 from course
 where dept_name = 'Biology')
except
 (select T.course_id
 from takes as T
 where S.ID = T.ID));
```



# Subqueries in the From Clause

- SQL allows a subquery expression to be used in the **from** clause
- Find the average instructors' salaries of those departments where the average salary is greater than \$42,000.

```
select dept_name, avg_salary
from (select dept_name, avg (salary) as avg_salary
 from instructor
 group by dept_name)
where avg_salary > 42000;
```

- Note that we do not need to use the **having** clause
- Another way to write above query

```
select dept_name, avg_salary
from (select dept_name, avg (salary)
 from instructor
 group by dept_name)
 as dept_avg (dept_name, avg_salary)
where avg_salary > 42000;
```



# Scalar Subquery

- Scalar subquery is one which is used where a single value is expected
- E.g. Lists all departments along with the number of instructors in each department
  - ```
select dept_name,
       (select count(*)
        from instructor
        where department.dept_name =
              instructor.dept_name)
       as num_instructors
      from department;
```
- Runtime error if subquery returns more than one result tuple



Modification of the Database

- Deletion of tuples from a given relation
- Insertion of new tuples into a given relation
- Updating values in some tuples in a given relation



Modification of the Database – Deletion

- Delete all instructors

delete from *instructor*

- Delete all instructors from the Finance department

delete from *instructor*

where *dept_name*= 'Finance';

- Delete all tuples in the *instructor* relation for those instructors associated with a department located in the Watson building.

delete from *instructor*

where *dept_name* **in** (**select** *dept_name*
from *department*
where *building* = 'Watson');



Deletion (Cont.)

- Delete all instructors whose salary is less than the average salary of instructors

```
delete from instructor
```

```
where salary< (select avg (salary) from instructor);
```

- Problem: as we delete tuples from deposit, the average salary changes
- Solution used in SQL:
 1. First, compute **avg** salary and find all tuples to delete
 2. Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)



Modification of the Database – Insertion

- Add a new tuple to *course*

insert into *course*

values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

- or equivalently

insert into *course* (*course_id*, *title*, *dept_name*, *credits*)

values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

- Add a new tuple to *student* with *tot_creds* set to null

insert into *student*

values ('3003', 'Green', 'Finance', *null*);



Insertion (Cont.)

- Add all instructors to the *student* relation with tot_creds set to 0

```
insert into student
```

```
  select ID, name, dept_name, 0  
  from instructor
```

- The **select from where** statement is evaluated fully before any of its results are inserted into the relation (otherwise queries like

```
insert into table1 select * from table1
```

would cause problems, if *table1* did not have any primary key defined.



Modification of the Database – Updates

- Increase salaries of instructors whose salary is over \$100,000 by 3%, and all others receive a 5% raise
 - Write two **update** statements:

```
update instructor  
    set salary = salary * 1.03  
  where salary > 100000;
```

```
update instructor  
    set salary = salary * 1.05  
  where salary <= 100000;
```

- The order is important
- Can be done better using the **case** statement (next slide)



Case Statement for Conditional Updates

- Same query as before but with case statement

```
update instructor
    set salary = case
        when salary <= 100000 then salary * 1.05
        else salary * 1.03
    end
```



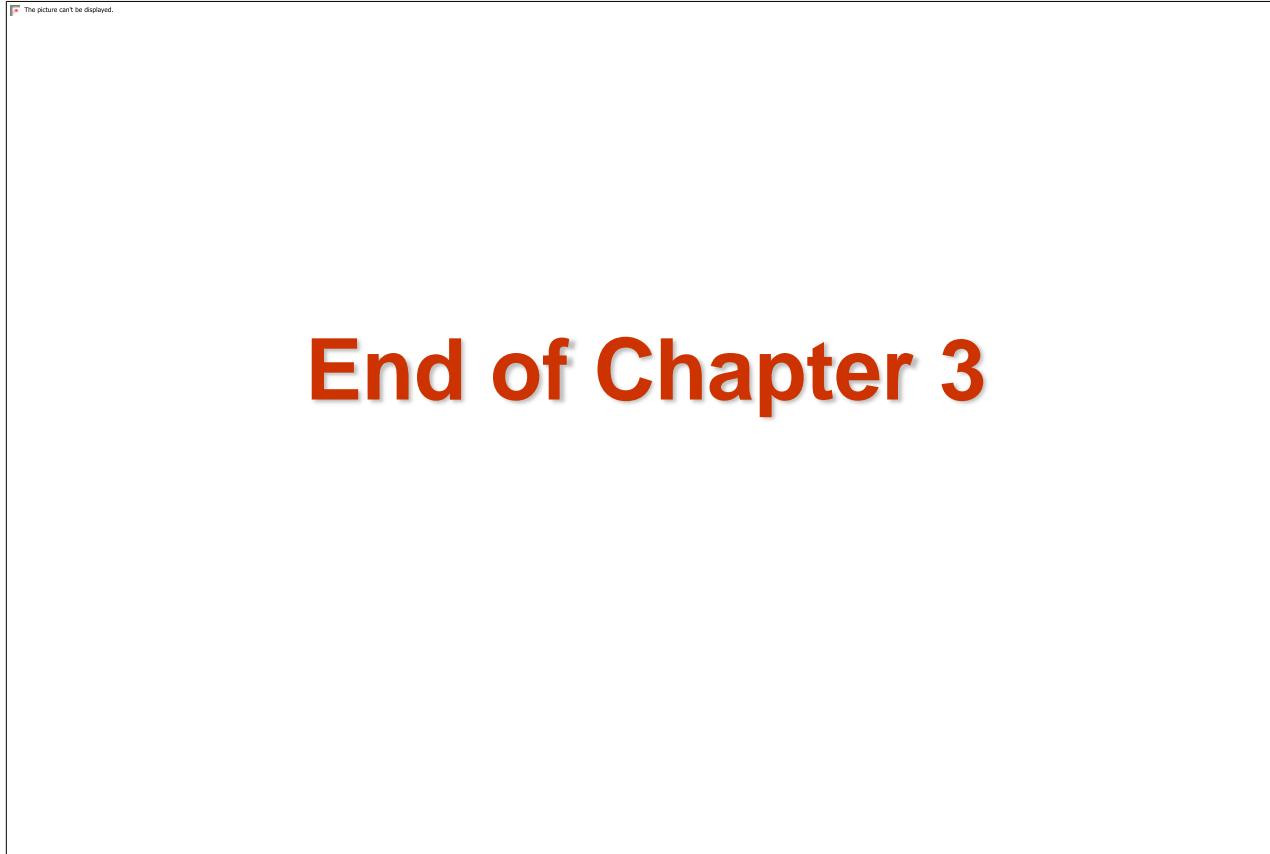
Updates with Scalar Subqueries

- Recompute and update tot_creds value for all students

```
update student S
  set tot_cred = ( select sum(credits)
                     from takes natural join course
                   where S.ID= takes.ID and
                         takes.grade <> 'F' and
                         takes.grade is not null);
```

- Sets *tot_creds* to null for students who have not taken any course
- Instead of **sum(credits)**, use:

```
case
  when sum(credits) is not null then sum(credits)
  else 0
end
```



End of Chapter 3

Database System Concepts, 6th Ed.

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Advanced SQL Features**

- Create a table with the same schema as an existing table:
`create table temp_account like account`



Figure 3.02

<i>name</i>
Srinivasan
Wu
Mozart
Einstein
El Said
Gold
Katz
Califieri
Singh
Crick
Brandt
Kim



Figure 3.03

<i>dept_name</i>
Comp. Sci.
Finance
Music
Physics
History
Physics
Comp. Sci.
History
Finance
Biology
Comp. Sci.
Elec. Eng.



Figure 3.04

<i>name</i>
Katz
Brandt



Figure 3.05

<i>name</i>	<i>dept_name</i>	<i>building</i>
Srinivasan	Comp. Sci.	Taylor
Wu	Finance	Painter
Mozart	Music	Packard
Einstein	Physics	Watson
El Said	History	Painter
Gold	Physics	Watson
Katz	Comp. Sci.	Taylor
Califieri	History	Painter
Singh	Finance	Painter
Crick	Biology	Watson
Brandt	Comp. Sci.	Taylor
Kim	Elec. Eng.	Taylor



Figure 3.07

<i>name</i>	<i>Course_id</i>
Srinivasan	CS-101
Srinivasan	CS-315
Srinivasan	CS-347
Wu	FIN-201
Mozart	MU-199
Einstein	PHY-101
El Said	HIS-351
Katz	CS-101
Katz	CS-319
Crick	BIO-101
Crick	BIO-301
Brandt	CS-190
Brandt	CS-190
Brandt	CS-319
Kim	EE-181



Figure 3.08

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	CS-347	1	Fall	2009
12121	Wu	Finance	90000	FIN-201	1	Spring	2010
15151	Mozart	Music	40000	MU-199	1	Spring	2010
22222	Einstein	Physics	95000	PHY-101	1	Fall	2009
32343	El Said	History	60000	HIS-351	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-101	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-319	1	Spring	2010
76766	Crick	Biology	72000	BIO-101	1	Summer	2009
76766	Crick	Biology	72000	BIO-301	1	Summer	2010
83821	Brandt	Comp. Sci.	92000	CS-190	1	Spring	2009
83821	Brandt	Comp. Sci.	92000	CS-190	2	Spring	2009
83821	Brandt	Comp. Sci.	92000	CS-319	2	Spring	2010
98345	Kim	Elec. Eng.	80000	EE-181	1	Spring	2009



Figure 3.09

<i>course_id</i>
CS-101
CS-347
PHY-101



Figure 3.10

<i>course_id</i>
CS-101
CS-315
CS-319
CS-319
FIN-201
HIS-351
MU-199



Figure 3.11

<i>course_id</i>
CS-101
CS-315
CS-319
CS-347
FIN-201
HIS-351
MU-199
PHY-101



Figure 3.12

<i>course_id</i>
CS-101



Figure 3.13

<i>course_id</i>
CS-347
PHY-101



Figure 3.16

<i>dept_name</i>	<i>count</i>
Comp. Sci.	3
Finance	1
History	1
Music	1



Figure 3.17

<i>dept_name</i>	<i>avg(salary)</i>
Physics	91000
Elec. Eng.	80000
Finance	85000
Comp. Sci.	77333
Biology	72000
History	61000



Truncate vs. Delete

- No DML triggers will be fired. ...
- DROP and **TRUNCATE** are DDL commands, whereas **DELETE** is a DML command.
- Therefore **DELETE** operations can be rolled back (undone), while DROP and **TRUNCATE** operations cannot be rolled back.
- All the tables' rows, indexes and privileges will also be removed with **TRUNCATE**.



Try Writing Some Queries in SQL

- Retrieve the instructors name where the salaries is between 100000 & 80000 both inclusive.
- Retrieve student information for where the department name has the value “Finance” or “Music”.
- Retrieve instructors who are Not in “Finance” OR “Music”
 - Retrieve all information about supplier whose name begin with letters ‘ja’ from supplier_master.

Select *from supplier_master where supplier_name ='ja%';



Tutorial Question

- Which are the other data types available than listed in the ppt slide?
- A is of char (10), B is varchar (10), both have value “Avi”
 - What is the result of comparison $A=B$?
- Differentiate between the command **drop table r;** and **delete from r;**
- Write the iterative process that generates tuples for the result relation of the **from clause**.



Tutorial Question-Answer

- Which are the other data types available than listed in the ppt slide?
 - Nvarchar type to store multilingual data using the Unicode representation.
 - However, many databases allow Unicode (in the UTF-8 representation) to be stored even in **varchar types**.
- A is of char (10), B is varchar (10), both have value “Avi”
 - What is the result of comparison $A=B$?
 - ▶ *May return false.*
- The command **drop table r;** vs **delete from r;**
 - The latter retains relation r , *but deletes all tuples in r. The former deletes not only all tuples of r, but also the schema for r.*
 - *After r is dropped, no tuples can be inserted into r unless it is re-created with the create table command.*



Tutorial Question-Answer

- The **from clause by itself defines a Cartesian product of the relations listed** in the clause. It is defined formally in terms of set theory, but is perhaps best understood as an iterative process that generates tuples for the result relation of the **from clause**.

for each tuple t_1 in relation r_1

for each tuple t_2 in relation r_2

...

for each tuple t_m in relation r_m

Concatenate t_1, t_2, \dots, t_m into a single tuple t

Add t into the result relation



Tutorial Question-Answer

- The *instructor relation* has 12 tuples and the example *teaches relation* has 13 tuples, their Cartesian product has $12 * 13 = 156$ tuples.
- Number of instructors are 200 instructors. Each instructor teaches 3 courses in the *teaches relation*. Then the above iterative process generates $200 * 600 = 120,000$ tuples in the result.



The select Clause (Cont.)

- SQL allows duplicates in relations as well as in query results.
- To force the elimination of duplicates, insert the keyword **distinct** after select.
- Find the names of all departments with instructor, and remove duplicates
 - **select distinct dept_name from instructor**
- The keyword **all** specifies that duplicates not be removed.
 - **select all dept_name from instructor**



And operator:

Process all rows in a table & display the result only when all of the conditions specified using AND operator is satisfied.

Example :

Retrieve the contents of the columns product_no, description, profit_percent, sell-price from the table product master where the values contained in the field profit_percent is between 10 & 20 both inclusive.

```
select product_no, description, profit_percent, sell_price from product_master  
where profit_percent>=10 AND  
Profit_percent<=20;
```



OR operator :

Process all rows in a table & display the result only when any of the conditions, specified using OR operator is satisfied .

Example

Retrieve client information like client_no, name, address, city, pin_code for all the clients where the pin code has the value 400054 or 400057;

```
select * from client_master where pin_code =400054 OR  
pin_code=400057;
```



Not operator :-

Process all the rows in a table and display the result only when none of the conditions specified using the Not operator are satisfied.

Example :

Retrieve specified client information for the clients who are Not in “Butwal” OR “Pokhara”

```
select client_no, name, address, city pin_code  
from client_master  
where Not (city='Butwal' or city=' pokhara');
```



Range Searching:

BETWEEN Operator:

Allows the selection of rows that contains values within a specified lower and upper limit.

Example :

- ✓ *Retrieve all information from the table product-master where the values contain within the field profit-percent is betⁿ 10 & 20 both inclusive.*

Select* from product-master

where profit_percent between 10 AND 20;



Natural Join (Cont.)

- Danger in natural join: beware of unrelated attributes with same name which get equated incorrectly
- List the names of instructors along with the titles of courses that they teach
 - Incorrect version (makes course.dept_name = instructor.dept_name)
 - ▶ **select name, title
from instructor natural join teaches natural join course;**
 - Correct version
 - ▶ **select name, title
from instructor natural join teaches, course
where teaches.course_id = course.course_id;**
 - Another correct version
 - ▶ **select name, title
from (instructor natural join teaches)
join course using(course_id);**



Where Clause Predicates

- Tuple comparison

- **select** *name, course_id*
from *instructor, teaches*
where (*instructor.ID, dept_name*) = (*teaches.ID, 'Biology'*);



Duplicates

- In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- **Multiset** versions of some of the relational algebra operators – given multiset relations r_1 and r_2 :
 1. $\sigma_\theta(r_1)$: If there are c_1 copies of tuple t_1 in r_1 , and t_1 satisfies selections σ_θ , then there are c_1 copies of t_1 in $\sigma_\theta(r_1)$.
 2. $\Pi_A(r)$: For each copy of tuple t_1 in r_1 , there is a copy of tuple $\Pi_A(t_1)$ in $\Pi_A(r_1)$ where $\Pi_A(t_1)$ denotes the projection of the single tuple t_1 .
 3. $r_1 \times r_2$: If there are c_1 copies of tuple t_1 in r_1 and c_2 copies of tuple t_2 in r_2 , there are $c_1 \times c_2$ copies of the tuple t_1, t_2 in $r_1 \times r_2$.



Duplicates (Cont.)

- Example: Suppose multiset relations $r_1 (A, B)$ and $r_2 (C)$ are as follows:

$$r_1 = \{(1, a) (2, a)\} \quad r_2 = \{(2), (3), (3)\}$$

- Then $\Pi_B(r_1)$ would be $\{(a), (a)\}$, while $\Pi_B(r_1) \times r_2$ would be $\{(a, 2), (a, 2), (a, 3), (a, 3), (a, 3), (a, 3)\}$
- SQL duplicate semantics:

```
select A1, A2, ..., An  
from r1, r2, ..., rm  
where P
```

is equivalent to the *multiset* version of the expression:

$$\prod_{A_1, A_2, \dots, A_n} (\sigma_P(r_1 \times r_2 \times \dots \times r_m))$$



- For each course section offered in 2009, find the average total credits (*tot cred*) of all students enrolled in the section, if the section had at least 2 students.”

```
select course id, semester, year, sec id, avg (tot cred)
from takes natural join student where year = 2009
group by course id, semester, year, sec id
having count (ID) >= 2;
```



Null Values and Aggregates

- Total all salaries

```
select sum (salary)  
from instructor
```

- Above statement ignores null amounts
- Result is *null* if there is no non-null amount
- All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes
- What if collection has only null values?
 - count returns 0
 - all other aggregates return null



Subqueries in the From Clause (Cont.)

- And yet another way to write it: **lateral** clause

```
select name, salary, avg_salary
from instructor I1,
     lateral (select avg(salary) as avg_salary
               from instructor I2
              where I2.dept_name= I1.dept_name);
```

- Lateral clause permits later part of the **from** clause (after the lateral keyword) to access correlation variables from the earlier part.
- Note: lateral is part of the SQL standard, but is not supported on many database systems; some databases such as SQL Server offer alternative syntax



With Clause

- The **with** clause provides a way of defining a temporary view whose definition is available only to the query in which the **with** clause occurs.
- Find all departments with the maximum budget

```
with max_budget (value) as
    (select max(budget)
     from department)
    select budget
    from department, max_budget
    where department.budget = max_budget.value;
```



Complex Queries using With Clause

- With clause is very useful for writing complex queries
- Supported by most database systems, with minor syntax variations
- Find all departments where the total salary is greater than the average of the total salary at all departments

```
with dept_total(dept_name, value) as
    (select dept_name, sum(salary)
     from instructor
     group by dept_name),
dept_total_avg(value) as
    (select avg(value)
     from dept_total)
select dept_name
from dept_total, dept_total_avg
where dept_total.value >= dept_total_avg.value;
```



Display the structure of table

- Describe a Table, View, Synonym, package or Function

Syntax:

- DESC *table*
- DESC *view*
- DESC *synonym*
- DESC *function*
- DESC package



Test for Absence of Duplicate Tuples

- The **unique** construct tests whether a subquery has any duplicate tuples in its result.
 - (Evaluates to “true” on an empty set)
- Find all courses that were offered at most once in 2009

```
select T.course_id
from course as T
where unique (select R.course_id
               from section as R
               where T.course_id= R.course_id
                     and R.year = 2009);
```



Null Values and Aggregates

- Salary: 20000
30000
null
40000
- Total all salaries
 - select sum (salary) from *instructor*
 - Above statement ignores null amounts
 - Result is *null* if there is no non-null amount
 - select count (salary) from *instructor*
 - select count(vehicles) from *instructor*
 - All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes