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# Βάσεις Δεδομένων

## Μάθημα 2-β Κεφάλαιο 3: Εισαγωγή στην SQL

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# Κεφάλαιο 3: Εισαγωγή στην 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



# Ιστορία

- IBM Sequel language developed as part of System R project at the IBM San Jose Research Laboratory
- Renamed Structured Query Language (SQL)
- ANSI and ISO 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.



# 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 each relation.
  - The physical storage structure of each relation on disk.



# 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.
- More are covered in Chapter 4.



# Create Table Construct

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

```
create table  $r$  ( $A_1 D_1, A_2 D_2, \dots, A_n D_n,$   
                (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  $A_i$
- Example:

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

- **insert into instructor values** ('10211', 'Smith', 'Biology', 66000);
- **insert into instructor values** ('10211', null, 'Biology', 66000);
- **Insert into instructor (ID,name, salary) values** ('10211', 'Smith', 66000);



# 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*

```
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)  
-- foreign key (dept_name) references department(name)  
primary key declaration on an attribute automatically ensures not null
```



# 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



# Drop and Alter Table Constructs

- **drop table** *student*
  - Deletes the table and its contents
- **delete from** *student*
  - Deletes all contents of table, but retains table
- **alter 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



# Basic Query Structure

- The SQL **data-manipulation language (DML)** provides the ability to query information, and insert, delete and update tuples
- A typical SQL query has the form:

**select**  $A_1, A_2, \dots, A_n$   
**from**  $r_1, r_2, \dots, r_m$   
**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 list 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 keyword **all** specifies that duplicates not be removed.

```
select all 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.
- 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.

```
SELECT product, customer, timologio, quantity*itemprice  
FROM sales;
```

```
SELECT YEAR(dateOfBirth), name  
FROM users;
```



# 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 from Clause

- 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

<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
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...



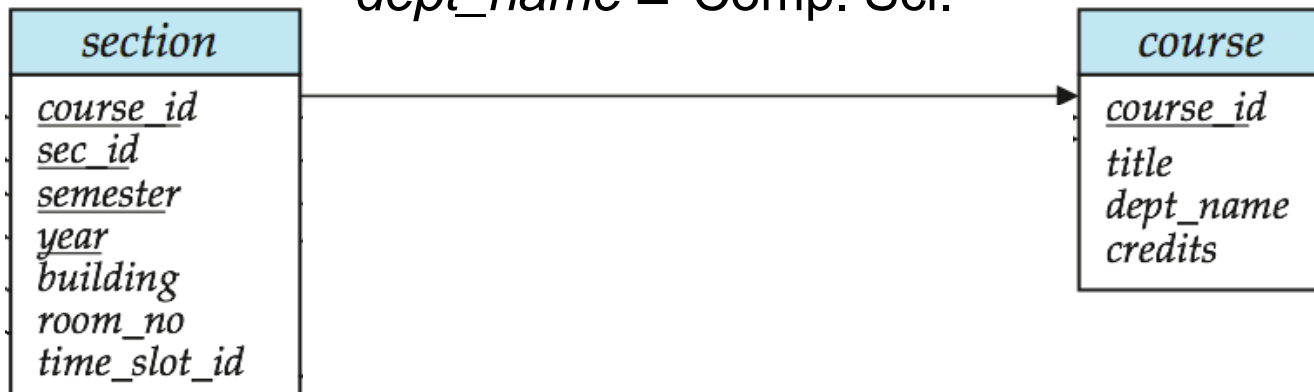
# Joins

- 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

- 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;**
- SELECT instructor.\*, teaches.course\_id, teaches.sec\_id, teaches.semester, teaches.year

From Instructor JOIN teaches ON instructor.ID=teaches.ID;

ID	name	dept_name	salary	course_id	sec_id	semester	year
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;*
  - **select** *name, course\_id*  
**from** *instructor natural join teaches;*



# 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 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*;
    - ▶ Instructor (tid, name, dept)
    - ▶ Teaches(tid, cid)
    - ▶ Course(cid, name, dept)
  - 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)*;



# The Rename Operation

- The SQL allows renaming relations and attributes using the **as** clause:

*old-name as new-name*

- E.g.

- **select** *ID, name, salary/12 as monthly\_salary*  
**from** *instructor*

*where monthly\_salary > 1000* ᅇ *where salary/12 > 1000*

- 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

*instructor as T* ≡ *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 '\'
```



# 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.
- 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*
- We may 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
- 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  $\sigma_{\theta}$ , 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  $t_1 \cdot t_2$  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  $A_1, A_2, \dots, A_n$   
from  $r_1, r_2, \dots, r_m$   
where  $P$ 
```

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

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



# Set Operations

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

**(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 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**  $s$
- $\max(0, m - n)$  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:  $5 + \textit{null}$  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:  $5 < null$  or  $null <> null$  or  $null = null$
- Three-valued logic using the truth value *unknown*:
  - OR:  $(unknown \text{ or } true) = true$ ,  
 $(unknown \text{ or } false) = unknown$   
 $(unknown \text{ or } unknown) = unknown$
  - AND:  $(true \text{ and } unknown) = unknown$ ,  
 $(false \text{ and } unknown) = false$ ,  
 $(unknown \text{ and } unknown) = unknown$
  - NOT:  $(\text{not } unknown) = unknown$
  - “*P* is unknown” evaluates to true if predicate *P* evaluates to *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*;



# 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

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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

<i>dept_name</i>	<i>avg_salary</i>
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;*



# Aggregate Functions – Having Clause

- 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



# 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



# 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.



# Example Query

- 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);
```

- **Note:** Above query can be written in a much simpler manner. The formulation above is simply to illustrate SQL features.



# 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

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

$$(5 < \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{true} \quad (\text{read: } 5 < \text{some tuple in the relation})$$

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

$$(5 = \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true}$$

$$(5 \neq \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true (since } 0 \neq 5)$$

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

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

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

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

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

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

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

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

However,  $(= \mathbf{all}) \not\equiv \mathbf{in}$



# Test for Empty Relations

- The **exists** construct returns the value **true** if the argument subquery is nonempty.
- **exists**  $r \Leftrightarrow r \neq \emptyset$
- **not exists**  $r \Leftrightarrow r = \emptyset$



# 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);
```

- **Correlated subquery**
- **Correlation name** or **correlation variable**



# 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));
```

- Note that  $X - Y = \emptyset \Leftrightarrow X \subseteq Y$
- *Note:* Cannot write this query using = **all** and its variants





# 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);
```



# 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;
```



# 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;
```



# Scalar Subquery

- Scalar subquery is one which is used where a single value is expected
- E.g. 

```
select dept_name,  
       (select count(*)  
        from instructor  
        where department.dept_name = instructor.dept_name)  
       as num_instructors  
from department;
```
- E.g. 

```
select name  
from instructor  
where salary * 10 >  
       (select budget from department  
        where department.dept_name = instructor.dept_name)
```
- 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
```