



Topic 3-Part 2 (SQL) (Chapter 3, 4, 5)

Database System Concepts

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(Modified for CS 4513)



Topic 3 – Part 2: 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)
- 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 in the textbook may work on your particular system.



SQL: DDL and DML

- SQL has two parts:
 - Data Definition Language (DDL)
 - Data Manipulation Language (DML)



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
- ❑ 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

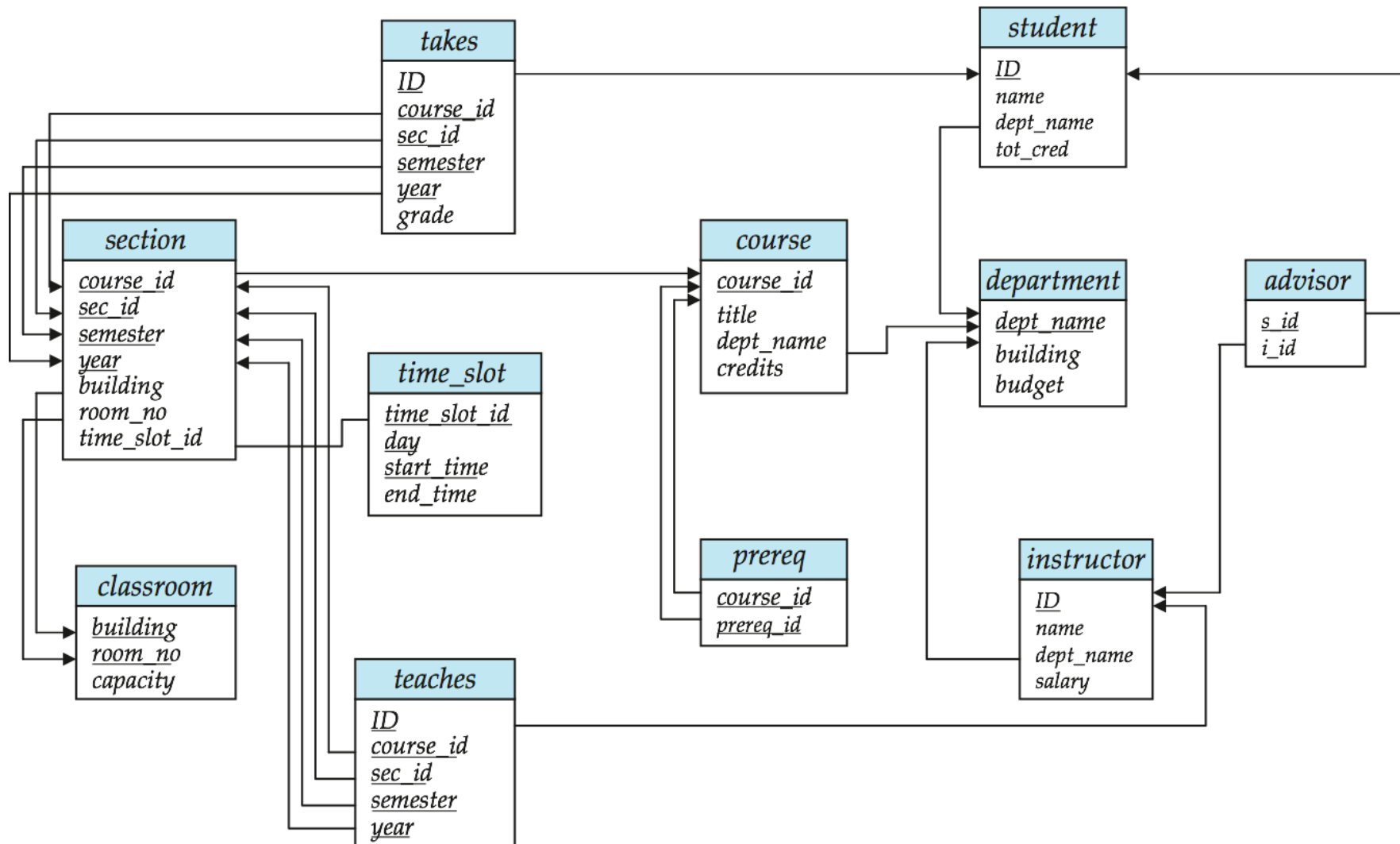
- An SQL relation is defined using the **create table** command:

create table r ($A_1 D_1, A_2 D_2, \dots, A_n D_n,$
 (integrity-constraint₁),
 ...,
 (integrity-constraint_k))

- 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: Schema Diagram for University Database





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 *dept_name* as the primary key for *department*

.

```
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**



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
- 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.



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
- 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



Cartesian Product: *instructor X teaches*

instructor

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

teaches

ID	course_id	sec_id	semester	year
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

inst.ID	name	dept_name	salary	teaches.ID	course_id	sec_id	semester	year
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
...
...



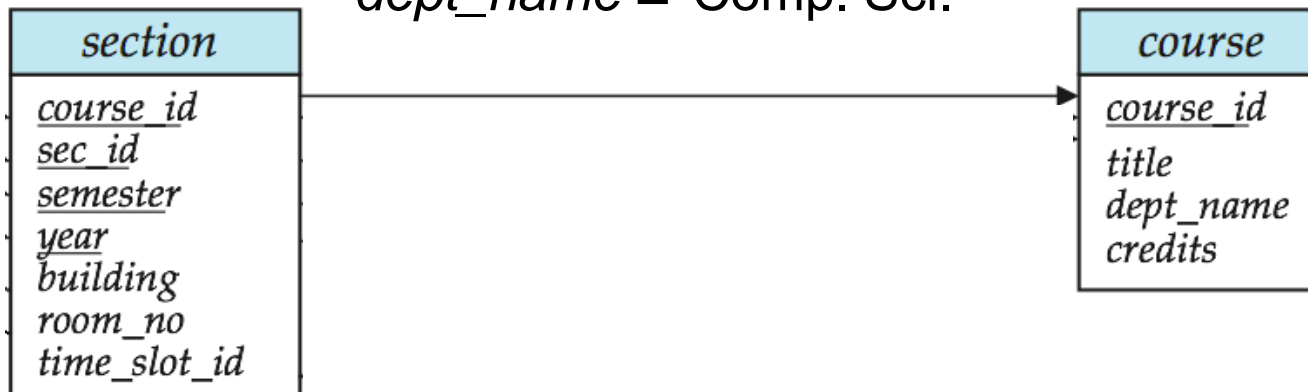
Joins

- 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.'
```





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*
- 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 \equiv *instructor T*
 - Keyword **as** must be omitted in Oracle



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'*);



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)
```

Note: replace “except” with “minus” in Oracle



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**.



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: $5 < null$ 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');
```



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');
```



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));
```



Subqueries in the From Clause

- ❑ SQL allows a subquery expression to be used in the **from** clause
- ❑ Find the names and 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 as in the following:

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




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
```



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



End of Topic 3 – Part 2

Database System Concepts

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