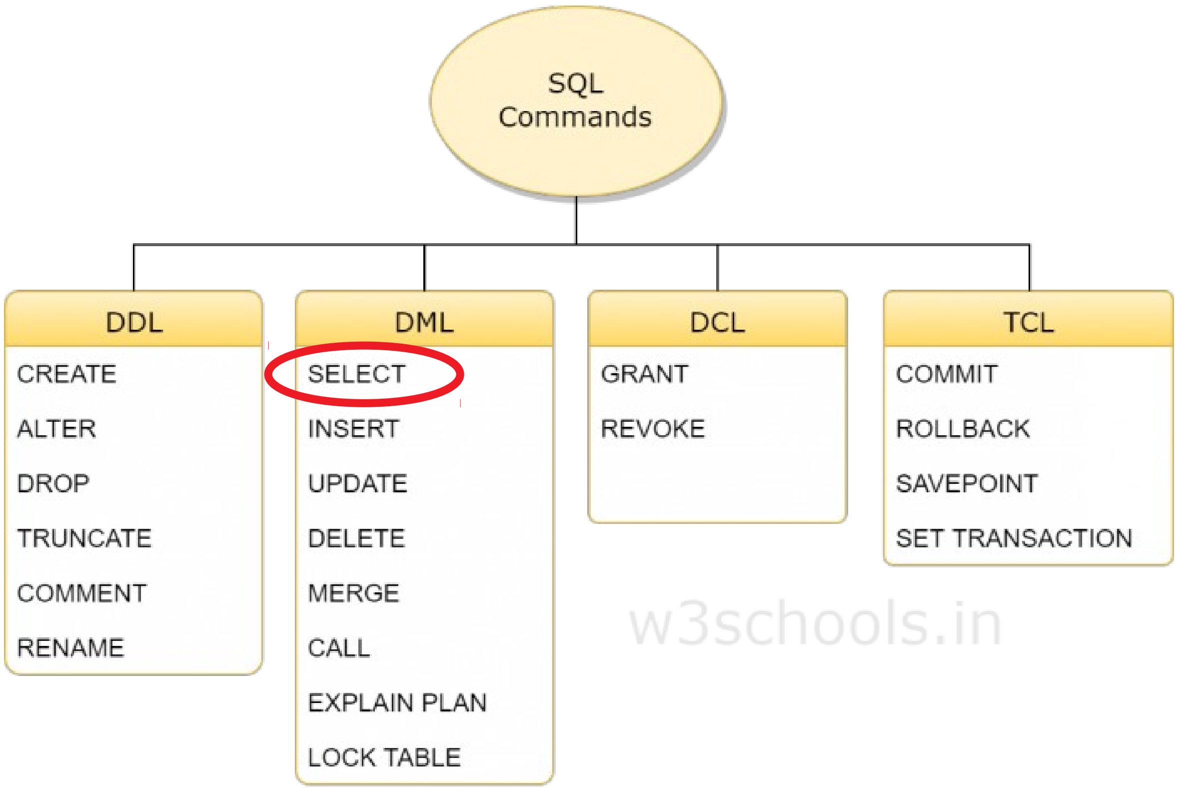
Heiko Paulheim

Looking Back

- We have seen
  - Reading data from tables



Outline

- Last week
  - Overview of The SQL Query Language
  - Basic Query Structure
  - Set Operations
  - Join Operators
  - Null Values
  - Aggregate Functions
  - Nested Subqueries
- Today
  - Data Definition
  - Data Types in SQL
  - Modifications of the database
  - Views
  - Integrity Constraints
  - Roles & Rights

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

Recap: Domain of an Attribute

- The set of allowed values for an attribute
  - Programmers: think *datatype*

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

Simple Domains 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 *d* digits to the right of decimal point. (ex., **numeric**(3,1), allows 44.5 to be stores exactly, but not 444.5 or 0.32)
- **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 and Time Data Types in SQL

- We have already encountered characters and numbers
- **date**: Dates, containing a (4 digit) year, month and date
  - Example: **date** ‘2005-7-27’
- **time**: Time of day, in hours, minutes and seconds.
  - Example: **time** ‘09:00:30’ **time** ‘09:00:30.75’
- **timestamp**: date plus time of day
  - Example: **timestamp** ‘2005-7-27 09:00:30.75’
- **interval**: period of time
  - Example: interval ‘1’ day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values

Arithmetics with Dates

- Dates can be compared
  - i.e., < or >
  - e.g., select employees who started before January 1st, 2017
  - Special function: NOW() (in MariaDB; name may differ for other DBMS)
- Dates can be added to / substracted from intervals and other dates
  - e.g., select students who have been enrolled for more than five years

- Implementation not standardized
  - Details differ from DBMS to DBMS!

User Defined Types

- **create type** construct in SQL creates user-defined type

create type *Dollars* **as numeric (12,2) final**

required due to SQL standard; not really meaningful

- **create table** *department*
  (*dept_name* **varchar** (20),
  building **varchar** (15),
  budget Dollars);

User-defined Domains

- **create domain** construct creates user-defined domain types

  create domain *person_name* **char**(20) **not null**

- Types and domains are similar
  - Domains can have constraints, such as **not null**, specified on them

    create domain *degree_level* **varchar**(10)
    constraint *degree_level_test*
    check (**value in** ('Bachelors', 'Masters', 'Doctorate'));

Domain Constraints vs. Table Constraints

- Some checks may reoccur over different relations
  - e.g., degrees for students or instructors
  - e.g., salutations
  - e.g., valid ranges for ZIP codes

bologna
process

- Binding them to a *domain* is preferred
  - Central definition
  - Consistent usage

Large Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object -- object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
  - **clob**: character large object -- object is a large collection of character data
- When a query returns a large object, a pointer is returned rather than the large object itself

Creating Relations

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

  create table r (A_1 D_1, A_2 D_2, ..., A_n D_n,
  (integrity-constraint$_1$),
  ...,
  (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 datatype/domain of values in the domain of attribute A_i

- Example:

  create table *instructor* (
  ID **char**(5),
  name **varchar**(20),
  dept_name **varchar**(20),
  salary **numeric**(8,2))

Recap: Keys

- Primary keys identify a unique tuple of each possible relation *r(R)*
  - Typical examples: IDs, Social Security Number, car license plate
- Primary keys can consist of multiple attributes
  - e.g.: course ID plus semester (CS 460, FSS 2019)
  - Must be minimal – (ID, semester, instructor) would work as well
- Foreign keys refer to other tables
  - i.e., they appear in other tables as primary keys

Defining Keys

- **primary key** (A_1, ..., A_n)
- **foreign key** (A_m, ..., A_n) **references** *r*
- *Example:*

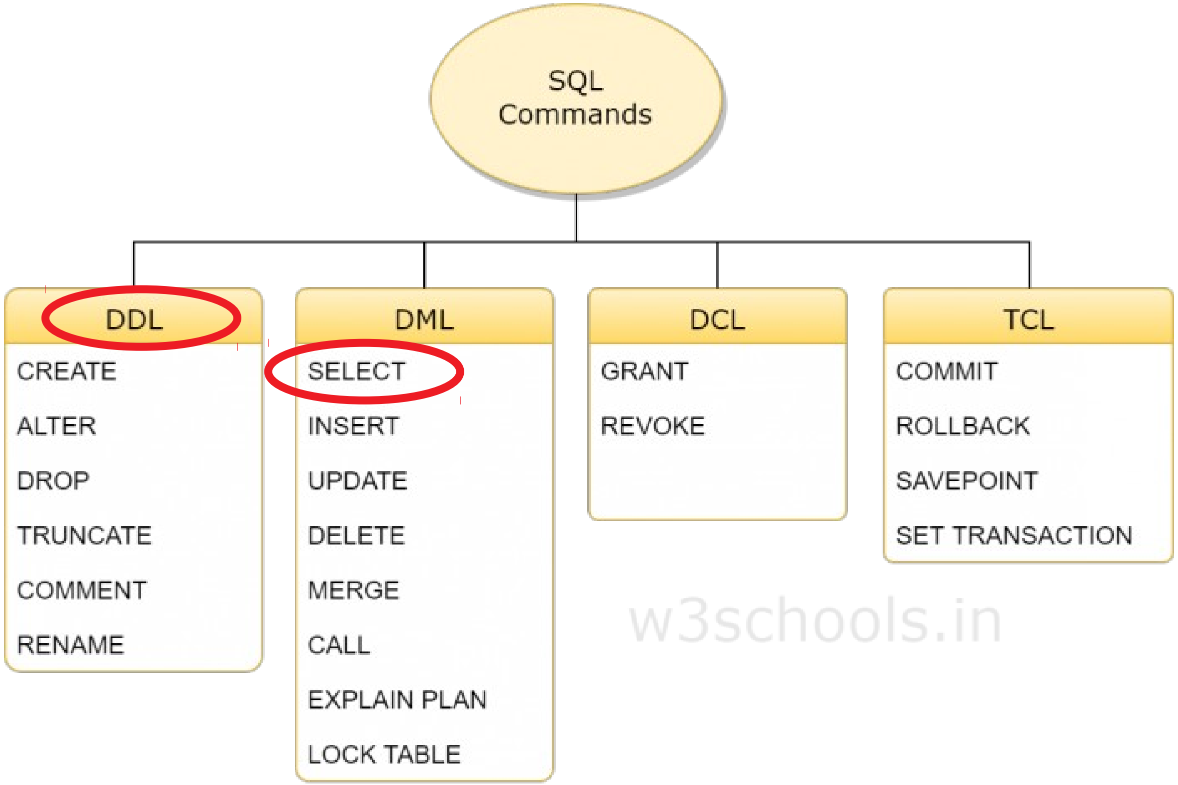
create table *instructor* (
ID **char**(5),
name **varchar**(20),
dept_name **varchar**(20),
salary **numeric**(8,2),
primary key (*ID*),
foreign key *(dept_name*)
references *department(dept_name));*

Removing and Altering Relations

- **Removing relations**
  - **drop table** *r*
- **Altering**
  - **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 existing 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*
    - not supported by many databases

Back to DML...

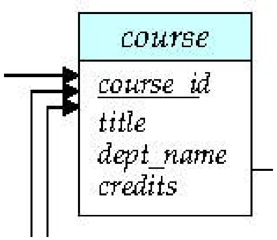
- We have seen
  - Basic DDL: how do we define tables?
  - SELECT: how do we read from tables?



Insertion into a Relation

- 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 of Data from Other Tables

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

  insert into *student*
  select *ID, name, dept_name, 0*
  from *instructor*

- As in the deletion example, the **select from where** statement is evaluated fully before any of its results are inserted into the relation

  Otherwise queries like

  insert into *table*1 **select** * **from** *table*1

  would cause problems

Inserting Data into Relations with Constraints

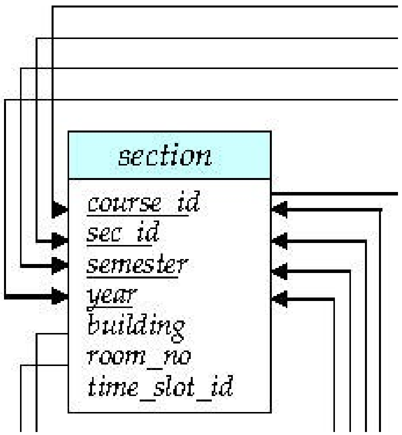
- Effect of primary key constraints:
  - **insert into** *instructor* **values** (‘10211’, ’Smith’, ’Biology’, 66000);
  - **insert into** *instructor* **values** (‘10211’, ’Einstein’, ’Physics’, 95000);
  - ...and we defined ID the primary key!

- Effect of **not null** constraints
  - **insert into** *instructor* **values** (‘10211’, **null**, ’Biology’, 66000);

- Recap: DBMS takes care of *data integrity*

Caveats with NOT NULL Constraints

- Rationale:
  - Each course takes place at a specific room and time slot
  - We'll create a **not null** constraint on those fields
  - *Note:* no online courses here

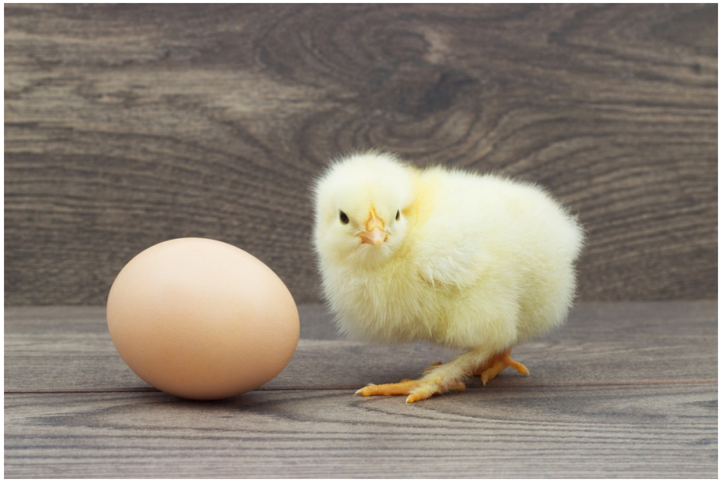


- Use case:
  - First: enter all courses in the system
  - Second: run clever time and room allocation algorithm
    - Which will then fill all the buildings and time slots

Caveats with NOT NULL Constraints (ctd.)

- Example: every employee needs a substitute
  - **create table** *employee* (
    ID **varchar**(5),
    name **varchar**(20) not null,
    substitute **varchar**(5) not null,
    primary key *(ID),*
    foreign key (*substitute*) **references** *employee(ID)*);

- What do you think?



Updating Data

- Cut salaries above 100,000 by 5%, below 100,000 by 3%
- Write two **update** statements:

thought experiment: Tom's salary is 102,000

update *instructor*
set *salary* = *salary* * 0.95
where *salary* > 100000;
update *instructor*
set *salary* = *salary* * 0.97
where *salary* <= 100000;

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

Conditional Updates with case Statement

- Cut salaries above 100,000 by 5%, below 100,000 by 3%

update *instructor*
set *salary* = **case**
when *salary* > 100000 **then** *salary* * 0.95
else *salary* * 0.97
end

Updates with Subqueries

- Recompute and update tot_creds value for all students

```
update student S
set tot_cred = (select sum(credits)
                from takes, course
                where takes.course_id = course.course_id
                  and 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 or passed any course
- Instead of **sum**(*credits*), use:

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

Deleting from a Relation

- **Delete**
  - Remove all tuples from the *student* relation
  - **delete from** *instructor*
  - May be refined (e.g., only removing *specific* tuples)
    - **delete from** *instructor* **where ...**

Deleting from a Relation

- 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’);

where clause may contain everything also usable for **select**

Deleting from a Relation

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

  delete from *instructor*
  where *salary* < (**select avg** (*salary*)
  from *instructor*);

- This would delete five tuples
  - But then, the average changes!

- How does the query behave if the deletion is processed one by one?

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

Deleting from a Relation

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

  delete from *instructor*
  where *salary* < (**select avg** (*salary*)
  from *instructor*);

- Processing this query in SQL
  - First, the **select** query is evaluated
    - i.e., the result is now treated as a constant
  - Then, the **delete** statement is executed

DELETE vs. TRUNCATE

- All records from a table can also be removed using

  truncate table *instructor;*

  Difference to

  delete from *instructor;*

  ?

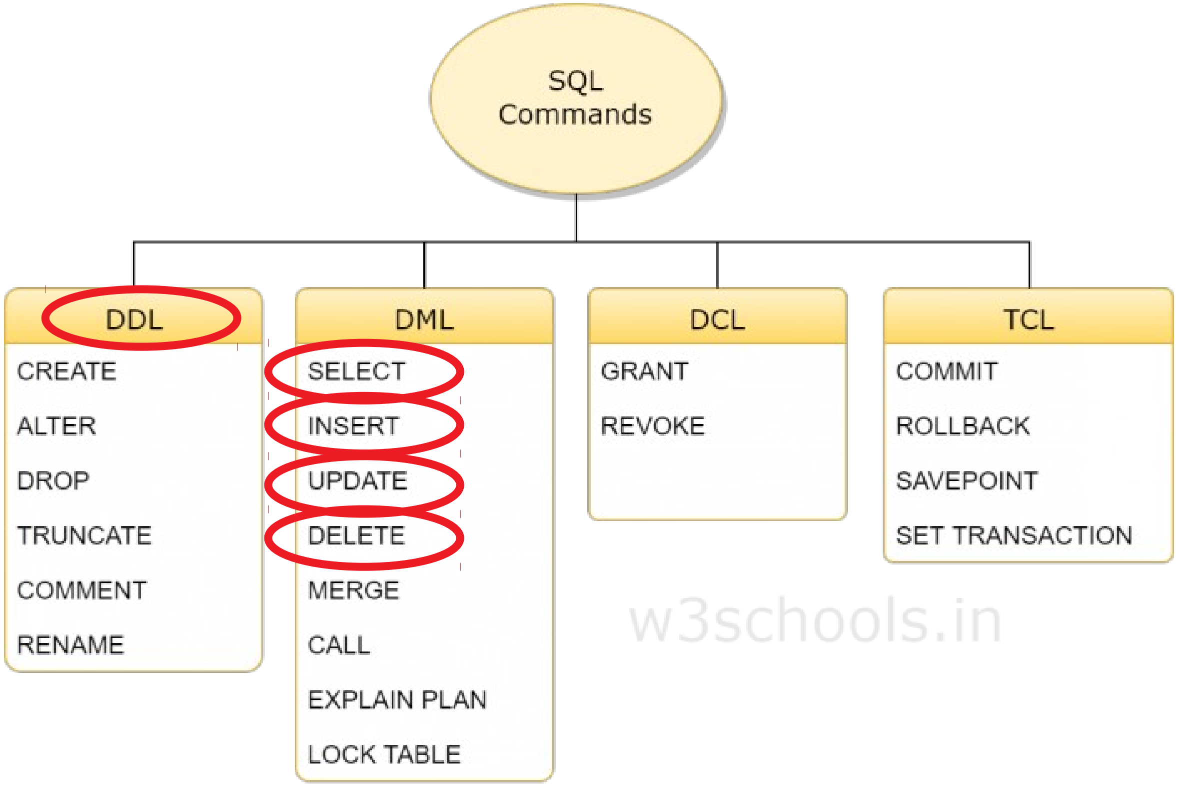
- **delete** keeps the table and deletes only the data
- **truncate** drops and re-creates the table
  - much faster
  - but cannot be undone
- **delete** is DML, **truncate** is DDL
  - Different rights may be necessary (see later!)

Description

`TRUNCATE TABLE` empties a table completely. It requires the `DROP` privilege (before 5.1.16, it required the `DELETE` privilege.) See `GRANT` .

Back to DML...

- We have seen
  - Basic DDL: how do we define tables?
  - SELECT: how do we read from tables?



Views

- Recap: logical database model
  - The relations in the database and their attributes
- Views:
  - Virtual relations
  - Different from those in the database
  - But with the same data
  - ...hide data from users
- Example: instructors' names and departments without salaries, i.e.,

  select *ID*, *name*, *dept_name*
  from *instructor*

Views

- Example: some users may see employees with salaries, others only without salary

- How about two tables
  - One with salaries
  - One without salaries
- ?

Defining Views

- A view is defined using the **create view** statement:
  create view *v* **as** < query expression >
  - <query expression> is any legal SQL expression
  - the view name is represented by *v*
- Once the view has been created
  - it can be addressed as *v* as any other relations
  - it will always contain the data read by the SQL expression
    - live, not at the time of definition!

Example Views

- Instructors without their salary

  create view *faculty* **as**
  select *ID*, *name*, *dept_name*
  from *instructor*

- Using the view: find all instructors in the Biology department

  select *name*
  from *faculty*
  where *dept_name* = ‘Biology’;

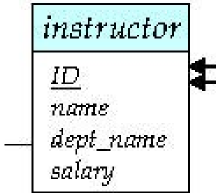
- Create a view of department salary totals

  create view *departments_total_salary*(*dept_name*, *total_salary*)
  as
  select *dept_name*, **sum** (*salary*)
  from *instructor*
  group by *dept_name*;

Updating Views

- Definition of a simple view (recap: instructors without salaries):

  create view *faculty* **as**
  select *ID*, *name*, *dept_name*
  from *instructor*



- Add a new tuple to *faculty* view which we defined earlier

  insert into *faculty* **values** (’30765’, ’Green’, ’Music’);

- This insertion must be represented by the insertion of the tuple

  (’30765’, ’Green’, ’Music’, null)

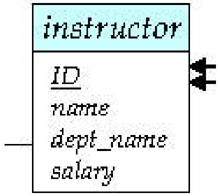
  into the *instructor* relation

This can only work if salary is *not* defined as **not null**!

Updating Views

- Consider the view

  create view *biology_faculty* **as**
  select *ID,name*
  from *faculty*
  where *dept_name* = ‘Biology’;



- and

  insert into biology_faculty
  values (43278,‘Smith’);

- Would this lead to

  insert into *instructor* **values** (43278,’Smith’,’Biology’,null);

  ?

Updating Views

- Most **where** constraints cannot be translated into a value to insert
- Consider

    where *dept_name* = ‘Biology’ **or** *dept_name* = ‘Physics’

  or

    where *salary* > 50000

- Hence, **where** clauses are typically not translated into a value

Updating Views

- Other example used before

  create view *departments_total_salary*(*dept_name*, *total_salary*)
  as
  select *dept_name*, **sum** (*salary*)
  from *instructor*
  group by *dept_name*;

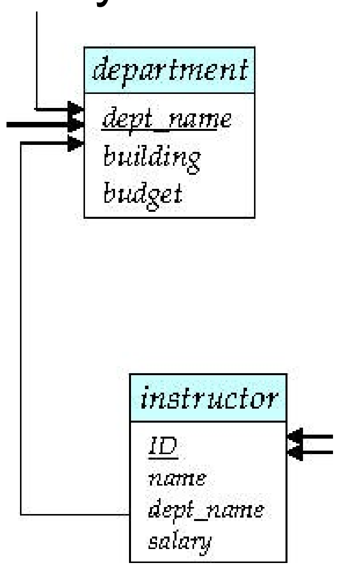
- What should happen upon

  update *departments_total_salary*
  set *total_salary* = *total_salary* * 1.05
  where *dept_name* = “Comp. Sci.”;

  ?

Updating Views

- **create view** *instructor_info* **as**
  select *ID*, *name*, *building*
  from *instructor*, *department*
  where *instructor*.*dept_name*= *department*.*dept_name*;
- **insert into** *instructor_info* **values** ('69987', 'White', 'Taylor');
  - which department, if multiple departments are in Taylor?
  - what if no department is in Taylor?



Updateable Views

- A view is called *updateable* if
  - The **from** clause has only one database relation
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause

- Most DMBS only allow updates on such views!

Materialized vs. Non-Materialized Views

- Normal views are not materialized
  - When issuing a **select** against a view, the underlying data is created on the fly
  - Pro: guarantees recent and non-redundant data, saves space
  - Con: some views may be expensive to compute (e.g., extensive use of aggregates)
- **Materializing a view**: create a physical table containing all the tuples in the result of the query defining the view
  - If relations used in the query are updated, the materialized view result becomes out of date
  - Need to **maintain** the view, by updating the view whenever the underlying relations are updated

Integrity Constraints

- Data errors may occur due to, e.g.,
  - Accidental wrong entries in form fields
  - Faulty application program code
  - Deliberate attacks
- Integrity constraints
  - guard against damage to the database
  - ensuring that authorized changes to the database do not result in a loss of data consistency
- Examples
  - A checking account must have a balance greater than $10,000.00
  - A salary of a bank employee must be at least $4.00 an hour
  - A customer must have a (non-null) phone number

Integrity Constraints on a Single Relation

- We have already encountered
  - **not null**
  - **primary** and **foreign key**
- We will get to know
  - **unique**
  - **check** (P), where P is a predicate

NOT NULL and UNIQUE Constraints

- **not null**
  - Declare *name* and *budget* to be **not null**

    name **varchar**(20) **not null**
    budget **numeric**(12,2) **not null**

- **unique** (A_1, A_2, …, A_m)
  - The unique specification states that the attributes *A*1, *A*2, … *A*m form a candidate key
  - Candidate keys are permitted to be null
    (in contrast to primary keys)

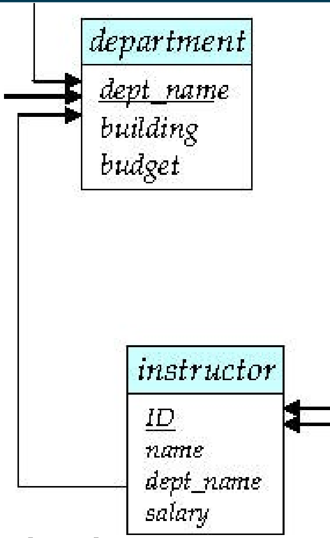
The CHECK Constraint

- **check** (P)
  - where P is a predicate

- Example: ensure that semester is either fall or spring

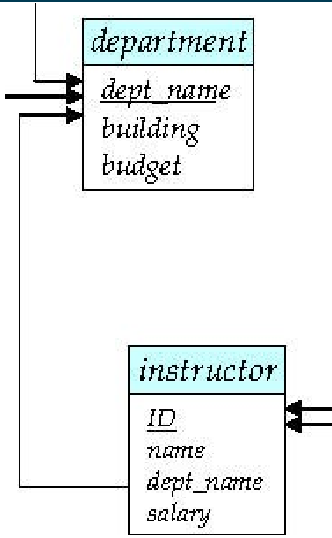
```
create table section (
  course_id varchar (8),
  sec_id varchar (8),
  semester varchar (6),
  year numeric (4,0),
  building varchar (15),
  room_number varchar (7),
  time slot id varchar (4),
  primary key (course_id, sec_id, semester, year),
  check (semester in ('Fall', 'Spring'))
);
```

Foreign Keys and Referential Integrity



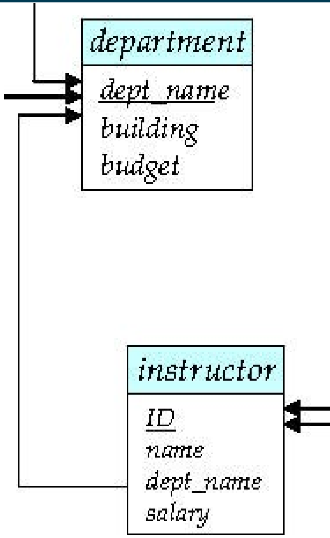
- Example:
  - instructors have a department
  - **each** department should also appear in the *department* relation
- Definition:
  - Let A be a set of attributes
  - Let R and S be two relations that contain attributes A and where A is the primary key of S
  - A is said to be a **foreign key** of R if for any values of A appearing in R these values also appear in S

Cascading Actions in Referential Integrity



- Example:
  - instructors have a department
  - **each** department should also appear in the *department* relation
- How to *ensure* referential integrity?
  - i.e., what happens if a department is deleted from the *department* relation
- Possible approaches
  - Reject the deletion — default action
  - Delete all instructors as well
  - Set the department of those instructors to **null**

Cascading Actions in Referential Integrity

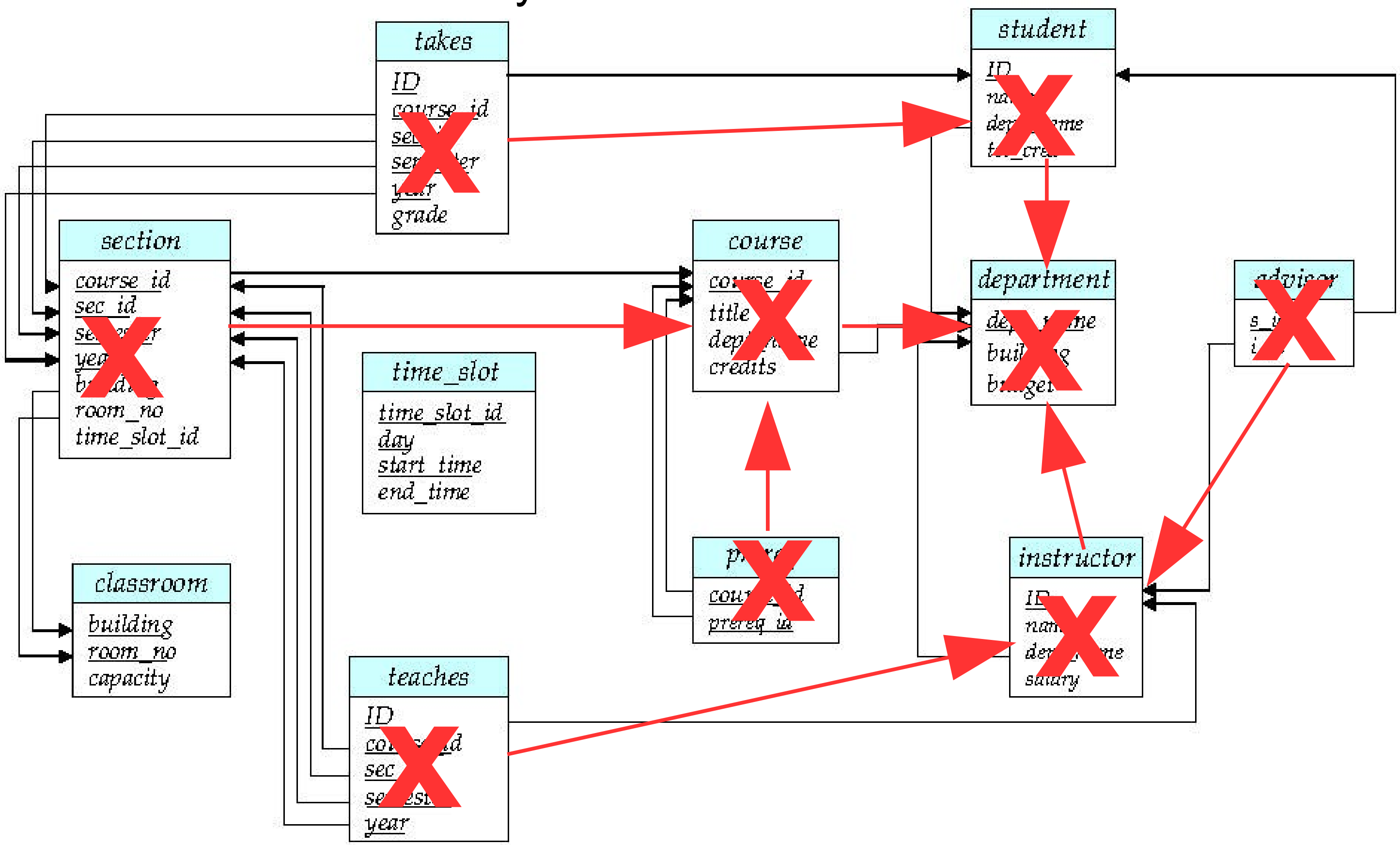


- Cascading updates
  - If a foreign key is changed (e.g., renaming a department)
  - ...then rename in all referring relations
- Cascading deletions
  - If a foreign key is deleted (e.g., deleting a department)
  - ...then delete all rows in referring relations
- **create table** *instructor* (

    . . .
    dept_name **varchar**(20),
    foreign key (*dept_name*) **references** *department*
        on delete cascade
        on update cascade,
    . . .
)

Cascading Actions in Referential Integrity

- Cascading deletions may run over several tables
  - ...so we should be very careful!



Cascading Actions in Referential Integrity

- **set null** for updates
  – If a foreign key is changed (e.g., renaming a department)
  – ...then set null for all referring relations
- **set null** for deletions
  – If a foreign key is deleted (e.g., deleting a department)
  – ...then set null in referring relations
- **create table** *instructor* (
  …
  dept_name **varchar**(20),
  foreign key (*dept_name*) **references** *department*
  on delete set null,
  on update set null,
  . . .
)

Authorization

- Rights for accessing a database may differ
  - Only administrators may change the schema

- Rights for accessing a database can be very fine grained
  - Not everybody may see a persons' salary
  - Not everybody may alter a person's salary
  - Nobody may alter their own salary
  - Special restrictions may apply for entering salaries over a certain upper bound
  - ...

Authorization

- Forms of authorization on parts of the database:
  - **Read** - allows reading, but not modification of data
  - **Insert** - allows insertion of new data, but not modification of existing data
  - **Update** - allows modification, but not deletion of data
  - **Delete** - allows deletion of data

- Forms of authorization to modify the database schema
  - **Index** - allows creation and deletion of indices
  - **Resources** - allows creation of new relations
  - **Alteration** - allows addition or deletion of attributes in a relation
  - **Drop, Truncate** - allows deletion of relations

Authorization Specification in SQL

- The **grant** statement is used to confer authorization

  grant <privilege list>

  on <relation name or view name> **to** <user list>
- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this later)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator)

Privilege Definition in SQL

- **select**: allows read access to relation,or the ability to query using the view
  - Example: grant users U_1, U_2, and U_3 **select** authorization on the *instructor* relation:

    grant select on *instructor* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges

Revoking Privileges

- The **revoke** statement is used to revoke authorization.

  revoke <privilege list>

  on <relation name or view name> **from** <user list>

- Example:

  revoke select on *branch* **from** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges the revokee may hold
- If <user list> includes **public,** all users lose the privilege except those granted it explicitly
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation
- All privileges that depend on the privilege being revoked are also revoked

Roles

- Databases may have many users
  - e.g., all students and employees of a university

- Managing privileges for all those individually can be difficult
  - User groups (also called: roles) are more handy
  - Example roles
    - Student
    - Instructor
    - Secretary
    - Dean
    - ...

Roles

- Creating roles and assigning them to individual users
  - **create role** instructor;
  - **grant** *instructor* **to Amit;**
- Granting privileges to roles
  - **grant select on** *takes* **to** *instructor*;

- Roles can form hierarchies
  - i.e., a role inherits from other roles

    create role *teaching_assistant*

    grant *teaching_assistant* **to** *instructor*;
  - *Instructor* inherits all privileges of *teaching_assistant*

Roles on Views

- Example: Geology department members can administrate their own staff, but not others

  create view *geo_instructor* **as**
  (**select** *
  from *instructor*
  where *dept_name* = ’Geology’);

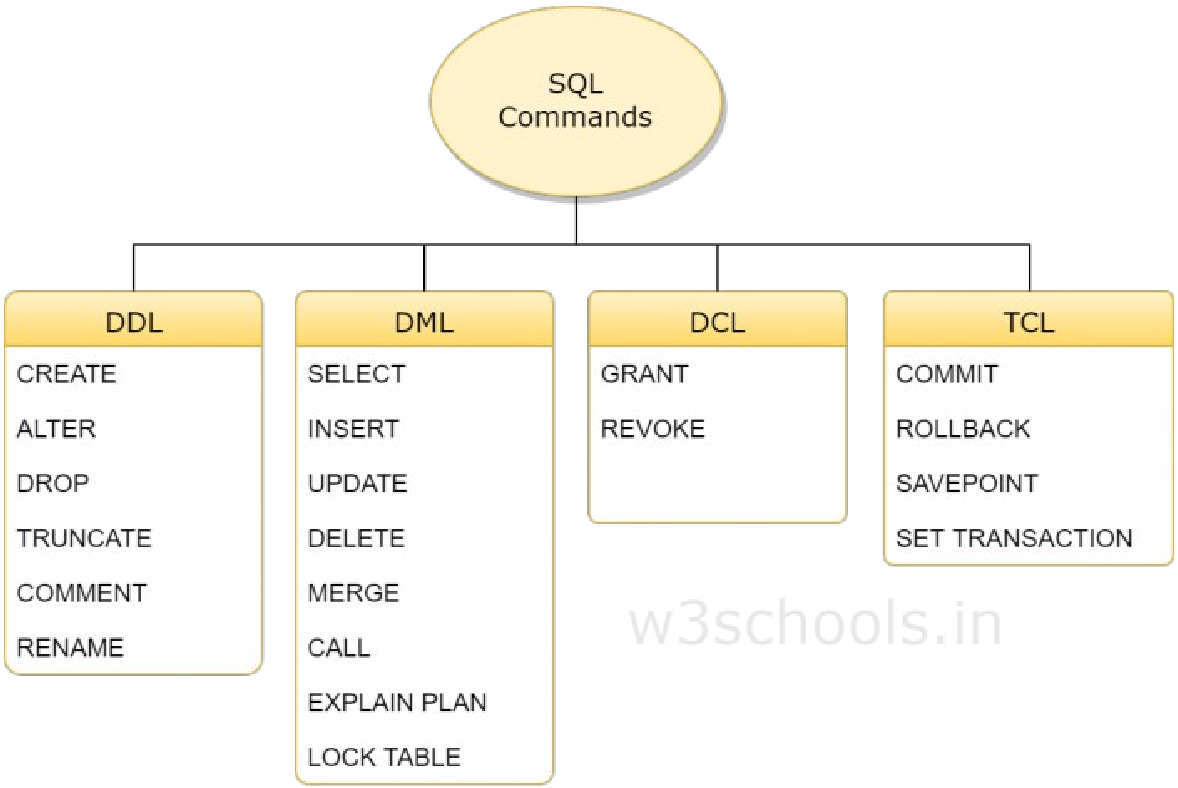
  grant select on *geo_instructor* **to** *geo_staff*

- Suppose that a *geo_staff* member issues

  select *
  from *geo_instructor*;

- What if
  - *geo_staff* does not have permissions on *instructor?*
  - creator of view did not have some permissions on *instructor?*

Wrap-up



Source: https://www.w3schools.in/mysql/ddl-dml-dcl/

Wrap-up

- Today, we have seen
  – How to manipulate data in databases
  – i.e., **insert**, **update**, and **delete** statements

- Views
  – are used to provide different subsets and/or aggregations of data
  – updateable views
  – materialized views

Wrap-up

- Integrity constraints
  - unique and not null constraints
  - cascading updates and deletions
- Access rights
  - can be fine grained
  - can be bound to user groups and roles
  - roles may inherit from each other

Questions?